Influence of the changing environment on sediment loads of the Lower Mekong River

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Abstract With the operation of the Chinese dams in the Upper Mekong River, the sediment issues of the Lower Mekong River (LMR) have attracted more attention. The reports of the impact of the Chinese dams are inconsistent or even contradictory, mainly due to scarcity of sediment measurements and lack of analysis of climate variations. This study employed a newly developed data set to overcome the data scarcity, and investigated both the influence of human activities and climate variations, as well as possible impacts of the Chinese dams on the sediment loads (SL) in the LMR. We differentiated the contributions of human activities and climate factors to the SL during 1962 to 2003 at Chiang Saen in Thailand, closest to the Chinese dams. The combined effects of human activities, including the Chinese dams, as a whole have increased the SL, while climate variations have decreased the SL. This suggests that the construction of the Chinese dams has slowed the increasing rate. Other stations further downstream have also been investigated.

Key words Lower Mekong River; Chinese dams; sediment loads; human activities; climate variations

INTRODUCTION

With the operation of the Chinese dams on the Upper Mekong River, increased attention has been directed towards understanding and assessing the possible impacts of the dams on the sediment flux of the Lower Mekong River (LMR). However, the previous studies resulted in inconsistent reports. Walling (2005) concluded that impacts of the construction of the Manwan and Dachaoshan dams were insignificant in the LMR. However, Lu & Siew (2006) and Kummu & Varis (2006) pointed out that the sediment loads (SL) at the Chiang Saen station, the nearest station to the dam site, decreased by more than half after the completion of the Manwan dam in the Upper Mekong River in 1993. In addition, they also reported that such impacts seemed insignificant at the downstream stations. For example, the increase of the SL can be seen during the post-dam period at the Mukdahan station. This debate may be due to the lack of observed sediment data for the LMR.

The sediment budget of the LMR has been built for the individual years during 1962–2003 using an improved rating curve method as proposed by Wang *et al*. (2008). Based on the sediment budget established, the present study analysed the possible impacts of the Chinese dams, as well as the different contributions to the SL variations of human activities and climate variations in the LMR.

DATA AND METHODS

Observed water discharge (WD) data and suspended sediment concentrations (SSCs) are available from the Mekong River Commission (MRC), although the frequencies of the sediment measurements are generally quite low. All of the available observed data were used in this study. In order to estimate the annual SL of the five mainstream gauging stations along the LMR for the individual years 1962–2003, Wang *et al*. (2008) used the traditional rating curve method for the years with good-quality data, and used an improved rating curve method that is based on the rating curve classification for the years without or with few data. Five stations: Chiang Saen, Luang Prabang, Nong Khai, Mukdahan and Khong Chiam, have more observed sediment records than the other stations.

The double-mass plot (Walling, 1997) was applied in this study, being a powerful and practical tool widely-used to identify sediment response to human activities (e.g. Walling, 1997, 2006; Xu, 2003). In addition, we applied a method similar to Xu (2003) to quantitatively investigate the different contributions of human activities and climate variations to the SL variations at the Chiang Saen station.

RESULTS AND DISCUSSION

The annual WD for each of the five stations did not show a statistically significant trend over the period 1962–2003, whereas their annual SL showed various trends. At Chiang Saen, two obvious breaks appear in the double-mass plot (Fig. 1). The double-mass plot shows a clear shift towards increased SL in 1986, when the construction of the Manwan dam began. The construction likely brought extra sediment into the stream, which increased the SL significantly. The double-mass curve turns down in 1993, the operation-start year of the Manwan dam and this break seems mostly likely due to sediment trapping by the dam. The entire time range of 1962–2003 can be divided into the three periods: Period 1 (1962–1985), Period 2 (1986–1992) and Period 3 (1993–2003); within each period, there is no clear break in the double-mass plot, suggesting that the variations of annual SL is mainly caused by the climate factors. The average SL increased from 79.45×10^6 t/year in Period 1, to 127.52×10^6 t/year in Period 2, and then decreased to 92.19×10^6 t/year in Period 3 (Table 1). The double-mass curve shows that the same WD could result in higher SL during Periods 2 and 3, in contrast to Period 1. This suggests that the soil disturbance due to the construction of the Manwan dam significantly increased soil erosion, which caused much higher SSC; the sediment trapping of the reservoir reduced the SSC after the operation of the dam.

