Sedimentation in the riparian zone of the Three Gorges Reservoir, China

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Abstract Annual water levels in the Three Gorges Reservoir (TGR) fluctuate by approx. 30 m, which can influence the riparian zone. Such changes include soil stabilization or restoration, re-vegetation, landscape management and environmental sanitation. However, there is a lack of information on the rates, magnitude and variability of sedimentation processes in this riparian zone. A field monitoring programme was conducted along the middle reach of the TGR during 2007–2009. Fifteen monitoring transects were instrumented with columnar sediment traps and erosion pins. Mean sediment deposition rates were 5.8 cm year^{-1} at the 145–150 m level and 2.3 cm year^{-1} at the 150–175 m level. The mean sediment deposition rate was approx. 12 cm year^{-1} at tributary inlets and shoals and a maximum of 18 cm year^{-1} occurred at the 145–150 m level. Sedimentation processes in riparian areas along the TGR will likely have an impact on the ecology and long-term operation of the TGR.

Key words sedimentation; riparian zone; water level fluctuation; Three Gorges Reservoir

INTRODUCTION

Sedimentation processes influence the flood control capacity and water quality of reservoirs (Forstner & Wittman, 1981; Walling, 2007, 2008). The Three Gorges Reservoir is used for flood control, hydroelectric power generation, water resource management and navigation in China. However, the construction and operation of the project and subsequent resettlement of the migrants has greatly impacted the regional soil erosion regime, sediment transportation process and the water quality. After construction of the TGR, it began filling in 2003 and was fully operational in 2007. Recent studies have highlighted concern regarding severe soil erosion, non-point pollution and ecological degradation of the reservoir riparian zone (e.g. He *et al.*, 2007; Thomas & Xie, 2008). The Yangtze River Water Resources Commission (YRWRC) monitors hydrological and sedimentation processes in the TGR publishes the data annually (YRWRC, 2003–2008). However, despite the approx. 30 m annual water level fluctuation in the TGR, there is a little information available on sedimentation processes in the riparian zone of the reservoir.

Riparian zones are the interface between aquatic and upland terrestrial ecosystems and play a critical role in the eco-hydrology of watersheds (Lowrance *et al.*, 1985, 1997; Richard, 1994). Because of their landscape position and frequent natural disturbance, riparian zones contain sharp biological and physical gradients. The Three Gorges Reservoir has a 349 km^2 riparian zone where water levels fluctuate from 175 m a.s.l. in winter to 145 m a.s.l. in the summer. There has been increasing concern regarding soil erosion/stabilization, re-vegetation, landscape management and environmental sanitation in this zone (e.g. Wu *et al.*, 2004; He *et al.*, 2007; Xie *et al.*, 2007). However, there is currently a lack of information on the rates, magnitude and variability of sedimentation processes in this zone. Based on YRWRC 2007–2009 data, this paper examines the variation of sedimentation with different water levels of the riparian zone in the middle reaches of the TGR.

SCENARIOS OF TGR AND STUDY AREA

The Three Gorges Reservoir is a multi-functional water control system built on the upper and middle reaches of the Yangtze River that was fully operational in 2007. The reservoir is 600 km long, has a surface area of 1060 km^2, and a water capacity of 39.3 billion m^3 at the highest water level of 175 m a.s.l. (Fig. 1) (Lu & Higgitt, 2001; Shao, 2008). The TGR plays a key role in flood control of the Yangtze River basin Water levels fluctuate approx. 30 m year^{-1} in an area of 349 km^2. In 2007, sediment-monitoring transects were instrumented near Zhongxian (30°23′N, 108°07′E; 117–550 m a.s.l.) in the mid-section of the TGR (Fig. 2).

