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Impact of the Three-Gorges Dam and water transfer project on Changjiang floods

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ABSTRACT

Increasing frequency of severe floods on the middle and lower Changjiang (Yangtze) River during the past few decades can be attributed to both abnormal monsoon rainfall and landscape changes that include extensive deforestation affecting river sedimentation, and shrinking lakes and levee construction that reduced the areas available for floodwater storage. The Three-Gorges Dam (TGD) and the South-to-North Water Transfer Project (SNWTP) will also affect frequency and intensity of severe floods in the Poyang Lake region of the middle Changjiang. Process-based National Integrated Catchment-based Eco-hydrology (NICE) model predicts that the TGD will increase flood risk during the early summer monsoon against the original justifications for building the dam, relating to complex river–lake–groundwater interactions. Several scenarios predict that morphological change will increase flood risk around the lake. This indicates the importance of managing both flood discharge and sediment deposition for the entire basin. Further, the authors assessed the impact of sand mining in the lake after its prohibition on the Changjiang, and clarified that alternative scenario of sand mining in lakes currently disconnected from the mainstream would reduce the flood risk to a greater extent than intensive dredging along junction channel. Because dry biomasses simulated by the model were linearly related to the Time-Integrated Normalized Difference Vegetation Index (TINDVI) estimated from satellite images, its decadal gradient during 1982–1999 showed a spatially heterogeneous distribution and generally decreasing trends beside the lakes, indicating that the increases in lake reclamation and the resultant decrease in rice productivity are closely related to the hydrologic changes. This integrated approach could help to minimize flood damage and promote better decisions addressing sustainable development.

1. Introduction

During the past few decades the middle and lower sections of the Changjiang River (Fig. 1) have experienced an increasing frequency of severe floods that had major impacts on the agricultural economy and forced massive evacuations of the adjoining alluvial valleys that are densely populated. Abnormally high rainfall events, such as during the 1954 and 1998 floods, have lead to severe floods, but landscape changes related to human activity were the main causes of an increasing severity of major floods (Cheng, 1999; Yin and Li, 2001; Piao et al., 2003; Zhao and Fang, 2004; Zhao et al., 2005). These include (1) deforestation and soil erosion in the upper reaches of the Changjiang basin, (2) shrinking of large lakes in the Changjiang alluvial valley, and (3) the construction of levees along river banks. All of these changes have resulted in the loss of floodwater storage. Dongting and Poyang Lakes are the largest freshwater lakes in China, and both drain into the Changjiang. They shrank significantly in area from the 1950s to the late 1990s, and decreased in volume from 27 to 17 billion m^3 and 32 to 21 billion m^3, respectively (Du et al., 2001; Yin and Li, 2001; Shankman and Liang, 2003; Zhao and Fang, 2004; Peng et al., 2005; Zhao et al., 2005). Previous studies indicate that increasing floodwater storage of both lakes to the former situation would decrease peak floods (Nakayama and Watanabe, 2008b). The 1998 flood had a record of the highest river stage on the middle Changjiang ever recorded. After this flood, the central and local governments in China adopted a new flood management policy that would ‘return land to lake’ to increase the floodwater storage during severe flood events. This policy includes the removal of some levees and opening of others when lake stage reaches a critical level, requiring an evacuation of those in the affected areas (Shankman and Liang, 2003; Peng et al., 2005). These efforts have increased floodwater storage ability much greater than during the 1998 flood (Dai et al., 2005; Shankman et al., 2009) and the lake restoration projects implemented in this region have decreased the lake degradation (Zhao et al., 2005) though not all planned land abandonment and increase in lake area have taken place for a variety of political and economic reasons.

The frequency and timing of severe floods on the middle and lower Changjiang will likely be affected by the Three-Gorges Dam

