



# Microbial responses to soil rewetting in erosional and depositional environments in relation to the organic carbon dynamics

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## ABSTRACT

In order to investigate the microbial responses to soil rewetting in erosional and depositional environments in relation to organic carbon dynamics, three contrastive plots (in erosional, transitional, and depositional areas) were imposed with varying erosion or deposit characteristics in a typical sloping cropland of the red soil region in south China. The cropland was rewetted uniformly by a simulated rainfall under field conditions, and the three plots in the land were sampled before and 180 h after rewetting. Soil organic carbon (SOC) pools, DNA-based microbial abundance, and community structure were measured. In response to rewetting, the erosional area had greater microbial abundance than the transitional or depositional sites. The variations in bacterial and fungal abundance were not significantly correlated with the dynamics of soil carbon pools at site or during the whole experimental period. Bacterial diversity increased immediately after rewetting at downslope positions, especially in the depositional area. Fungal community structure was less sensitive to rewetting than that of bacteria and was rather dynamic at the erosional site compared with the depositional site. Together with site variables, the carbon data set significantly ( $P < 0.01$ ) explained the variations of bacterial and fungal community structures after rewetting. To conclude, site erosion or deposit characteristics may affect the drying/rewetting (D/R) susceptibility of soil biogeochemical carbon cycles by inducing shifts in functional microbial communities with different responses to rewetting.

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## 1. Introduction

Global, regional, and local carbon cycles can severely influence climate change, which has been widely studied for years (Cox et al., 2000; Lal et al., 2012). However, carbon dynamics in water-eroded soils remains poorly understood and quantified and thus is a key uncertainty in global carbon budgets (Lal, 2006; Lal and Pimentel, 2008; Boix-Fayos et al., 2009). Water erosion is coupled with changes in local soil properties and biological processes and can affect soil carbon dynamics through many complicated processes (Shi et al., 2010), including selective migration with runoff and sediment, mineralization conducted by soil microbial respiration, and enrichment and sequestration in the depositional area (Lal, 2005). In fact, the fate of eroded soil organic carbon (SOC) or the dynamics of reserved carbon in erosional sites is

closely related to soil microorganisms as they mediate critical carbon transformations (Carney et al., 2007). This pattern is strongly regulated by environmental stressors and perturbations, e.g., soil drying and rewetting (D/R) (Gordon et al., 2008), which will subject soil microbes to physiological stresses by decreasing substrate diffusion and thus lead to changes in metabolism (Schimel et al., 2007).

Water erosion exposes SOC and releases soil microorganisms that are physically protected within aggregates in erosional areas. Selective transpositions induced by runoff will then drive soil carbon and soil particles to be redistributed in the landscape (Chartier et al., 2013; Shi et al., 2013). Finer particles and associated SOC are preferentially transported away from eroding slopes to low-lying depositional environments (Berhe et al., 2007), which creates different habitats for soil microorganisms in erosional and depositional environments. In an erosional environment, coarse soil particles remain in situ and restrict soil aggregation. As a result, SOC is exposed to microbial attack and gradually mineralized to CO<sub>2</sub> owing to lack of protection (Lal, 2005). In contrast, in a depositional environment, abundant substrate and suitable temperature/moisture conditions may benefit soil microorganisms and aggregate formation, which will profoundly increase the soil organic matter (SOM) turnover and perhaps SOC sequestration (Renwick et al.,

Abbreviations: D/R, drying/rewetting; SOC, soil organic carbon; SOM, soil organic matter; DOC, dissolved organic carbon; EA, erosional area; TA, transitional area; DA, depositional area.

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2004). The breakup of initial soil aggregates at erosional sites and the erosion during transport may be responsible for increased microbial mineralization and CO<sub>2</sub> emissions, while encapsulation of SOC within soil aggregates may be a major limitation to its microbial decomposition in a depositional environment (Polyakov and Lal, 2008). Ultimately, all these mechanisms involved in soil carbon turnover are affected by D/R perturbation.

Similar to the Mediterranean ecosystems (Boix-Fayos et al., 2009), many areas of the red soil region in south China also suffer from frequent D/R and serious erosion caused by climate change and poor management. We recognize that D/R stressors have remarkable effects on microbial physiology and community composition, which imply the carbon turnover and nutrient flow in terrestrial ecosystems (Schimel et al., 2007; Gordon et al., 2008). However, the effects of D/R on soil structure (i.e., aggregation) as well as soil microorganisms in erosional and depositional environments are still unclear and may be an important mechanism that controls the carbon turnover in these two environments. In fact, soil aggregate dynamics and its relationship with microbial community were suggested as key controlling factors on SOC dynamics, and D/R cycles may enhance aggregate turnover and SOM decomposition (Denef et al., 2001).

