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Changes of the organic carbon content and stability of soil aggregates affected by soil bacterial community after afforestation

F.Z. Zhao[a,b,*], X.D. Fan[a], C.J. Ren[c], L. Zhang[d], X.H. Han[c,**], G.H. Yang[c], J. Wang[a,b], R. Doughty[e]

[a] Shaanxi Key Laboratory of Earth Surface System and Environmental Carrying Capacity, Northwest University, Xi'an, Shaanxi 710127, China
[b] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Water and Soil Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling 712100, Shaanxi, China
[c] College of Agronomy, Northwest A&F University, Yangling, 712100, Shaanxi, China
[d] Shaanxi Land Construction Group, Shaanxi LCG Land Project Technology Institute, Key Laboratory of Degraded and Unused Land Consolidation Engineering the Ministry of Land and Resources of China, Xi'an, Shaanxi 710075, China
[e] Department of Microbiology and Plant Biology, Center for Spatial Analysis, University of Oklahoma, Norman, OK 73019, USA

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ABSTRACT

Soil aggregation is one of the most important factors affecting soil organic carbon (SOC) stabilization, and the stability of aggregates depends in part on soil microbial diversity and composition. Interactions between the soil bacterial community and SOC content in soil aggregates after afforestation are poorly understood. In this study, we investigated difference in the diversity of soil bacterial with high-throughput 16S rRNA sequencing, as well as the SOC content in soil aggregates representing a chronosequence of 42, 27, and 17 years of *Robinia pseudoacacia* L. succession (RP42, RP27, and RP17), and in farmland (FL) soil for comparison (millet (*Setaria italica*) and soybean (*Glycine* max) rotation).The SOC content in RP17, RP27, and RP42 plots were significantly higher than that of FL by an average of 85.57%, 142.37%, and 76.69% in large macro-aggregates (> 1 mm), small macro-aggregates (0.25–1 mm), and micro-aggregates (< 0.25 mm), respectively. The Simpson index for the FL plot was significantly higher than that of the RP17, RP27, and RP42 plots, whereas the Shannon index followed the opposite trend. The dominant bacterial phyla detected were *Proteobacteria*, *Acidobacteria*, and *Actinobacteria* in each afforested and FL sites. These data revealed significant correlations between soil aggregate characteristics, such as SOC content, mean weight diameter (MWD), and geometric mean diameter (GMD), with the relative abundance of *Proteobacteria*, *Actinobacteria*, *Acidobacteria*, *Chloroflexi*, *Gemmatimonadetes*, *Nitrospirae*, *Verrucomicrobia*, and *Planctomycetes*. These relationships suggested that the effects of afforestation on SOC stabilization in soil aggregates are modulated by both soil aggregate size and also soil bacterial diversity. We demonstrate that the interaction between soil aggregate size and soil microbes might be a key factor in effective soil conservation, restoration, sustainability of agroecosystems, and erosion prevention.

1. Introduction

Afforestation is a key management technique used to mitigate the effects of climate change (Naveed et al., 2016) and plays an important role in regulating ecosystem function and biodiversity (Bhagwat et al., 2008), ecosystem restoration (Deng and Shangguan, 2017), and preventing soil degradation (Zhu et al., 2017). In the past few decades, global efforts to promote afforestation have rapidly increased (Carson et al., 2010). As of 2015, ~278 million ha of land were being utilized as plantations, which were equivalent to 7% of the global forest area (Carson et al., 2010). Consequently, afforestation is important for both soil nutrient cycling and carbon (C) sequestration in terrestrial ecosystems. Afforestation also influences soil microbial communities and soil aggregate stability (Duchicela et al., 2012). Although previous studies have investigated the effects of afforestation on soil microbial communities (Carson et al., 2010; Garcia-Franco et al., 2015; Cavagnaro et al., 2016; Deng et al., 2016; Ren et al., 2016b) and soil aggregate stability (An et al., 2013; Garcia-Franco et al., 2015), some details remain uncertain. For example, much is unknown about the stability of soil organic carbon (SOC) in soil aggregates after

* Correspondence to: FZ Zhao, Shaanxi Key Laboratory of Earth Surface System and Environmental Carrying Capacity, Northwest University, Xi'an, Shaanxi 710127, China.
** Corresponding author.
E-mail addresses: zhaofazhu@nwu.edu.cn (F.Z. Zhao), hanxinhui@nwsuaf.edu.cn (X.H. Han).

