Catena 156 (2017) 393–400

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Zonal characteristics of sediment-bound organic carbon loss during water erosion: A case study of four typical loess soils in Shaanxi Province

Zhongwu Li[a,b,c,*], Xiaodong Nie[b,c], Jijun He[d], Xiaofeng Chang[a], Chun Liu[a,b,c], Lin Liu[a], Liying Sun[e]

[a] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, CAS and MWR, Yangling, Shaanxi Province 712100, PR China

[b] College of Environmental Science and Engineering, Hunan University, Changsha, 410082, PR China

[c] Key Laboratory of Environmental Biology and Pollution Control, Hunan University, Ministry of Education, Changsha, PR China

[d] Base of the State Laboratory of Urban Environmental Processes and Digital Modeling, Key Laboratory of 3D Information Acquisition and Application, Ministry of Education, Capital Normal University, 100048 Beijing, PR China

[e] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, PR China

ARTICLE INFO

Keywords:
Soil organic carbon
Chinese Loess Plateau
Zonal soils
Simulated rainfall events

ABSTRACT

The soils of the Loess Plateau of China exhibit zonal characteristics, with declining clay percentages from the southern to northern regions. However, these differences have been largely ignored in studies of soil erosion and the related organic carbon (OC) loss. The goal of this study was to investigate the effect of gradual changes in soil texture on the loss and selective transport of soil and soil organic carbon (SOC) on the Loess Plateau of China. Four typical soils with decreasing clay contents (26.3%, 21.2%, 15.6% and 12.1%) in Shaanxi Province were selected and studied. Rainfall-simulated experiments were performed in 1 m (width) × 5 m (length) plots with a rainfall intensity of 120 mm h^{-1} on three slope gradients (15°, 20° and 25°). The runoff and sediment yields, particle size distributions of the sediments, OC concentrations and enrichment ratios of OC in sediment (ERoc) during rainfall processes were measured and calculated. A comparison of the rainfall characteristics between rainfall events in different soils indicated that a decrease in the clay percentage increased the intensity of rill erosion. The runoff rates of different events decreased with the clay percentage, whereas no general pattern was observed in the sediment yield rate due to differences in the initial timing and intensity of rill erosion. Furthermore, the ERoc values in the sediments of all the events were between 0.64 and 1.44, with 90% of values between 0.80 and 1.20. Similarly, the effective particle size distribution of the sediments exhibited relatively constant values with rainfall duration. Non-significant correlations ($P > 0.05$) between ERoc and dispersed and non-dispersed sediment particles suggested that the transport of sediment and OC was non-selective. Moreover, significant linear correlations were observed between the amount of SOC loss and sediments in all the events. However, there was no significant difference in total SOC loss between the rainfall events, except for in events with a soil clay percentage of 15.6%. SOC losses in soils with 26.3% and 21.2% clay percentages were mainly due to the high SOC concentrations of the original soils, whereas those in other soils were due to the large amount of lost sediment. However, the variations in soil loss and SOC loss were not associated with changes in the clay content of the soil. These results suggest that zonal soils with decreasing clay contents do not influence the selective transport of OC, but soil textures affect the sediment and SOC loss through complicated mechanisms.

1. Introduction

Soil erosion is a universal environmental issue. Accelerated erosion not only results in soil loss but also leads to the transport of soil organic carbon (SOC) (Girmay et al., 2009). Due to the vital function of SOC in sustainable social and environmental development (Lal, 2004a, 2004b), the role of soil erosion in SOC dynamics has attracted considerable attention from all over the world (Kirkels et al., 2014; Kuhn et al.,

Abbreviations: SOC, soil organic carbon; ERoc, enrichment ratio of organic carbon; YL, Yangling county; CW, Changwu county; AS, Ansai county; SD, Suide county

* Corresponding author at: State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, CAS and MWR, Yangling, Shaanxi Province 712100, PR China.

