Long-term erosion measurements on sloping lands in northern Vietnam: impact of land use change on bed load output

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Soil erosion in highly incised catchments of northern Vietnam harms both upstream and downstream communities (Valentin et al. 2008). Sediment discharged from these catchments reflects a loss of fertile topsoil that farmers depend on for the production of crops and pastures. In addition, increased sediment loads in streams and rivers reduce water quality and the longevity of water storages, with significant economic implications.

The aim of this study was to improve the knowledge of erosion processes on cultivated steep slopes and of sediment transport by river at the small catchment scale (<1 km^2) and in relationship to the land-use management of steep agricultural catchments. We set up a long-term project to monitor the hydrology and erosion in a catchment with 1 main outlet (MW) and 4 sub-catchments (W1–W4; Fig. 1). The entire 50-ha catchment has slopes between 40 and 100% leading to no easy solutions for mechanization.

The 5 monitoring weirs were equipped in 2000 with concrete sediment traps, water-level recorders and automatic water samplers to measure and assess discharge and sediment loads (Tran Duc Toan et al. 2003). This catchment is included in the research network of MSEC (Multiscale Environmental Changes; Valentin et al. 2008).

The catchment lies within Dong Cao village, 60 km north-east of Hanoi, and is typical of the agricultural environment of the agrarian transition occurring in northern Vietnam from the late 1980s. Over the past 30 years, farming on the hillslopes has moved from intensive upland rice to cassava to a mix of cassava, pasture, fodder and planted forest. The predominant land use has gradually changed from cassava to tree plantations and long fallows, with a decline in the total area of cassava from 40% of the catchment area in 2001 to less than 0.5% in 2004. The reasons for these land use changes are complex (Clément et al. 2007).

Figure 1. Plan of the Dong Cao catchment, northern Vietnam (MSEC network).

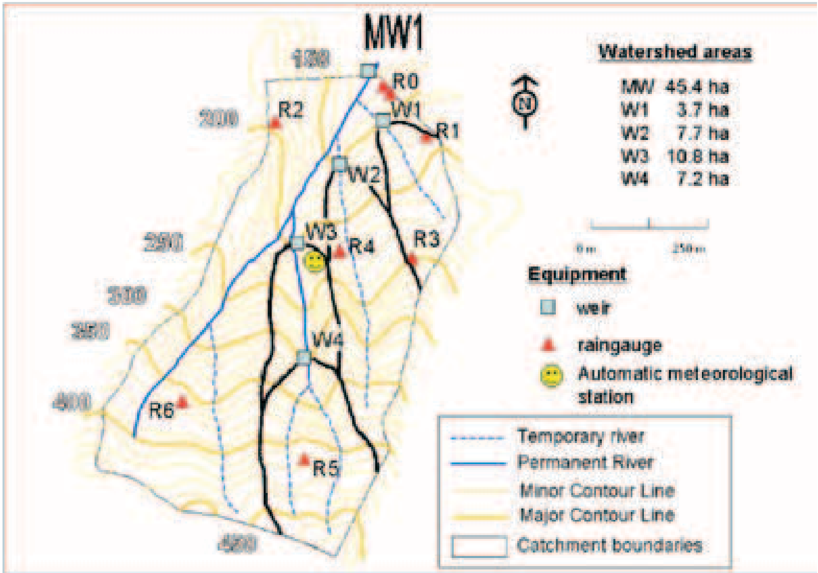
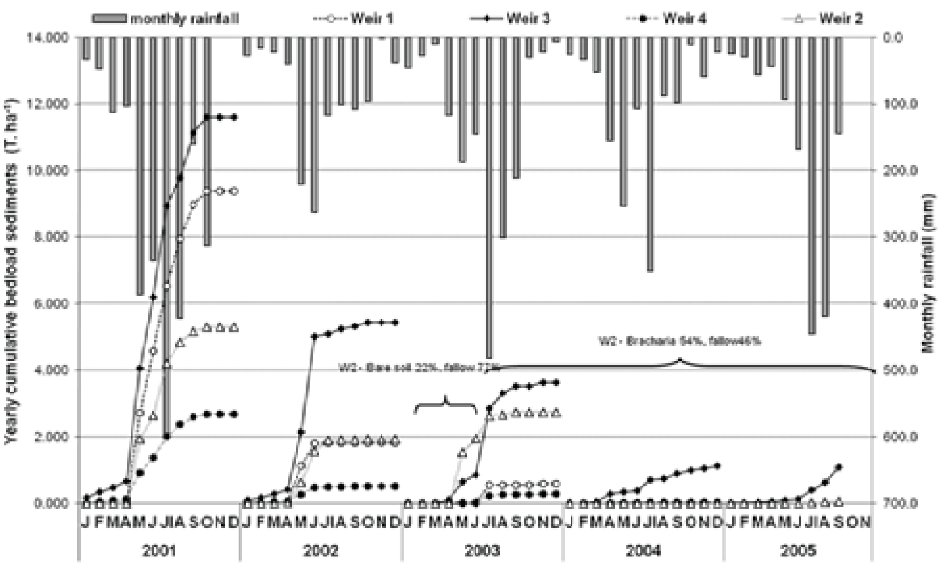


