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RESEARCH ARTICLE

Effects of collapsing gully erosion on soil qualities of farm fields in the hilly granitic region of South China

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Abstract
Collapsing gully erosion is a specific form of soil erosion types in the hilly granitic region of tropical and subtropical South China, and can result in extremely rapid water and soil loss. Knowledge of the soil physical and chemical properties of farmland influenced by collapsing gully erosion is important in understanding the development of soil quality. This study was conducted at the Wuli Watershed of the Tongcheng County, south of Hubei Province, China. The aim is to investigate soil physical and chemical properties of three soil layers (0–20, 20–40 and 40–60 cm) for two farmland types (paddy field and upland field) in three regions influenced by collapsing gully erosion. The three regions are described as follows: strongly influenced region (SIR), weakly influenced region (WIR) and non-influenced region (NIR). The results show that collapsing gully erosion significantly increased the soil gravel and sand content in paddy and upland fields, especially the surface soil in the SIR and WIR. In the 0–20 cm layer of the paddy field, the highest gravel content (250.94 g kg^{-1}) was in the SIR and the lowest (78.67 g kg^{-1}) was in the NIR, but in the upland filed, the surface soil (0–20 cm) of the SIR and the 40–60 cm soil layer for the NIR had the highest (177.13 g kg^{-1}) and the lowest (59.96 g kg^{-1}) values of gravel content, respectively. The distribution of gravel and sand decreased with depth in the three influenced regions, but silt and clay showed the inverse change. In the paddy field, the average of sand content decreased from 58.6 (in the SIR) to 49.0% (in the NIR), but the silt content was in a reverse order, increasing from 27.9 to 36.9%, and the average of the clay content of three regions showed no significant variation ($P<0.05$). But in the upland filed, the sand, silt and clay fluctuated in the NIR and the WIR. Soils in the paddy and upland field were highly acidic (pH<5.2) in the SIR and WIR; moreover lower nutrient contents (soil organic matter (SOM), total N and available N, P, K) existed in the SIR. In the 0–20 cm soil layer of the paddy field, compared with the NIR and the WIR, collapsing gully erosion caused a very sharp decrease in the SOM and total N of the SIR (5.23 and 0.56 g kg^{-1}, respectively). But in the surface soil (0–20 cm) of the upland field, the highest SOM, total N, available N, available P and available K occurred in the NIR, and the lowest ones were in the SIR. Compared with the NIR, the cation

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exchange capacity (CEC) in the SIR and WIR was found to be relatively lower. These results suggest that collapsing gully erosion seriously affect the soil physical and chemical properties of farmland, lead to coarse particles accumulation in the field and decrease pH and nutrient levels.

Keywords: collapsing gully erosion, farmland, hilly granitic region, soil nutrient, soil properties, South China

1. Introduction

Soil erosion represents one of the most important, but poorly quantified common global environmental problems (Xia *et al.* 2009; Park *et al.* 2014). In the hilly granitic region of tropical and subtropical South China, there is a serious soil erosion type called collapsing gully erosion. Collapsing gully defined as an erosional landform with a very high rate of sediment transfer, is formed in the hillslopes with the cover of thick granite weathering crust and caused by the joint operation of mass wasting and flowing water erosion with the former playing the dominant role (Xu and Zeng 1992; Xu 1996). The granite weathering crust, which has undergone intense chemical weathering, with thicknesses in the range of 20–60 m is widely distributed (Lan *et al.* 2003). Several factors such as geological structure, soil properties, vegetation cover conditions and slope geometry strongly influence the rate of collapsing gully erosion (Scott Munro and Huang 1997; Woo *et al.* 1997). In the hilly granitic region, the impact of collapsing gully erosion is devastating. From 1950 to 2005, collapsing gully erosion affected 1 220 km^2 in this region (Zhong *et al.* 2013), and monitoring data show that the numbers of the collapsing gullies are more than 239 000 and widely distributed in 7 regions of South China, including Guangdong, Jiangxi, Hubei, Hunan, Fujian, Anhui, and Guangxi (Deng *et al.* 2015). The collapsing gullies are similar to gullies in China's Loess Plateau and the badland landscape occurring in other humid tropical and subtropical areas of the world, but the collapsing gully has its own essential feature (Xu 1996). The deposition of eroded materials from the collapsing gullies has buried dozens of hectares of farmland and silted up the streams. Coarse and sandy materials smear over the fields, leading to sandification of land, marked decline in land productivity and sometimes farmland abandonment (Lam *et al.* 1997; Luk *et al.* 1997a; Sheng and Liao 1997).

Most of the relevant researches during the past decades focused on the influence factors of collapsing gully erosion (Xu and Zeng 1992; Xu 1996; Luk *et al.* 1997a) and the variations in soil physical properties in different soil profiles of the collapsing gully wall (Wu and Wang 2000; Xia *et al.* 2015) and the effects of vegetation cover (Woo and Luk 1990; Woo *et al.* 1997b; Zhang *et al.* 2004) and human activities (Kimoto *et al.* 2002) on soil and water loss and sediment discharge in the hilly granitic regions. Woo and Luk (1990) reported that most slopes consist of an unknown combination of loose materials and weathered granite and the resistance to sediment entrainment cannot be easily determined. The results also indicated that the potential sediment yield from the collapsing gullies increases as vegetation cover decreases. Monitoring the water and sediment yield from collapsing gully is also the main aspect of the researches (diCenzo and Luk 1997; Luk *et al.* 1997b; Uchida *et al.* 2000). By using composite fingerprinting technique, the research shown that in the alluvial fan, 10% of the alluvial fan's sediment originated from the surface layer soils in the active collapsing gully, and the soil surface layer is more easily washed away in an active collapsing gully than in a stable collapsing gully (Lin *et al.* 2015). Some literatures assessed the nutrient status and nutrient fluxes of the soils in the upland and the lowland areas of collapsing gully (Sioh *et al.* 1990; Lam *et al.* 1997). Deng *et al.* (2014) found that collapsing gully erosion causes serious desertification and structural deterioration of the soil in the alluvial fan farmland. Based on the real-time kinematic global position system (RTK GPS) positioning technology, Zhang *et al.* (2015) studied the basic physical and chemical properties and nutrient distribution of the collapsing alluvial fan. The results found that the content of alkali hydrolysable nitrogen and available potassium were risen regularly with the increase of distance from the fan starting point and available phosphorus was increased enormously. Deng *et al.* (2015) evaluated the effects of different land uses on the soil physic-chemical properties and erodibility of collapsing gully alluvial fan, and reported that the soil physic-chemical properties were increased in different degrees under the different land uses. However, the effects of collapsing gully erosion on soil properties of farmland are poorly documented in the hilly granitic region, South China. The objectives of this study include (a) to describe and assess the soil properties status of the paddy and upland field in different regions influenced by collapsing gully erosion and (b) to determine the differences and state of the soil nutrient between different soil layers of the field in the different influenced regions. Results from the present study may broaden our knowledge of collapsing gully erosion effects on field soils and provide solutions to the amelioration and utilization of farmlands.