Available online at www.sciencedirect.com
ScienceDirect
Catena 72 (2008) 29–36
CATENA
www.elsevier.com/locate/catena

Multifractal characteristics of soil particle size distribution under different land-use types on the Loess Plateau, China

De Wang [a], Bojie Fu [a,*], Wenwu Zhao [b], Huifeng Hu [a], Yafeng Wang [a]

[a] *State Key Lab. of Urban and Regional Ecology, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, P.O. Box 2871, Beijing 100085, China*
[b] *College of Resources Science and Technology, Beijing Normal University, Beijing 100875, China*

Received 3 August 2006; received in revised form 10 March 2007; accepted 28 March 2007

Abstract

Soil particle-size distribution (PSD) is one of the most important physical attributes due to its great influence on soil properties related to water movement, productivity, and soil erosion. The multifractal measures were useful tools in characterization of PSD in soils with different taxonomies. Land-use type largely influences PSD in a soil, but information on how this occurs for different land-use types is very limited. In this paper, multifractal Rényi dimension was applied to characterize PSD in soils with the same taxonomy and different land-use types. The effects of land use on the multifractal parameters were then analyzed. The study was conducted on the hilly-gullied regions of the Loess Plateau, China. A Calcic Cambisols soil was sampled from five land-use types: woodland, shrub land, grassland, terrace farmland and abandoned slope farmland with planted trees (ASFP). The result showed that: (1) entropy dimension (D_1) and entropy dimension/capacity dimension ratio (D_1/D_0) were significantly positively correlated with finer particle content and soil organic matter. (2) D_0, D_1 and D_1/D_0 were significantly influenced by land use. Land use could explain 24.6–58.5% of variability of D_0, D_1/D_0 and D_1, which may be potential parameters to reflect soil physical properties and soil quality influenced by land use.

Keywords: Soil particle-size distributions; Land-use effect; Multifractal characteristics; Soil erosion

1. Introduction:

Soil particle-size distribution (PSD) is one of the most important physical attributes due to its great influence on soil properties related to water movement, productivity, and soil erosion (Huang and Zhang, 2005; Montero, 2005). An area with high soil erosion rate induced by water, and fine particle-size fractions (accompanied by nutrients) are selectively removed or deposited during soil erosion process. In fact, land use largely influence PSD by helping or hindering soil erosion (Martínez-Casasnovas and Sánchez-Bosch, 2000; Erskine et al., 2002; Basic et al., 2004). In this sense, characterization of PSD may be a promising indicator to reveal the influence of land use on soil properties.

Several different methods were developed to represent soil PSDs (Buchan et al., 1993; Skaggs et al., 2001). Textural analysis was commonly used in the past to characterize soil PSDs. However, the size definitions of the three main particle fractions (clay, silt and sand) are rather arbitrary, and they do not provide complete information on the soil PSDs. Moreover, in the textural triangle, soils grouped in a textural class exhibit a wide range of PSD (e.g. the silt loam in the textural triangle contains soils that vary in silt content roughly between 50% and 80%), providing incomplete information of PSD.

A better approach used to characterize PSDs was fractal mathematics (Turcotte, 1986; Tyler and Wheatcraft, 1992; Wu et al., 1993; Bittelli et al., 1999; Millan et al., 2003; Filgueira et al., 2006). PSDs were often rendered as functions based on the power-law dependence on particle mass on particle diameter. Such power-law was interpreted as being the result of a fractal distributions characterized as a single dimension. However, many studies using detailed experimental data have shown that a single fractal dimension is not sufficient to describe PSD in soil (Wu et al., 1993; Kozak et al., 1996; Grout et al., 1998; Bittelli et al., 1999; Millan et al., 2003). Wu et al. (1993) found three domains within PSDs determined over six orders of magnitude in the

* Corresponding author. Tel.: +86 10 68597542; fax: +86 10 68597583.
E-mail address: bfu@rcees.ac.cn (B. Fu).

0341-8162/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.catena.2007.03.019

particle size. Bittelli et al. (1999) found three domains with fractal dimensions defining scaling in the clay, silt, or sand domains.

In order to obtain more detailed information of soil PSD, multifractal techniques were introduced from information science to soil science. (Grout et al., 1998; Posadas et al., 2001; Montero and Martín, 2003; Montero, 2005). Grout et al. (1998) proposed multifractal techniques as promising alternative to single fractal dimension. Montero and Martín (2003), Montero (2005) evaluated the applicability of Hölder spectrum and Rényi dimensions analysis combined with laser diffractometry to 20 contrasting PSDs in soils, and showed well defined scaling properties. Posadas et al. (2001) suggested that D_1 can be used to distinguish single from multifractal scaling. Caniego et al. (2003) used D_1/D_0 to quantify the dispersion of the measure over the set of cell size. Martín et al. (2001, 2005) suggested that an entropy-based parameter is a useful parameter for classifying soil texture within the classical textural triangle.