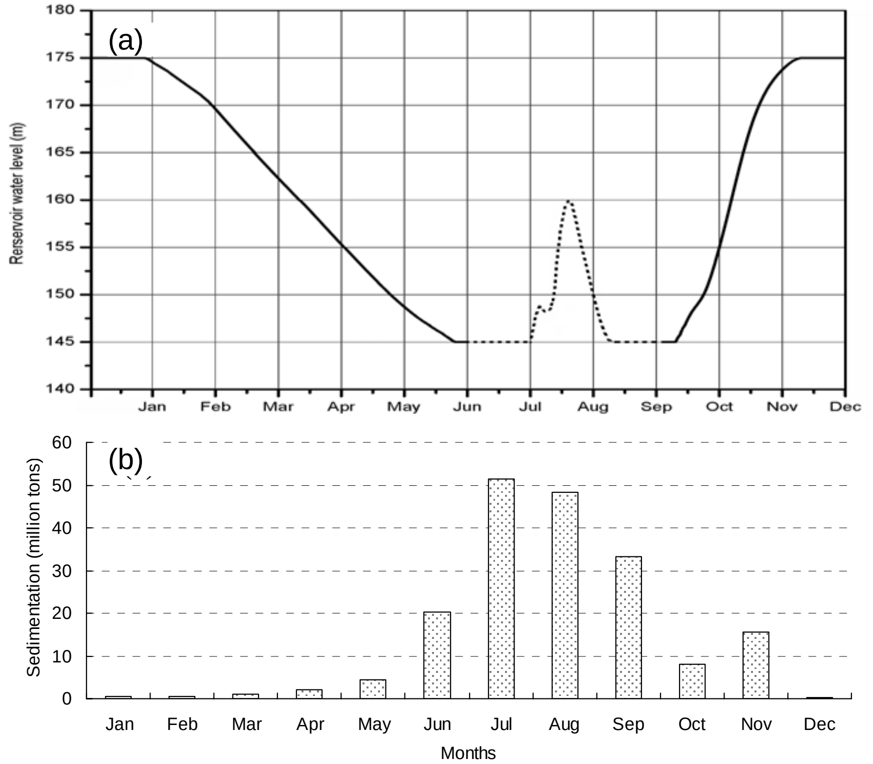

Fig. 1 (a) Schedule of water level fluctuation and (b) monthly (2008) sedimentation in the TGR.

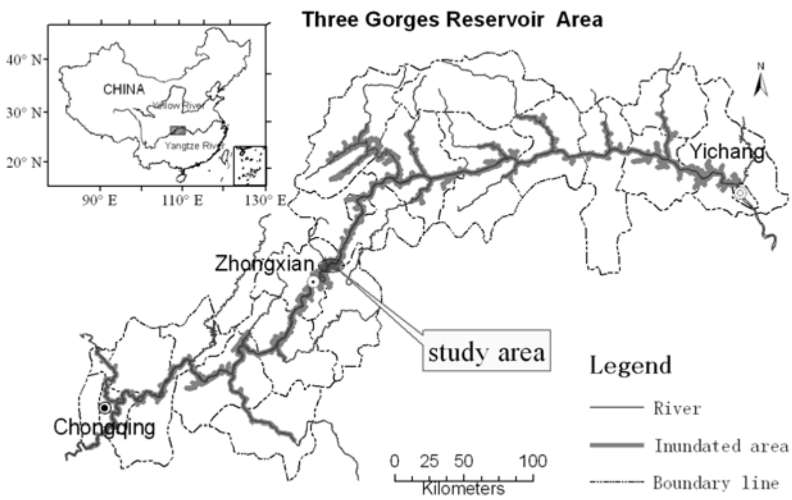

Fig. 2 Location of the study area and riparian zone of the TGR.

METHODS

At Zhongxian, 15 monitoring transects were located at different topographic sites along a 15-km stretch of the riparian zone. Specially designed barrels and traditional erosion pins were used to measure sediment erosion and deposition (Fig. 3). Sediment-traps consisting of a bucket (25 cm diameter and 30-cm deep) covered with a net cap to remove straw/small pieces of wood. The erosion pins and sediment-traps were installed along transects perpendicular to the channel, spanning areas where the water levels fluctuated from 145 to 175 m. Erosion pins and sediment trapping barrels were deployed in September and data were collected when water levels fell the following summer.

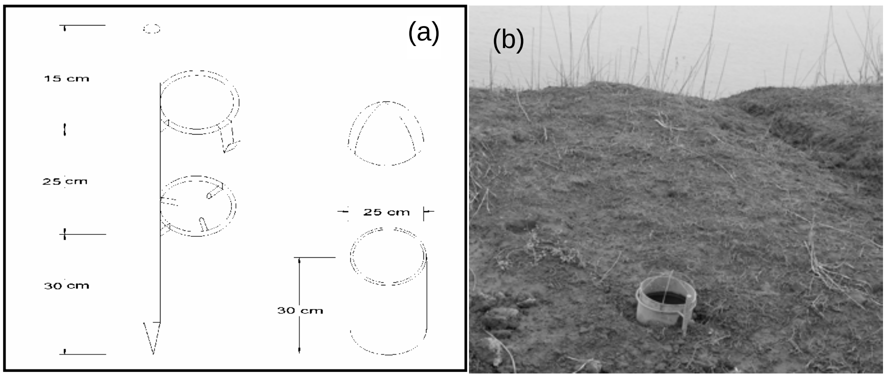

Fig. 3 Design of the sediment-trap (a) and field installation (b).

