Pedosphere **25**(4): 489–500, 2015
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Soil Enzyme Activities on Eroded Slopes in the Sichuan Basin, China

NIE Xiaojun[1], ZHANG Jianhui[2,*] and GAO Han[1]

[1] *Land Research Integrated Monitoring and Sustainable Utilization in Central China, Field Science Observation & Research Base of the Ministry of Land and Resources of China, School of Surveying and Land Information Engineering, Henan Polytechnic University, Jiaozuo 454003 (China)*

[2] *Key Laboratory of Mountain Surface Processes and Ecological Regulation, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041 (China)*

(Received December 15, 2014; revised May 21, 2015)

ABSTRACT

Determining how soil erosion affects enzyme activity may enhance our understanding of soil degradation on eroded agricultural landscapes. This study assessed the changes in enzyme activity with slope position and erosion type by selecting water and tillage erosion-dominated slopes and performing analyses using the ^{137}Cs technique. The ^{137}Cs data revealed that soil loss occurred in the upper section of the two eroded slope types, while soil accumulation occurred in the lower section. The invertase activity increased downslope and exhibited a pattern similar to the ^{137}Cs data. The spatial patterns of urease and alkaline phosphatase activities were similar to the ^{137}Cs inventories on the water and tillage erosion-dominated slopes, respectively. On both the eroded slope types, the invertase activity and soil organic carbon content were correlated, but no correlation was observed between the alkaline phosphatase activity and total phosphorus content. Nevertheless, the urease activity was correlated with the total nitrogen content only on the water erosion-dominated slopes. The enzyme activity-to-microbial biomass carbon ratios indicated high activities of invertase and urease but low activity of phosphatase on the water erosion-dominated slopes compared with the tillage erosion-dominated slopes. Both the invertase activity and the invertase activity-to-microbial biomass carbon ratio varied with the slope position. Changes in the urease activity-to-microbial biomass carbon ratio were significantly affected by the erosion type. These suggested that the dynamics of the invertase activity were linked to soil redistribution on the two eroded slope types, whereas the dynamics of the urease and alkaline phosphatase activities were associated with soil redistribution only on the water or tillage erosion-dominated slopes, respectively. The erosion type had an obvious effect on the activities of invertase, urease and alkaline phosphatase. Soil redistribution might influence the involvement of urease in the N cycle and alkaline phosphatase in the P cycle. Thus, enzyme activity-to-microbial biomass ratios may be used to better evaluate microbiological activity in eroded soils.

Key Words: ^{137}Cs technique, microbial biomass C, N cycle, P cycle, soil organic C, soil redistribution, tillage erosion, water erosion

Citation: Nie X J, Zhang J H, Gao H. 2015. Soil enzyme activities on eroded slopes in the Sichuan Basin, China. *Pedosphere*. **25**(4): 489–500.

Soil erosion is a primary cause of land degradation in mountainous and hilly areas of China, such as the Qinghai-Tibet Plateau, the Loess Plateau, and the black soil region in Northeast China (Zhao *et al.*, 2013; Li *et al.*, 2014; Liu *et al.*, 2014). Effective measures such as afforestation programs and land conversion programs on sloping landscapes have been undertaken to combat erosion-induced soil degradation in these areas. However, in the hilly areas with intense farming, such as the Sichuan Basin, which is known as China's breadbasket, soil erosion is still a serious impediment to the development of sustainable agriculture. Intensive soil erosion mostly occurs on sloping agricultural landscapes in the Sichuan Basin. Soil erosion from sloping landscapes has been estimated to account for 60%–80% of the total soil erosion in the region (Chen *et al.*, 2000). To minimize the risk of water erosion, most of the hillslopes in the region have been apportioned by local farmers into slope segments with different gradients. Unfortunately, this agricultural practice has led to intensive tillage erosion. Field evidence from different regions of the world has emphasized that water and tillage erosion processes are two major soil erosion processes on tilled sloping landscapes (Van Oost *et al.*, 2006; García-Orenes *et al.*, 2009; Mandal and Sharda, 2013; Lieskovský and Kenderessy, 2014). Moreover, the impacts of tillage and water erosion on temperate agricultural soils are of approximately the same order of magnitude (Van Oost *et al.*, 2006). Currently, the negative effect of tillage erosion on soil quality is drawing more attention in the Sichuan Basin.

