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Effects of erosion patterns on nutrient loss following deforestation on the Loess Plateau of China

Fenli Zheng[a], Xiubin He[b,*], Xuetian Gao[a], Chang-e Zhang[c], Keli Tang[a]

[a] *National Laboratory of Soil Erosion and Dryland Farming on Loess Plateau, Institute of Soil and Water Conservation, CAS and MRS, Northwestern Sci-Tech University of Agriculture and Forestry, 26 Xinong Rd., Yangling, Shaanxi 712100, PR China*

[b] *Institute of Mountain Hazards and Environment, Ministry of Water Conservance, CAS, No. 9, Block 4, South Renmin Road, Chengdu, Sichuan 610041, PR China*

[c] *Chinese Academy of Agricultural Science, No.12, Zhongguancun South Street, Beijing 100081, PR China*

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Abstract

Soil degradation caused by deforestation is one of main environmental problems all over the world. The objective of this paper was to quantitatively evaluate the effects of erosion patterns on organic matter, nitrogen and phosphorus (P) losses, by monitoring soil erosion and nutrient loss in newly deforested lands in the Ziwuling region on the Loess Plateau of China from 1986 to 1996. Eight field runoff plots, with various sizes to enable documentation different combinations of dominant erosion processes, were established on a hillslope. Results showed that the nutrient loss was dramatically affected by erosion patterns and erosion intensity. Seven years after deforestation, organic matter, total nitrogen, ammonium nitrogen and available P reduced by 69, 46.7, 65.6 and 86.6%, respectively. The most severe soil erosion and nutrient loss occurred in the ephemeral gully channels. Organic matter, total nitrogen, ammonium nitrogen and available P had different nutrient enrichment ratios in eroded sediment. The available P had the highest enrichment ratios, followed by ammonium nitrogen. The nutrient enrichment ratios were closely related to sediment concentration and erosion patterns. In sheet erosion zone, the nutrient enrichment ratios in eroded sediment decreased with an increase of sediment concentration; in the combined erosion zones of sheet, rill and shallow gully, the nutrient enrichment ratios in sediment initially decreased and then increased with an increase of sediment concentration. The nutrient enrichment in eroded sediment also greatly affects by rainfall characteristics such as rainfall amount and intensity.
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Keywords: Erosion patterns; Nutrient loss; Nutrient enrichment; Deforestation; Rainfall; The Loess Plateau of China

1. Introduction

Soil erosion, in addition to causing on-site loss of topsoil and reducing the productivity of the land, brings about major off-site environmental effects such

* Corresponding author. Tel.: +86 28 85232105; fax: +86 28 85222258.
E-mail address: xiubinh@imde.ac.cn (X. He).

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as water body pollution and eutrophication (e.g., Lal, 1976; Morgan, 1995; He et al., 2003). There are many studies concerning the prediction of soil losses based on the universal soil loss equation (USLE) (e.g., Wischmeier and Smith, 1978) or the water erosion prediction project (WEPP) (e.g., Nearing et al., 1989). Meanwhile, a large number of studies have investigated eutrophic components (e.g., Sharpley et al., 1991; Sharpley and Halvorson, 1994), pesticides, herbicides (Miguel and Clara, 2003) and agricultural chemicals transfer (e.g., Johnson and Baker, 1982, 1984; Smolikowski et al., 2001). The later has recently been an interesting research area for both soil and environmental scientists.

A number of studies have been designed to determine the effects of factors, such as rainfall intensity, runoff rate, slope, clay content and storm pattern on nutrient losses in the Loess Plateau. Bai et al. (1991) reported that nutrient loss increased with increasing slope steepness under simulated rainstorm conditions in a 5-m long and 1.5-m wide soil box. Monke et al. (1977) studied relationships between runoff, erosion and nutrient movement in the interrill areas, and pointed out that the proportion of clay in sediment decreased with an increasing runoff rate while trends in nutrient contents showed an opposite trend. They also showed that enrichment ratios in sediment ranged from 1.2 to 2.3. Flanagen and Foster (1989) studied storm pattern effects on nitrogen (N) and phosphorus losses, and found that N and P in eroded sediment were significantly enriched. Young et al. (1986) showed that nutrient enrichment in eroded sediment decreased with increasing runoff rate and suspended sediment concentration. Alberts and Moldenhauer (1981) and Alberts et al. (1981) studied the transport of N and P with sediment in runoff passing through cornstalk residue strips. They reported that particles less than 0.002 mm in diameter had highest total N and P concentrations with concentrations decreasing in larger size classes. Sharpley et al. (1991) measured soil erosion and associated N and P losses with sediment under natural rainfall as affected by land management. They also found that both N and P contents in sediment were strongly related to sediment concentration of individual runoff events (Eqs. (1) and (2)):

$$N_s = 0.03{X_s}^{-0.68} \quad (1)$$

$$P_s = 0.72{X_s}^{-0.30} \quad (2)$$

where N_s is content of N in sediment (g/kg), P_s content of P in sediment (g/kg) and X_s is sediment concentration (g/L).

Similarly, Johnson and Baker (1982, 1984) reported on the relationship between Kjeldahl-N and total P in sediment in over 650 individual runoff samples collected from corn and soybean fields over a 5-year period. They also reported a strong relation between N and P contents in sediment and sediment concentration in runoff events, respectively (Eqs. (3) and (4)).

$$N_s = 6675{X_s}^{-0.11} \quad (3)$$

$$P_s = 4315{X_s}^{-0.18} \quad (4)$$

where N_s is content of N in sediment (mg/kg), P_s content of P in sediment (mg/kg) and X_s is sediment concentration (g/L).

Regardless of the exponent differences in the above equations, the research results indicated that nutrient content in eroded sediment decreased with an increase of sediment concentration.

On the Loess Plateau of China, heavy rainfall during summer and earlier autumn causes severe soil erosion. Soil erosion patterns change from sheet, rill to shallow gully (like ephemeral gully) erosion from top to bottom along loessial hillslopes (Fig. 1) (Zheng and Huang, 2002). These different soil erosion patterns have different soil detachment and transport capacities, therefore, they have different impacts on soil nutrient loss. Numerous studies have been conducted on soil erosion on the Loess Plateau, and sediment issues in the Yellow River basin (e.g., Huang, 1953; Zhu, 1956, 1981; Chen et al., 1988; Tang, 1991; Jing et al., 1993; Chen, 1993; Wang and Jiao, 1996; Cai et al., 1998; Xu, 1999; Zheng and Gao, 2000; Laflen et al., 2000). These research findings have increased the understanding of soil erosion issues and associated environmental problems. Since the 1980s, there have been a few papers that have also investigated the relationship of soil erosion to nutrients loss on the Loess Plateau (Tang et al., 1987; Peng and Wang, 1995; Hamilton and Luk, 1993). However, little attention has been given to quantify the effects of the soil erosion process on nutrient loss, particularly, the effects of erosion patterns on nutrient loss after conversion of forestlands into croplands.

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