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Soil particle size distribution characteristics of different land-use types in the Funiu mountainous region

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ABSTRACT

Soil particle composition is one of the main physical properties of soil that affects soil fertility, and the fractal dimension of soil particle size distribution (PSD) can be used to quantitatively evaluate the particle composition of different soils. The single fractal dimension of soil PSD can quantitatively characterize the roughness of the soil particle, and the multifractal dimension of soil PSD can quantitatively characterize the inhomogeneous property of soil particle composition. Sloping farmland is widely distributed in hilly areas of China that are subject to the most serious soil erosion, and the loss of soil will lead to changes in soil particle composition and soil physical properties. Previous studies have not been used to evaluate the heterogeneity of soil PSD between sloping farmland and other land use types by the multifractal method. In order to quantitatively assess the differences in soil properties between the slope land and other types of land use, this paper takes four types of land use (sloping farmland, shrub-grass sloping land, terraced farmland, and oak forestland) in the warm-temperate granite mountainous areas in eastern central China as research objects. A laser particle size analyzer and soil fractal model were applied to compare the soil PSD of different land-use types and their corresponding single fractal dimension (D_v) and generalized fractal dimension (D_q). The results showed that there were clear differences between the D_V and D_q of soil PSD in different land-use types. The D_v of the soil PSD increased as follows: sloping farmland < level terraced land < shrub-grass sloping land < oak forestland, indicating that the soil particle composition coarseness was highest in sloping farmland and lowest in the oak forestland. The sequence of characteristic parameters of D_q (capacity dimension, D_0; information dimension, D_1; and correlation dimension D_2) was as follows: sloping farmland < level terraced land < shrub-grass sloping land < oak forestland, indicating that the inhomogeneity of soil particle composition was the highest in sloping farmland, and lowest in oak forestland. The D_v, D_0, D_1, and D_2 of the soil PSD were significantly positively correlated to the content of clay and silt particles, and were significantly and negatively correlated to the content of sand particles, indicating that the fewer clay particles and silt in the soil or the higher the proportion of sand, the higher the coarseness and the inhomogeneity of soil particle composition. This study showed that the soil coarseness and the inhomogeneity of the sloping farmland soil particle composition are significantly greater than those of other land-use types. The mass loss of the soil fine particles (clay and silt particles) is an important cause of coarsening and increased inhomogeneity of the sloping farmland. This study provides a soil fractal index for quantitative assessment of soil texture and the degradation of soil properties in landscapes prone to soil erosion such as sloping farmland.

1. Introduction

The Funiu mountainous region is within the “soil functional region” defined by the Ministry of Water Resources in China (The Ministry of Water Resources of the People’s Republic of China, 2012) and is one of the regions suffering most from soil erosion in the Huaihe river basin

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Table 1
Summary of sampling sites under different land-use types.

Land-use type	Vegetation type	Slope/°	Altitude/m	Soil thickness/ cm	Gravel content/%	Litter thickness/cm	Canopy density	Vegetation coverage	Main vegetation species
Oak forest land (OF)	*Quercusac utissima* forest	20	580	15	15	1.5	0.7	0.6	*Quercusacutissima,Dendranthemapotentilloides*, *Grewiabiloba*, *Cleistogeneschinensis*, *Artemisia sacrorum*
Shrub-grass sloping land (SG)	Shrub	15	390	30	–	0.5	–	0.8	*Lespedeza bicolor*, *Vitex negundo*, *Dendranthemapotentilloides*, *Artemisia sacrorum*, *Themeda japonica*, *Cleistogeneschinensis*
Terraced farmland (TF)	Crop	15	380	30	25	–	–	–	Corn (*Zea mays*), Wheat (*Triticumaestivum*)
Sloping farmland (SF)	Crop	15	350	30	35	–	–	–	Corn (*Zea mays*), Wheat (*Triticumaestivum*)

and across the northern mountainous region (Montero, 2005; Liu et al., 2009). The land-use type is an important factor affecting soil erosion, and sloping farmland is a major source of soil erosion in the Funiu mountainous region. Sloping farmland is also a land-use type that shows the most serious soil loss from slope erosion. The slope erosion induces mass loss of fine soil particles, thus resulting in the coarsening of the soil texture and degradation of the soil structure and properties. The soil particle size distributions (PSD) are closely related to the texture, structure, and performance of the soil (Montero, 2005; Liu et al., 2009), and studies on the differences in soil PSD between sloping farmland and other types of land use play an important role in understanding the effects of soil erosion on the soil texture and performance of sloping farmland.

Methods based on fractal theory (Mandelbrot, 1967) have recently become important techniques to quantitatively study the PSD characteristics (Burrough, 1981; Perfect and Kay, 1995; Alir and Arash, 2011; Li et al., 2011). In previous reports, the conventional pipette method or the hydrometer methods were typically used to measure the soil particle composition and assess the single fractal dimension of the soil PSD (Yang et al., 1993; Wang et al., 2006; Deng et al., 2017). As the laser diffraction method (laser particle analyzer) has recently been applied more frequently to measure the soil particle composition (Wu et al., 1993; Eshel et al., 2004; Pieri et al., 2006; Dur et al., 2004), studies focusing on the multifractal parameters of the soil PSD have correspondingly increased in number (Martín and Montero, 2002; Miranda et al., 2006; Kravchenko, 2008; Paz-ferrerio et al., 2010; Wang et al., 2015). Research has indicated that multifractal parameters can help to elucidate the complexity and inhomogeneity of the soil PSD. In particular, investigations on the variation of the soil PSD multifractal parameters and inhomogeneity under different land-use types or vegetation types have been reported (Wang et al., 2008, 2010; Gao et al., 2014a; Gao et al., 2014b; Fu et al., 2008). However, to our knowledge, there has been no previous study of the effects of sloping farmland on the PSD using the multifractal parameters approach.

This research examined sloping farmland, terraced farmland, shrub-grass sloping land, and oak forestland in the Funiu mountainous region, and applied single fractal and multifractal methods to analyze the soil PSD characteristics of different land-use types, and evaluate the differences in coarseness and inhomogeneity of soil particle composition on slope farmland with those of other land use types. The study provides a soil fractal index for the quantitative evaluation of soil texture and loss of soil quality in sloping farmland and land-use types that are vulnerable to soil erosion.

2. Materials and methods

2.1. Site information

The Yinghe small watershed (33°54′16″–33°56′34″N, 112°42′49″–112°44′20″E), is located in Lushan county, Henan province, which is in the eastern Funiu mountain, China, and belongs to the upper stream of the Shahe river which is in the Huaihe watershed. Lushan county has a temperate continental monsoon climate, with an annual mean precipitation of 685 mm, annual evaporation of 965 mm, annual temperature of 15.3 °C, annual sunshine duration of 1626 h, and frost-free period of 245 days. The land shape of the Yinghe small watershed is primarily characterized by low mountains and hills, and the elevation is 224.3–732.5 m above sea level. The parent material is mainly granite and gneiss, and the soil texture primarily consists of silty loam and sandy loam (Xu et al., 2013).

The vegetation type in the Yinghe small watershed belongs to warm temperate deciduous forest. The arborous plants are primarily *Quercus acutissima*, *Pistacia chinensis*, and *Vernicia fordii*; shrubs are primarily *Vitex negundo* var. *Heterophylla*, *Lespedeza bicolor*, *Ziziphus jujuba* var. *Spinosa,* and *Grewia* biloba; and herbaceous plants are primarily *Carex tristachya*, *Artemisia sacrorum*, *Leonurus artemisia*, *Artemisia argyi*,