Among the available soil quality indicators, soil or-

*Corresponding author. E-mail: zjh@imde.ac.cn.

ganic carbon (SOC), nitrogen (N) and phosphorus (P) have been widely studied in eroded soils. There is increasing evidence that water erosion accelerates the losses of SOC, N and P from soils (Polyakov and Lal 2004; Nie *et al.*, 2013a) and that tillage erosion mainly increases the spatial variability of these nutrients (Heckrath *et al.*, 2005). Studies conducted previously in the Sichuan Basin further demonstrated that the effects of water and tillage erosion on the spatial distribution of SOC, N and P on sloping landscapes are different due to selective soil transport by water and complete soil disturbance by tillage (Zhang *et al.*, 2006; Ni *et al.*, 2007; Cerdà *et al.*, 2007, 2009, 2010; Haile and Fetene, 2012; Prokop and Poręba, 2012). However, little is known about the effect of soil erosion on soil microbial properties, such as enzyme activity, in relation to nutrient dynamics in the Sichuan Basin.

Soil enzyme activity is a more vital contributor to soil quality than soil nutrients (Dick, 1997) because all biochemical transformations that occur in soil depend on or are related to the presence of enzymes (Tabatabai, 1994). The impact of soil erosion on enzyme activity has been addressed in degraded soils (García and HernÁndez, 1997; Moreno-de las Heras, 2009; Park *et al.*, 2014), thus enhancing our understanding of the biochemical processes of soil degradation by erosion. Among the available soil enzyme parameters, invertase, urease and phosphatase activities are regarded as three desirable indicators of the supplies of SOC, N and P, respectively. Invertase participates in the C cycle by catalyzing the hydrolysis of sucrose into glucose and fructose. Urease is involved in the N cycle and catalyzes the hydrolysis of urea into CO_2 and NH_3, which is of particular interest because urea is an important N fertilizer. In the P cycle, phosphatase catalyzes the hydrolysis of both organic phosphate esters and phosphoric anhydrides into inorganic P. In the Sichuan Basin of China, the losses of SOC, N and P induced by soil erosion are threatening food security (Su *et al.*, 2010). To ensure crop production, farmers are accustomed to increasing fertilizer use to offset soil nutrient losses. However, the effect of long-term increases in fertilization on crop production is unknown for eroded slopes. The conventional practice accelerates N and P pollution of the local aquatic environment. Conservation measures considering soil enzymes would likely contribute to the development of sustainable agriculture in the Sichuan Basin. In this context, there is a need to assess the effect of soil erosion on the activity of soil enzymes such as invertase, urease and phosphatase in relation to C, N and P cycling.

Cesium-137 (^{137}Cs) is a well-established soil erosion tracer (Walling and Quine, 1991), and determination of erosion (less ^{137}Cs in test sites than in reference sites) or deposition (more ^{137}Cs in test sites than in reference sites) can be performed by comparing ^{137}Cs inventories of test sites with those of reference sites. Furthermore, ^{137}Cs inventories in eroded soil are inversely proportional to the erosion degree. The relationships between ^{137}Cs and soil chemical properties (*e.g.*, C, N and P) are well known (Zhang *et al.*, 2006; Ni *et al.*, 2007; Nie *et al.*, 2013a; Li *et al.*, 2014), supporting the use of the ^{137}Cs technique as a valuable tool for assessing the effect of soil erosion on soil quality.

In this study, we used the ^{137}Cs technique to evaluate erosion-enzyme relationships in eroded soils of the Sichuan Basin, China, aiming 1) to examine the dynamics of soil invertase, urease and alkaline phosphatase activities on water and tillage erosion-dominated landscapes and 2) to elucidate the impacts of water and tillage erosion on soil invertase, urease and alkaline phosphatase activities. Because water erosion may easily liberate more organic substrates from soil aggregates to increase enzymatic catalysis (Berhe *et al.*, 2012), we hypothesized that the activities of soil invertase, urease and alkaline phosphatase would be higher on water erosion-dominated landscapes than tillage erosion-dominated landscapes.

MATERIALS AND METHODS

Study area

This study was conducted in Jianyang County, Sichuan Province, in the Sichuan Basin of the southwestern part of China (30°04′28″–30°39′00″ N, 104°11′34″–104°53′36″ E). The study area is typical of the hilly areas of Sichuan (400–587 m above sea level), exhibiting a humid subtropical climate with a mean annual temperature of 17 °C and a mean annual rainfall of 872 mm, 90% of which occurs between May and October. The soils in the study area, derived from purple mudstone and sandstone of the Jurassic Age, are classified as Orthic Regosols in the FAO soil classification system. The soils are clay loam in texture (27% clay, 29% silt and 44% sand) and generally contain less than 20 g kg^{-1} organic matter.

Hoes are the predominant tillage implement in this area. One major tillage operation is carried out per year, starting at the bottom of the slope and moving upslope step by step; however, within every step, the tillage direction is downslope (*i.e.*, always grading downward). Due to long-term intensive hoeing, the upper parts of the slope are characterized by a thin soil