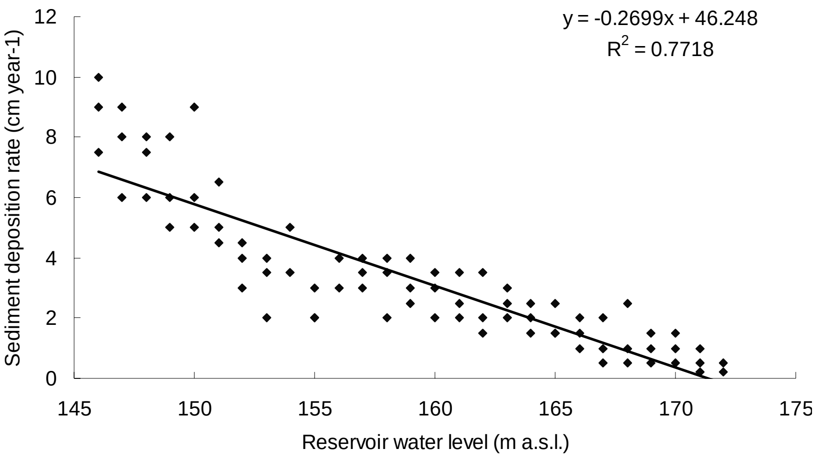

Fig. 4 Changes in sedimentation rates with water levels fluctuation.

RESULTS AND DISCUSSION

Five of the 100 erosion pins were deployed in areas of net erosion and 95 pins were located in areas of net sediment deposition. Suspended sediment deposition rates decreased with water level increase (Fig. 4). Mean sediment deposition rates were 5.8 cm year^{-1} in the 145–150 m zone and 2.3 cm year^{-1} in the 150–175 m zone. Near tributary inlets and shoals, the sediment deposition rate was approximately 12 cm year^{-1} with the maximum of 18 cm year^{-1}in the 145–150 m zone (Fig. 4).

Figure 5 shows that there was a difference in sedimentation rate measurements between the erosion pin and sediment trap methods. Sedimentation rates measured by sediment traps were higher than erosion pins, especially at the low water levels of 150 m a.s.l. (Fig. 5). At 146 m, one of the sediment traps was completely filled and the mean sedimentation rate at this site was 26 cm year^{-1}, more than twice that measured by erosion pins. Two factors which could cause this result are: (1) that the barrels influence flow dynamics possibly leading to higher observed sediment deposition rates, and (2) sediment in the traps was not eroded, while the sedimentation rates measured by erosion pins may have been influenced by water-wave erosion.

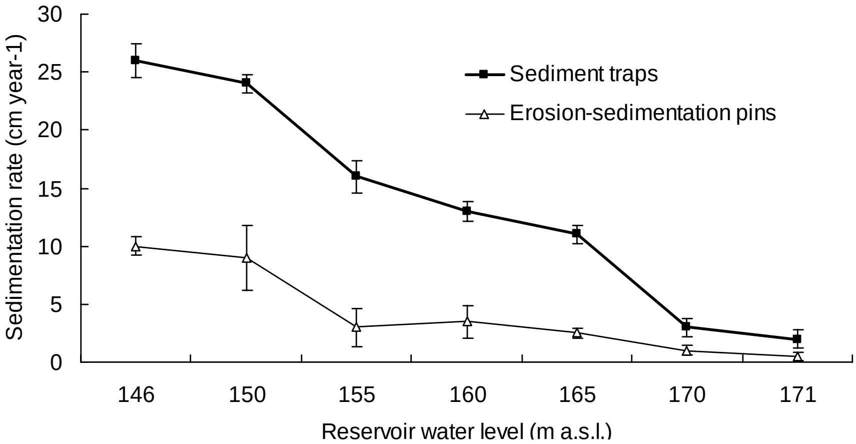

Fig. 5 Difference in sedimentation rates by methods of erosion pins and sediment-trapping barrels.

CONCLUSIONS

The present study reveals the dynamic nature of sediment deposition processes in the riparian zone of the reservoir. Sedimentation rates were higher along the middle reaches of the TGR. The sedimentation rate changed with topography and fluctuating water levels. In the upper reaches, especially near inlets of large tributaries and shoals, sedimentation rates were much higher than observed in the middle reaches and the lower reaches. A long-term and systematic monitoring system is required to fully investigate the factors that govern sediment transport and deposition processes within the reservoir, as well as areas annually inundated by fluctuating water levels. Such a large area with significant high deposition rates of suspended sediment in the riparian zone of the TGR and the severe soil erosion during the rainy season in summer, will likely have a great impact on water quality of the TGR. Based on the Yangtze River hydrological stations, such as Ping Shan, Zhu Da, Cuntan, Yichang, Shashi, Hankou and Datong, runoff, sediment discharge is mainly concentrated in the 5–10 months, while the riparian zone is totally exposed. Therefore, we indicate that the soil erosion of upland slopes is the primary source of the sediment depositing at the reservoir riparian zone. However, further research work should be done: tracer studies are required to determine the provenance and fate of sediments and associated contaminants in Upper Yangtze River basin and the TGR.

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