Figure 2. Annual cumulative bed load (lines) measured in Dong Cao catchment, northern Vietnam. Columns show monthly rainfall. Weir 1, forested; weir 2, pasture fallow (*Brachiaria ruziziensis*) from 2003; weir 3, cassava; weir 4, old natural fallow (>10 years).



Sub-catchment W1 was planted in 2001 to mainly *Acacia mangium* forest with a few *Venitia montana*. The trees were cut in 2006 and replaced by natural fallow. Sub-catchment W3 was planted to cassava until 2003 and has been left fallow since 2004. The entire catchment has been left fallow since 2006.The decline in cassava cropping brought the opportunity in 2003 to introduce a livestock component with the sowing of *Brachiaria ruziziensis* for fodder on sub-catchment W2 (from 2003 to 2005). Sub-catchment W4 is covered in natural long-term fallow with dense shrubs.

The annual soil loss recorded through bed load measurements decreased from 3.6 Mg ha^{-1} y^{-1} in 2001, before the establishment of pasture or plantation, to 0.1-0.3 Mg ha^{-1} y^{-1} from 2004.

Bed load monitoring from 2000 to 2005 highlights the rapid impact of land use change on soil loss (Fig. 2).

At W1, our results highlight the decline in bed load due to the shift from cassava to plantation forest in 2001. Before 2001, W1 lost a high bed load (9 Mg ha^{-1} y^{-1}). Only 1 year after the forest was planted, the bed load decreased to only 2 Mg $ha^{-1}y^{-1}$, and in subsequent years it declined to nil, suggesting that runoff contributing to sediment discharge had ceased.

At W2, measurements clearly show a decrease in soil loss within the first year after the shift from cassava to improved fallow in 2003. The initial establishment of the grass, with the associated bare soil, caused an initial increase in erosion (to 3 Mg ha^{-1} y^{-1}). Soil losses subsequently declined to <0.2 Mg ha^{-1} y^{-1}.

W3 (cassava then natural fallow from 2004) consistently recorded the highest bed loads. In 2001, the bed load discharge reached almost 12 Mg ha^{-1} y^{-1}; this was reduced to ~1 Mg ha^{-1} y^{-1} from 2004, since the cassava plantation ended. The decrease in 2002 was due solely to a reduction in rainfall (1047 mm vs.10-year average of 1500 mm).

At W4 (old fallow), there has been no land-use change. High rainfall in 2001 caused a high bed load, but in other years the bed load was <0.5 Mg ha^{-1} y^{-1}.

Long-term continuous monitoring of erosion in Dong Cao catchment shows that the bed load recorded at catchment level is better explained by land use change than by land clearing. Indeed, even if forests and fodder crops effectively eliminate erosion 1 year after establishment, their establishment induces the highest erosion load. A future study will report on changes in suspended load.

Keywords

Soil erosion, surface runoff, dead mulch cover, maize cropping

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The 3rd International Conference on Conservation Agriculture in Southeast Asia

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Proceedings

Hanoi, Vietnam
December 10-15, 2012
www.conservation-agriculture2012.org