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A preliminary estimate of human and natural contributions to the decline in sediment flux from the Yangtze River to the East China Sea

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Abstract

This paper attempts to give a comprehensive explanation of the sediment discharge decrease from the Yangtze River to the East China Sea, taking into consideration its large scale and the basin wide complexity of changing human activities and precipitation. We examined various influencing factors include climate change, water and soil conservation measures, sand dredging, floodplain deposition and channel erosion, and dam construction. Correlation/regression analysis was used to examine the relations between data such as precipitation and water discharge, erosion or deposition in the river channel and sediment supply from the river basin. The sediment and water discharge of two major stations (Yichang and Datong) on the main river and 13 stations of the major tributaries were provided. The average precipitation in each tributary and its relationship with the water and sediment discharge were examined, and contributions of water and soil conservation measures, sand dredging, floodplain deposition and channel erosion, and dam construction to the sediment decrease were discussed. A quantitative estimation of the contribution of each impact factors to the sediment decline was attempted. Dam construction was the dominant factor (~88%) contributing to the decline in sediment influx, followed by the water and soil conservative measures (15±5%). Climate change is responsible for a slight increase in sediment influx, approximately 3%. Floodplain deposition and channel erosion had an adverse effect, and the contribution of sand dredging was very limited.

1. Introduction

The decrease of river sediment discharge into the sea and the consequent impacts on the coastal environment have become a global topic in recent years. Severe coastal erosion occurred at the Nile River mouth after the completion of the high Aswan Dam. In the Colorado River, water diversions and sediment trapping by dams have prevented a great portion of sediment from reaching the Colorado Delta, which has resulted in coastal recession (Carriquiry and Sanchez, 1999). After the construction of the Ribarroja-Mequinenza dam complex in northern Spain, about 96% of Ebro River sediment was trapped in the reservoir and the progradation of the delta as a whole ceased (Sánchez-Arcilla et al., 1998). The Yellow River (Huanghe) in China, once the world's largest in terms of sediment discharge (Milliman and Meade, 1983), is now supplying only about 150×10^6 t/a (2000–2005) of sediment to the sea due to dam construction and water withdrawals (Ministry of Water Resource Committee (MWRC), 2006; Wang et al., 2007). The Yellow River delta as a whole is degrading. In the Yangtze River, the largest river in China, there has been a significant decreasing trend in sediment discharge since the late 1960s (Chen et al., 2001; Yang et al., 2002, 2006a). In response to this drastic decrease, the deltaic coast is turning from progradation to recession (Yang et al., 2006b). All these examples strongly suggest that dam construction is the main contribution to the decrease of the river sediment discharge, in common with other studies (Bobrovitskaya et al, 2003; Syvitski et al, 2003, 2005; Vörösmartry et al., 2003; Walling and Fang, 2003). Though sediment flux is also sensitive to other factors such as climate change, which might be a very important factor if fast paced, such studies are very limited. Dams can significantly decrease river sediment discharge

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into the sea (Milliman, 1997), but in some cases the comparative contribution of a dam might be much less. For example, in the Yellow River basin, the decreased precipitation and increased population greatly aggravated the water deficiency. As a result, water extraction (along with sediment) was greatly enhanced (Liu and Zheng, 2002; Lu, 2004), reducing the ability of the river to carry sediment to the lower reaches. Soil and water conservation measures also have significant contributions to the sediment decrease of the Yellow River (Xu, 2003; Walling, 2006; Wang et al., 2007). Syvitski et al. (2005) demonstrated that the influencing factors of the river sediment varied in different climate zones.