E-mail address: lizw@hnu.edu.cn (Z. Li).

http://dx.doi.org/10.1016/j.catena.2017.05.001
Received 23 August 2016; Received in revised form 26 April 2017; Accepted 3 May 2017
Available online 10 May 2017
0341-8162/ © 2017 Elsevier B.V. All rights reserved.

2012). Quantitatively assessing SOC loss is important for evaluating its effect on the environment.

Two main processes affect SOC loss during water erosion. One is the selective transport of organic carbon (OC). In general, materials enriched in OC can be transported preferentially due to their relatively low densities (Polyakov and Lal, 2004). The OC concentration in the sediment can decrease due to the depletion of carbon-rich substances and the transport of carbon-poor minerals (Schiettecatte et al., 2008a). The second process is soil loss. During water erosion, up to 90% of SOC in runoff may be in particulate form (Lowrance and Williams, 1988), thus soil loss can greatly influence SOC loss. As reported in the literature (Schiettecatte et al., 2008b; Nie et al., 2013; Nie et al., 2015; Li et al., 2016), all erosion processes (or stages), including the detachment, transport and deposition of soil materials by erosive forces, affect SOC loss. A common belief suggests that the "stripping" process may cause SOC loss during erosion (Schiettecatte et al., 2008a). This mechanism is highly related to soil aggregates, which are groups of primary soil particles and organic matter. Soil dispersion, transport and deposition are often associated with the formation and stability of soil aggregates. For example, sediment sorting was observed during water erosion in previous studies (Shi et al., 2012; Wang et al., 2014). Finer sediment (< 0.4 mm) is transported preferentially (Asadi et al., 2011), whereas coarser and heavy particles settle out more easily than do finer fractions (Schiettecatte et al., 2008b). Additionally, selective transport of SOC has been observed in various studies (Jin et al., 2009; Schiettecatte et al., 2008a; Zhang et al., 2013), and significant correlations between the enrichment ratios of organic carbon (ERoc) and clay (ERclay) have been observed (Nie et al., 2015). Meanwhile, sediment collected during low-intensity storms contained more OC than did materials displaced during high-intensity storms (Jacinthe et al., 2004). This trend was observed because fine particles are usually richer in soil-sorbed nutrients than are coarse particles (Palis et al., 1990). The loss of organic matter generally leads to the breakdown of soil aggregates; consequently, finer particles are transported preferentially by erosion (Celik, 2005). Müller-Nedebock and Chaplot (2015) performed studies around the world and found that ERoc varied between 0.2 and 10.0 in various soil types, reflecting the key role that soil texture plays in OC enrichment in sediments and the potential fate of OC. Furthermore, soil texture may have a considerable impact on soil crusting, which affects SOC loss (Maïga-Yaleu et al., 2015). In addition, Augustin and Cihacek (2016) found that clay and silt contents in the soil were positively correlated with the OC content and the sand content was negatively correlated with the OC content, indicating that soil texture has a notable impact on the soil water-holding capacity, which may affect soil loss. Therefore, primary soil particles, as vital components of aggregates, affect SOC loss by influencing the amount of adsorbed SOC and the stability of soil aggregates. Specifically, differences in soil textures may result in variations in soil and SOC losses.