Most studies on SOC dynamics and carbon sequestration in relation to soil erosion focus on migration and redistribution during erosion, but not on the fate of in situ and eroded carbon that was intercepted and captured within the landscape after erosion. Moreover, organic carbon is lost from soil mainly through mineralization into CO<sub>2</sub> (Gregorich et al., 1998), and this pathway is closely associated with soil microorganisms. However, few studies are concerned with the variation of microbial community composition in response to rewetting within eroded sloping croplands or how these dynamics can profoundly influence carbon turnover. Therefore, the aims of this paper are to (i) report the changes in SOC stock and microbial community composition (including abundance and community structure) induced by rewetting over a period of 180 h, and (ii) evaluate the relationship between microbial community composition and SOC dynamics in response to rewetting at three sites with different erosion degrees and deposit characteristics within a typical sloping cropland.

## 2. Materials and methods

### 2.1. Experimental site

The experiment was conducted at a Soil and Water Conservation monitoring station (111°22' E., 27°03' N.) located in the Shuangqing district in Shaoyang City of Hunan Province, in the hilly red soil region of south China (Fig. 1). The study area is in a subtropical monsoon climate zone, with annual mean minimum and maximum temperatures of 16.1 and 17.1 °C, respectively. Mean annual precipitation is 1327.5 mm, 55% of which occurs from May through August, the months of the rainy season. In summer, with high temperatures and frequent high intensity thunderstorms, this area is subjected to serious water erosion and periodic D/R. The soil type is typically Quaternary red clay, with clay-to-loam texture. The U.S. Soil Taxonomy classified the soils as Ultisols.

The experimental site, a typical sloping cropland, was planted with *Polygonatum odoratum* (Mill.) Druce for 10 years until 2009 and then left unused until the experiment was performed on 15 July 2011. The farming method for this land was chisel plow. Above-ground biomass of crops was typically stacked at the top of the sloping land to avoid being flooded after digging the root block, which might raise carbon content in surface soil. The sloping cropland consists of closely dissected short and steep slopes in lengths of 1–3 m and gradients between 5% and 15% (Fig. 2B). As such, erosional and depositional environments were delineated and water and eroded sediment from the erosional area were rapidly directed downslope where reduced slope gradient



Fig. 1. Location of the study site.

would decelerate and obstruct the sediment-laden runoff water, and thereby induce deposition.

### 2.2. Experimental design

The experiments were carried out in the summer of 2011 (15–22 July) and lasted 180 h. A block (2 m wide × 5 m long) was taken from the selected sloping cropland using metal frames. The block was divided into five equivalent plots A, B, C, D, and E (2 m × 1 m) along the slope. Plots A, C, and E were chosen as experimental treatments and sampling sites according to their erosional or depositional characteristics within the cropland (Fig. 2A). From the perspective of topography,

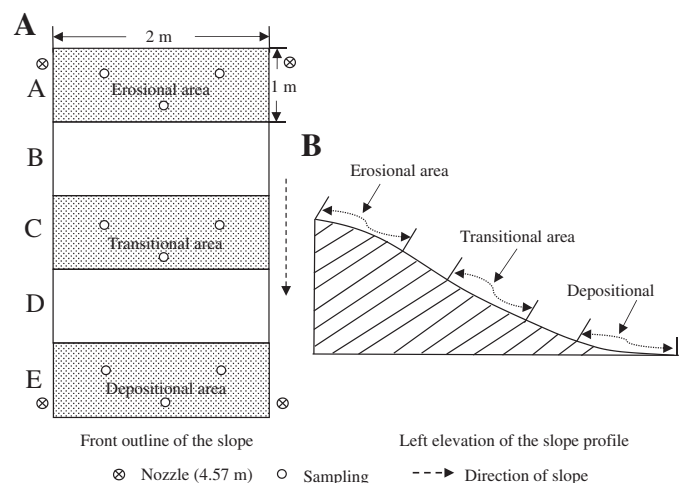


Fig. 2. Design of plots and sampling sites for rewetting by rainfall simulation.

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