Simulation of Streamflow and Sediment with the Soil and Water Assessment Tool in a Data Scarce Catchment in the Three Gorges Region, China

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The Three Gorges Region in China is currently subject to a large-scale land use change, which was induced by the construction of the Three Gorges Dam on the Yangtze River. The relocation of towns, villages, and agricultural areas is expected to affect the water balance and increase erosion rates and sediment yields in the affected catchments. Hydrologic and water quality models are frequently used to assess the impact of land use changes on water resources. In this study, the eco-hydrological Soil and Water Assessment Tool (SWAT) model is applied to the Xiangxi Catchment in the Three Gorges Region. This paper presents the calibration and validation of streamflow and sediment loads at Xingshan gauging station. The calibration of daily streamflow resulted in a satisfactory fit of simulated and observed data, which is indicated by Nash–Sutcliffe efficiency (NSE) values of 0.69 and 0.67 for the calibration (1981–1986) and validation (1988–1993) periods, respectively. In contrast, the model was not able to simulate the monthly average sediment loads correctly, as indicated by very low NSE values of 0.47 (calibration) and 0.08 (validation). This might be due to inadequate representation of spatial rainfall variability by the available climate stations, insufficient input data, uncertainties in the model structure, or uncertainties in the observed sediment loads. The discussion of these possible reasons for the incorrect prediction of sediment loads by SWAT reveals the need for further research in the field of hydrological and water quality modeling in China.

The construction of the Three Gorges Dam on the Yangtze River has induced a large-scale land use change in the Three Gorges Region in Central China. The most important driver of this land use change is the inundation of agricultural areas, towns, and villages (Seeber et al., 2010), which forced people to resettle and relocate their cropland from the fertile valley bottoms to steeply sloping uphill areas with shallow soils characterized by a poor structure and low organic matter content (Shi et al., 2004). This is expected to influence not only the water balance in the affected catchments but also the diffuse inputs of sediment to rivers due to an increase in erosion. Having a direct effect on evapotranspiration (ET) and runoff generation as well as sediment yield, changes in land use can affect water supply and water quality (Fohrer et al., 2001; Chaplot et al., 2004; Mishra et al., 2007). Erosion and nonpoint-source pollution of rivers with sediment and nutrients are the major environmental problems in the Three Gorges Region (Heggelund, 2006; Shen et al., 2010a; Tian et al., 2010), for which Shi et al. (1992) estimated an annual soil loss of 157 million tons and an annual sediment delivery to the Yangtze of 41 million tons. The risk of erosion is expected to increase considerably due to recent and future changes in land use (Lu and Higgitt, 2000; Meng et al., 2001; Schönbrodt et al., 2010).

High soil erosion rates and sediment inputs can lead to sedimentation in the Three Gorges Reservoir and can thus affect its operation and life span (Higgitt and Lu, 2001; Shi et al., 2004). Also, a higher risk of reservoir eutrophication can be expected because of increasing inputs of nutrients, especially phosphorus, adsorbed to sediment and due to reduced flow velocities and prolonged residence times of water in the reservoir (Zeng et al., 2006; Dai et al., 2010). Additionally, sediment deposited in the reservoir might desorb large amounts of phosphorus (Wang et al., 2009) and thereby further increase the eutrophication risk. Since the impoundment of the Three Gorges Reservoir started, algae blooms have been frequently observed, especially in the backwater areas of tributaries of the Yangtze River (Zhong et al., 2005; Zeng et al., 2006; Ye et al., 2007; Li et al., 2008; Zhang et al., 2010; Xu et al., 2012).

Abbreviations: DEM, digital elevation model; ET, evapotranspiration; HRU, hydrologic response unit; MAE, mean absolute error; MUSLE, Modified Universal Soil Loss Equation; NSE, Nash–Sutcliffe efficiency; PBIAS, percent bias; SWAT, Soil and Water Assessment Tool.