The soils of the Chinese Loess Plateau have experienced severe soil and water losses (Fu et al., 2011; Li et al., 2017). The total eroded area of the Loess Plateau is approximately 454,000 km^2, of which 337,000 km^2 is affected by water erosion (Jin et al., 2008a). The average erosion rate of cultivated land on the Loess Plateau is estimated to be 60 tons ha^{-1} y^{-1} (Luk, 1991). The main soils of the Loess Plateau developed from calcareous loess parent material, and have a low soil organic matter content that averages approximately 10 g kg^{-1}. The soils of the Loess Plateau are particularly sensitive to water erosion because of their texture (silt loam), physical properties, and low soil organic matter contents (Jin et al., 2008b). The formation of soil on the Chinese Loess Plateau was thought to be due to wind transport (Zhu, 1991), and differences in soil particles were observed on the Loess Plateau. It has been reported that the soil anti-erodibility was the highest in the southwestern region of the Loess Plateau, moderate in the western region and weakest in the northern region (Wang, 1994). Therefore, differences in formation processes may cause differences in soil type and affect soil erosion and soil loss. However, most studies did not distinguish between regional differences on the Chinese Loess Plateau. Commonly, specific areas in previous studies were often referred to as "the entire Loess Plateau". This may result in overestimated or underestimated soil or SOC loss. Consequently, the differences in soil erosion and SOC losses in different regions of the Loess Plateau must be urgently determined.

The primary objective of this study was to explore the effects of regional characteristics on sediment-bound OC loss in soils with different soil textures on the Loess Plateau in Shaanxi Province, China. We hypothesized that SOC loss shows gradual changes in ERoc in the studied soils. Specifically, we hypothesized that ERoc decreases from south to north and the SOC loss increased from south to north. To test these hypotheses, we simulated rainfall experiments in the laboratory. The experiments used four zonal soils with decreasing clay contents. We studied the loss of sediment and the associated SOC, including the selective transport of OC in the sediment and the sorting of sediment particles.

2. Materials and methods

2.1. Site description and soil sampling

The Chinese Loess Plateau covers a total area of 624,000 km^2 (Shi and Shao, 2000), and spans seven provinces, including Shaanxi, Gansu, Qinghai, and others. Soil erosion studies have been conducted in all these provinces. Meanwhile, a large proportion of these studies were performed in Shaanxi Province because of the representativeness of the study area and the severity of soil erosion there. In this study, four typical soils in Shaanxi Province were selected to explore the soil characteristics and SOC losses. The soils were collected from Yangling (YL) (34°16′ N, 108°4′ E), Changwu (CW) (35°12′ N, 107°47′ E), Ansai (AS) (36°58′ N, 109°20′ E), and Suide (SD) (37°31′ N, 110°16′ E), Shaanxi Province, China (Fig. 1). The sampling points were chosen mainly based on the soil texture, which exhibited regular variations in these soils. Furthermore, field-monitoring stations for soil and water conservation are located at all the four sites. Moreover, previous studies reported that different degrees of water erosion had occurred at these sites (Wang et al., 2006; Li et al., 2013).

No fertilizers (neither chemical nor organic fertilizers) were applied to these lands during the plant growth period. All of the selected lands were cultivated with crops before sampling, and the plough layer of these lands was approximately 20 cm. First, soils were collected from the surface layers (20 cm) of the croplands. Then, the collected soils were transported to the laboratory and air dried at room temperature. Next, plant residuals and gravels were removed, and the soils were gently crushed and passed through a 10 mm sieve before the experiments. Eventually, the soils were mixed thoroughly, sealed, and saved for the rainfall experiments. The basic physicochemical properties of the four soils are displayed in Table 1.

2.2. Experimental devices

The simulated rainfall experiments were conducted at the State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau. To eliminate the effect of water quality on the study, deionized water was used in the simulated rainfall experiments. A rainfall simulator with a height of 6–6.5 m was used to generate rainfall over the plots. The rainfall intensity was controlled based on the nozzle size and water pressure. The uniformity coefficients of rainfall ranged from 70% to 90% (Chen et al., 2008), and calibrations of rainfall intensities were conducted prior to the experiments.

Experimental plots were constructed using metal sheets with dimensions of 5 m (length) × 1 m (width) × 0.5 m (depth). The plots were placed on movable platforms for ease of movement. Additionally, the lower end of each plot was equipped with a funnel-shaped collection trough. The plots could be electrically adjusted to a desired

Download English Version:

https://daneshyari.com/en/article/5770014

Download Persian Version:

https://daneshyari.com/article/5770014

Daneshyari.com