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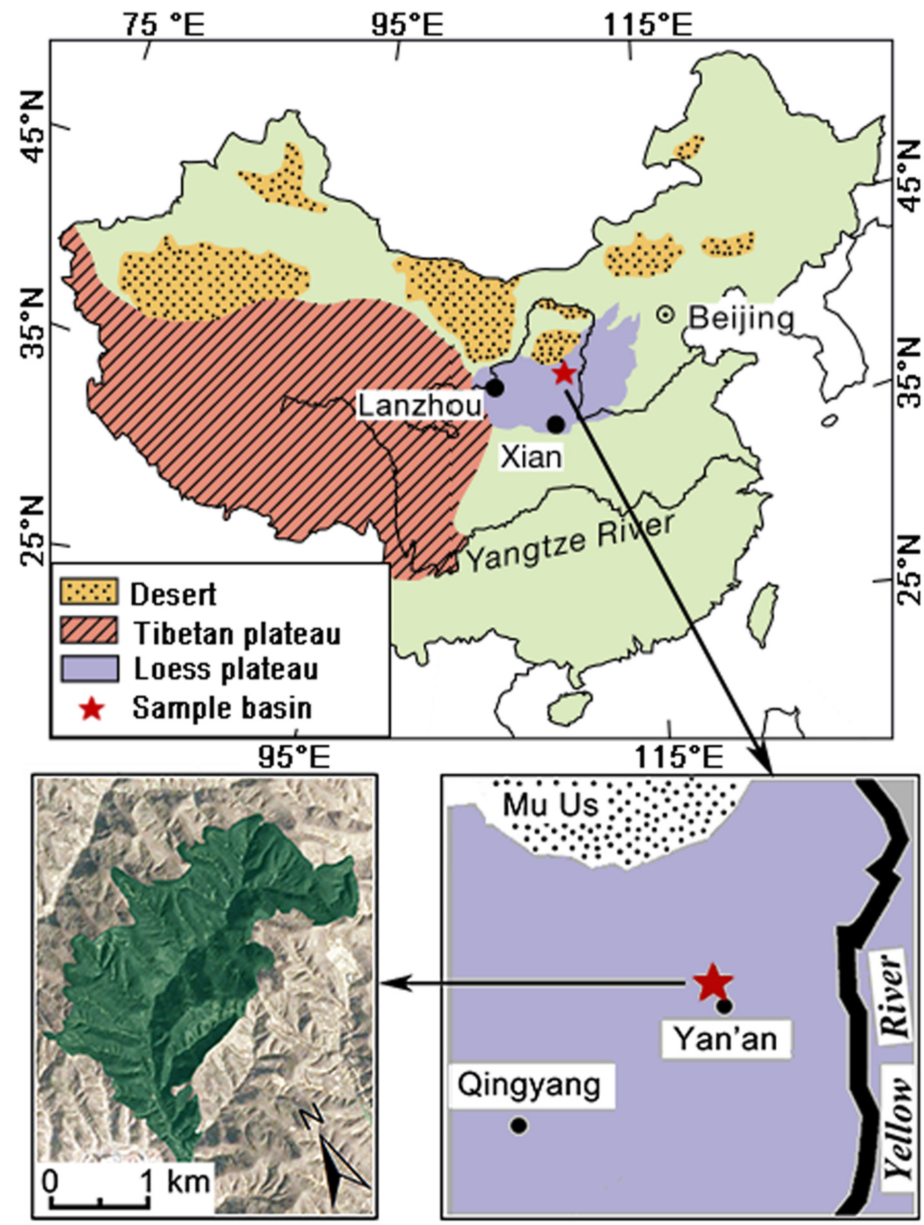

Fig. 1. Location of the Loess Plateau and the study basin.

afforestation. Since soil aggregate stability depends on soil microbial activity, variations in soil aggregate stability after afforestation may be caused by changes in the soil bacterial community. Therefore, the effects of afforestation on soil microbial activity, SOC content in soil aggregates, and soil aggregate stability must be investigated in order to quantify terrestrial C dynamics and predict soil quality (Dou et al., 2016; Mueller et al., 2017; Mukherjee et al., 2014). To further our knowledge of soil productivity and forest ecosystems after afforestation, a clear understanding of the relationships between afforestation, soil microorganisms, and soil aggregate stability is urgently needed.

Measures of soil aggregate stability, including the mean weight diameter (MWD) and geometric mean diameter (GMD), are important ecosystem indicators that are strongly related to soil services such as carbon storage (Xie et al., 2017; Zhang et al., 2017), organic matter stabilization (Chaplot and Cooper, 2015; Mueller et al., 2017; Wei et al., 2017), and erosion prevention (Six et al., 2000; del Pino and Ruiz-Gallardo, 2015; Zhu et al., 2017). Variations in soil aggregate stability are clearly linked with changes in soil microbial communities (Duchicela et al., 2012; Lee-Cruz et al., 2013; Six et al., 2006). A recent study found that different aggregate size classes support distinct microbial habitats, which in turn, support colonization by different microbial communities (Trivedi et al., 2017). This finding suggests that the microbial contribution to SOC accumulation is governed by the interactions between the microbial community structure and soil aggregate stability. Since litter input is a major source of labile organic C for microbial activity, promoting the binding of clay and silt-size particles to form micro-aggregates within macro-aggregates may increase soil stability (Garcia-Franco et al., 2015). Bacteria are involved in stabilizing soil particles (Dorioz et al., 1993), and several studies have shown that soil aggregates of different sizes, as well as different locations within soil aggregates, can be selected for colonization by different bacterial communities (Blaud et al., 2012; Davinic et al., 2012; Fall et al., 2004; Hemkemeyer et al., 2015). Since the interactions between bacteria and soil aggregate stability remain unclear, a better understanding of the impact of afforestation on soil bacterial and soil aggregate stability is essential for sustainable forest management and production.

The Loess Plateau in China covers approximately $62.4 \times 104\,km^2$