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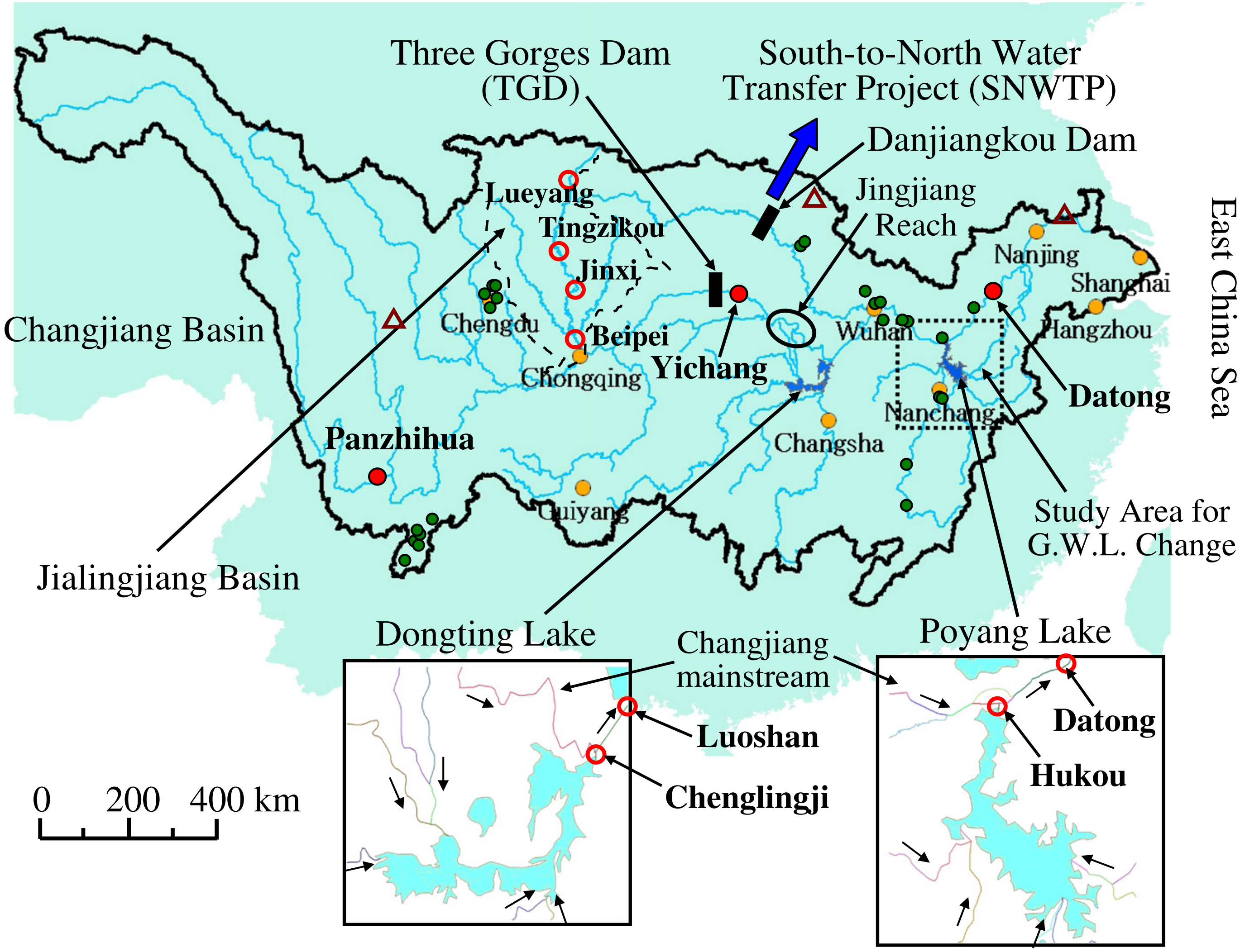

Fig. 1. Location of study area in the Changjiang basin. Bold black line is the border of basin. The validation data are also plotted in this figure about river discharge (open circle; 10 points; Changjiang Water Conservancy Committee (1998–1999)), soil moisture (open triangle; 3 points of the Global Soil Moisture Data Bank; Entin et al. (2000); Robock et al. (2000)), and groundwater level (green dot; 25 points; China Institute for Geo-Environmental Monitoring (2003)). The detailed information about the observation stations is shown in Table 2. Black dotted-line is border of study area around Poyang Lake.

(TGD) (Fig. 1). The filling of the TGD reservoir has resulted in increased evaporation and water usage, as well as decreased downstream discharge during summer season (Chen, 2000; Yang et al., 2006; Dai et al., 2008; Yi et al., 2010). However, the TGD might increase flood risk in the Poyang Lakes region during large floods, such as in 1954 and 1998, contrary to the widely held belief that it will reduce the threat of severe floods (Shankman and Liang, 2003; Shankman et al., 2006). To increase floodwater storage capacity of the reservoir and protect against late summer floods, the reservoir is lowered during the spring and early summer months. The release of water from the dam during this period increases discharge and water level on downstream sections of the Changjiang, which will slow Poyang Lake discharge into the Changjiang and in some cases cause the mainstream to back-flow into the lake, increasing its water level and flood occurrence. Flood risk will be also affected by changes in the complex river–lake relationship that has been altered significantly under increasing human intervention (Hongfu et al., 2007; Wang et al., 2008).

Change in downstream Changjiang sediment load could also affect flood risk. Sediment from the upstream section of the Changjiang collects in the reservoir, and the low sediment load downstream of the dam will result in channel bed incision. Channel incision along the middle Changjiang will increase channel capacity in the zone nearest the dam, resulting in lower river stage (Xu and Milliman, 2009). Increasing floodwater storage has been planned along this section of Changjiang, which is far upstream of Poyang Lake (Li et al., 2004). Because of channel incision, river stage will be below the level needed for floodwater to access these areas. With the river unable to spread into planned retention areas, an undiminished discharge will move downstream. Also, channel aggradation and reduction in channel capacity have been predicted for the channel reach further downstream near Poyang Lake, which could further increase flood severity (Li et al., 2004; Yang et al., 2006; Shankman et al., 2009). But not all agree that this is likely to occur (Wang et al., 2007). Although this huge construction project runs counter to the current trend among developed countries for removal of large dams, predicting the response of environmental modifications to the whole basin after considering some effects is important to maximize the benefits and minimize the flood risk (Liu et al., 2008b).

An evaluation of sediment deposition in the lake is also important to predict the effect of the TGD (Xiang et al., 2002; Dai et al., 2005; de Leeuw et al., 2009; Shankman et al., 2009). Because dredging in the Poyang Lake began in 2001 after sand mining in the Changjiang River had been banned, sediment balance in the lake would change