In all these studies, the fractal and multifractal analyses were mostly focused on PSDs in soils of different taxonomies. However, little attention was paid to the influences of land-use patterns on PSDs from the same soil. In the water erosion-prone area, fine particle-size fractions as well as soil organic matter (SOM) and nutrients were selectively removed due to water erosion. Land use could influence soil PSD by hindering or helping water erosion (Renard et al., 1997).

Thus, the objective of this study was to see the effect of land-use types on multifractal parameters of PSDs in the typical loess soil. The multifractal parameters were obtained by Rényi dimensions analysis. Soil organic matter content (SOM), as the best surrogate for soil quality influenced by land use (Dumanski and Pieri, 2000; Liu et al., 2002; Wang et al., 2003), was selected to be contrasted with multifractal parameters.

2. Materials and methods

2.1. Study area

Soils were sampled within two catchments with total area of 50 km^2 from Ansai County (36°31′–37°20′ N and 108°52′–109°26′ E) of Shaanxi Province, the center part of the Loess Plateau, China (Fig. 1), which is well known for its high erosion rate. Ansai County has a typical semiarid continental climate with an average temperature of 8.6 °C and an average annual precipitation of 520 mm with high variability (about 74% of the rain falls between July and September). The landform is a typical loess hilly-gullied landscape with elevations ranging from 997 to 1731 m above sea level (most of the land is between 1200 and 1500 m). The soils, mostly formed on the deep and loose loess deposit, are classified as Calcic Cambisols (FAO-UNESCO, 1988), which have a rather homogenous silty loam texture (Fig. 2).

Our work focused on 5 different land-use types: woodland, shrub land, grassland, terrace (long-term cultivated farmland) and abandoned slope farmland with planted trees (ASFP). The woodland was mainly locust trees (*Robinia pseudoacacia* L.), poplar (*Populus* spp.) and willow (*Salix* spp.). Littleleaf peashrub (*Caragana microphylla* Lam.) and seabuckthorn (*Hippophae rhamnoides* L.) exist on the shrub land. The grassland was mainly covered by annuals such as sweet wormwood (*Artemisia annua* L.), annual fleabane (*Erigeron annuus* Pers.) and bunge needlegrass (*Stipa bungeana* Trin.). Crops in the terrace were mainly potatoes

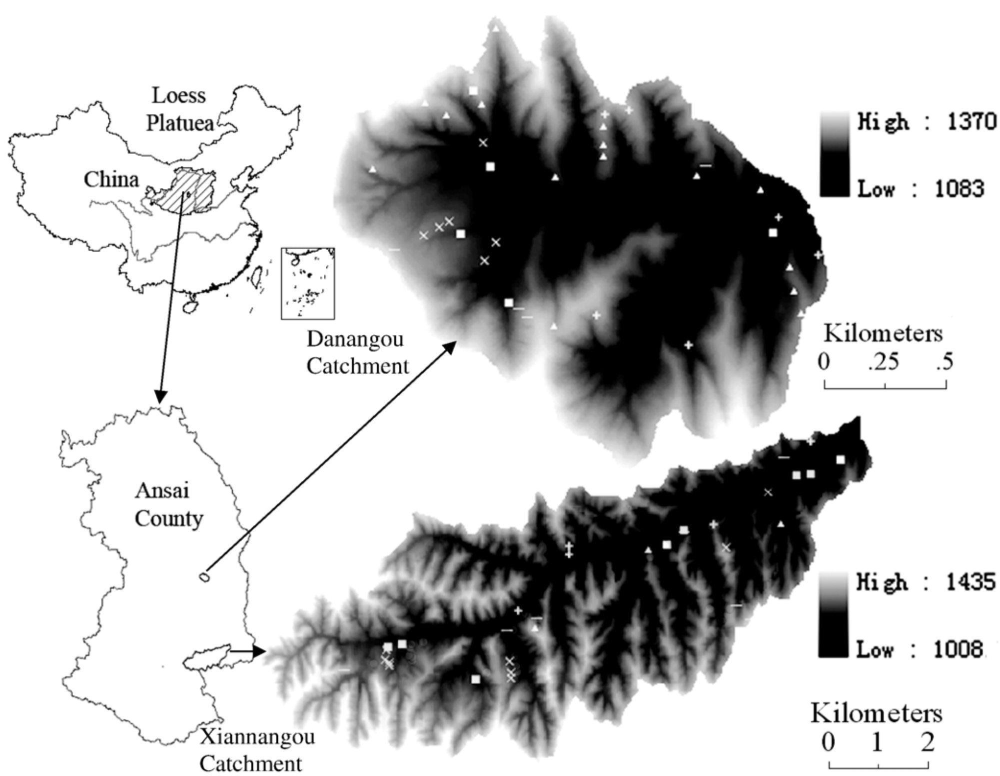

Fig. 1. Study area and soil sample sites. □ woodland; – shrub land; △ ASFP (abandoned slope farmland with planted trees); × terrace; + grassland.