Using Period 1 as a baseline, we tried to discriminate the different contributions of human activities and climate variations at Chiang Saen in the other two periods (Table 1). Figure 2 shows a good linear relation between the annual SL and annual WD in Period 1. Assuming no further impacts of human activities in Periods 2 and 3, this SL–WD relation should be similar for all three periods. Hence, using such a regression relation as well as the annual WD data of Periods 2 and 3, we estimated that the average SL due to climate factors should be 59.68 and 76.81×10^6 t/year for Periods 2 and 3, respectively. The increases in SL due to human activities should be 67.85 and 15.38×10^6 t/year for the Periods 2 and 3, respectively. In addition, compared with 79.45×10^6 t/year, the average SL in the Period 1 (the baseline period), the increase in SL due to the climate variations should be –19.77 and -2.64×10^6 t/year for Periods 2 and 3, respectively.

Although the construction and operation of the Chinese dams probably had a clearer impact on the SL of the LMR at Chiang Saen, such impacts seemed insignificant at the other four downstream stations (Fig. 1). At Luang Prabang, a significant trend of decreasing SL can be seen over the period 1962–2003. Only one notable break can be observed in the double-mass plot, showing the curve shifts downward around 1975. Similarly, a decreasing trend of SL can also be seen over the period 1962–2003 at Nong Khai, and only one break appears in the double-mass plot in 1975; however, the trend of change seems less significant than at Luang Prabang. At Mukdahan, a trend of increasing SL can be seen for 1962–2003. Two breaks, both upward, occur in the double-mass plot, in 1990 and in 2000. At Khong Chiam, the change trend of SL is similar to that at Mukdahan. Hence, the break at 1993 on the double-mass plot of Chiang Saen seems invisible at the four downstream stations, and their double-mass curves do not show a significant impact from the construction of the Chinese dams. The decrease of SL due to the Chinese dams may have been balanced before reaching Luang Prabang, which agrees with Lu & Siew (2006) and Kummu & Varis (2006).

The temporal variability of SL of a river may be attributed to climate variations and human activities. The destruction of vegetation and land surface disturbance may increase the SL, while the soil conservation activities and reservoirs may reduce the SL. However, just as Walling (2006) indicated, "although programmes for soil conservation and sediment control can result in reduced SL, the trapping of sediment by dams represents the dominant cause of reduced loads". Therefore, given that six more dams are under construction or are planned in the Upper Mekong River, the concerns relating to the possible impacts of Chinese dams will remain.