In the Yangtze River basin, although several studies have been carried out, some basic questions remained. For example, previous studies have attributed the reservoirs as the main cause of the decrease of the sediment load of the Yangtze River (Yang et al., 2006a, b), but the precise extent of the contribution of the reservoirs is still not very clear. The factors such as the climate change and soil conservation are also very important in changing the river sediment load. Evaluation of the contribution from these factors to the decline is also needed. Other factors such as river channel, floodplain and sand dredging also play a role in the decline as discussed by various papers. For example, Dai et al. (2006) demonstrated that the self-adjustment of the river channel could effectively impact river sediment discharge. Chen et al. (2005) argued that the sand dredging in the middle and lower reaches of the Yangtze River played a very important role in the decrease of sediment discharge into the sea. Walling et al. (1998) suggested that channel and floodplain storage is very important in the suspended sediment budget of the river system. The deposition and mobilization of the riverine sediment in large river systems, such as the Yangtze River, may be much more complicated if the impact factors, both natural and anthropogenic, are taken into consideration. Therefore, the identification and interpretation of the hydrological changes of the large river basins can be much more difficult (Lu et al., 2003). As a result, an in-depth understanding of the causal mechanism of the variation of sediment discharge of the Yangtze River is very necessary. This paper aims to give a comprehensive explanation for the decreasing sediment discharge of the Yangtze River, considering major possible influencing factors such as climate change, water and soil conservation measures, sand dredging, floodplain deposition and channel erosion, and dam construction.

2. Physical setting

The Yangtze River, the largest river in China, originates on the Qinghai-Tibet Plateau at 5100 m elevation and extends 6300 km eastward to the East China Sea. The catchment covers a total area of $1.81 \times 10^6\,km^2$ and, at present, is home to a population of more than 400 million. The uppermost 3300 km of the river is named Jinshajiang, and this stretch extends to the confluence of the Minjiang. The Minjiang, Jialingjiang, and Hanjiang are major tributaries that join the main river from the north, while Wujiang Lake Dongting and its four tributaries, and Lake Poyang and its four tributaries join the main river from the south (Fig. 1, Table 1). The upper reaches of the river end at Yichang, 30 km downstream of the Three Gorges Dam (TGD), in Hubei Province. All the main tributaries of the Yangtze River are gauged (Fig. 1, Table 1), which made it possible to conduct a detailed analysis of sediment transport and mobilization. In the main river, there are two key stations, Yichang and Datong, located at the upper and the lower reach, respectively. The annual water discharge at Yichang station ($434\,km^3/a$) is lower than that of Datong station, which is $890\,km^3/a$, whereas the sediment discharge at Yichang station ($468 \times 10^6\,t/a$) is higher than that of Datong station ($409 \times 10^6\,t/a$), as the sediment of the Yangtze River is mainly derived from the upper reach.

Along the middle and lower reaches of the river, there are many lakes linked with the main stream. As a

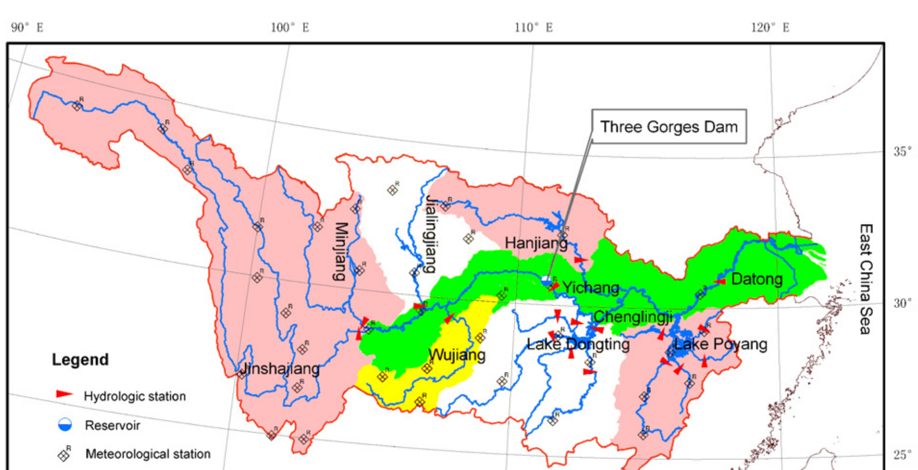

Fig. 1. Sketch map of the Yangtze River showing the main tributaries and the gauging stations in this study.