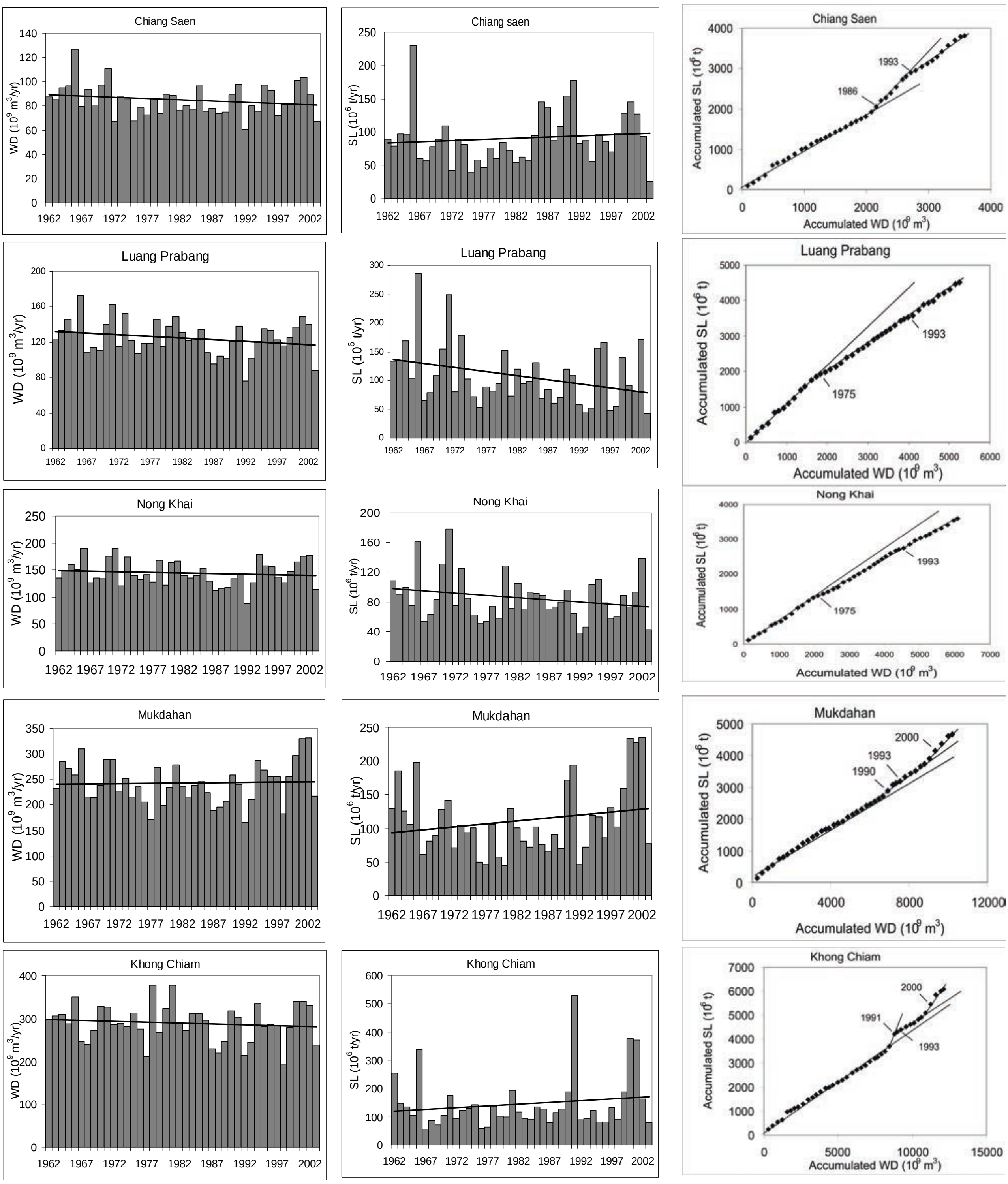

Fig. 1 The variations of water discharge (WD), sediment load (SL) and the associated double-mass plots at the five stations of Chiang Saen, Luang Prabang, Nong Khai, Mukdahan and Khong Chiam, respectively.

CONCLUSIONS

During the entire period 1962–2003, at the five main gauging stations along the LMR, the SL had different responses to human activities and climate variations. The possible impacts of the Chinese

Table 1 Increase in sediment loads at Chiang Saen by human activities and by climate.

Periods	Observed sediment load (10^6 t/year)	Estimated sediment load only due to climate factors (10^6 t/year)	Increase in sediment load due only to human activities (10^6 t/year)	Increase in sediment load due only to climate factors (10^6 t/year)
1 (1962–1985; the baseline)	79.45	---	---	---
2 (1986–1992)	127.52	59.68	67.84	–19.77
3 (1993–2003)	92.19	76.81	15.38	–2.64

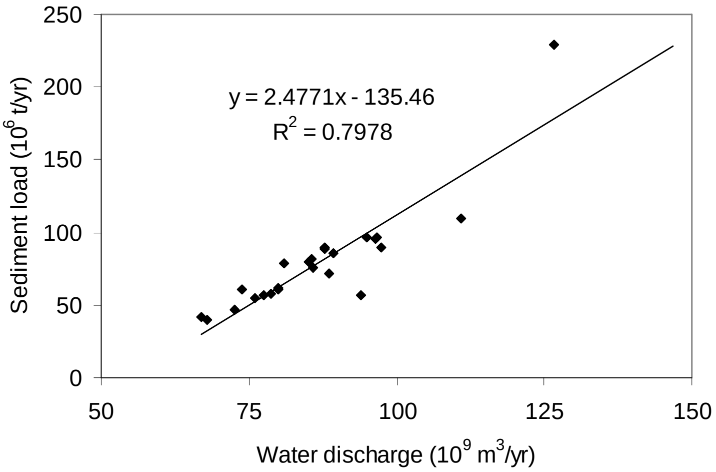

Fig. 2 The annual sediment load plotted against the annual water discharge for Period 1 (1962–1985) at the Chiang Saen station.

dams on the SL of the LMR seemed significant at Chiang Saen only. At Chiang Saen, compared to the pre-Manwan dam construction period, human activities, such as soil disturbance due to dam construction, likely caused more serious soil erosion and hence increased the SL, while the climate factors reduced the SL during the Manwan dam construction period. Compared with the construction period, the increases of the SL from human activities declined after the dam operation. This suggests that the SL at Chiang Saen was significantly impacted by the construction and operation of the Chinese dams.

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