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Effects of land use patterns on soil aggregate stability in Sichuan Basin, China

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Abstract

Soil aggregate stability as a key indicator of soil structure, is a product of interactions between soil environment, management practices, and land use patterns. The objective of this study was to analyze the impact of various land use patterns on soil aggregate stability in Sichuan Basin of southwestern China. The dry- and water-stable aggregate size distributions were determined by manual dry sieving procedure and Yoder's wet sieving procedure, respectively, while microaggregates and its mechanical and chemical stabilities by Kachisky's method, oscillator method, and citrate-dithionate (C-D) reagent method, separately. The results indicated that fractal dimension and surface fractal dimension were useful indicators to reflect soil aggregate distribution. Land use patterns have an obvious influence on soil aggregate stability. In the study area, water stability, mechanical stability, and chemical stability followed the sequence, Barren land > forestland > orchard > cropland, and the original stability and collapse velocity were sensitive to soil properties and soil structure. The difference of aggregate stability under different land use patterns is mainly due to the intensity of human disturbance and cultivation. Improper land use patterns will lead to breakdown of unstable aggregates, producing finer and more-easily transportable particles and microaggregates. In the future, inappropriate cultivation and land use patterns should be changed to protect soil structure, to improve soil aggregate stability and soil fertility in Sichuan Basin.

Keywords: Aggregate size distribution; Soil aggregate stability; Fractal dimension; Land use pattern; Purple soil; Sichuan Basin; China

1. Introduction

Soil structure consists of an aggregate formed by the arrangement of soil particles, and depends on the interactions between primary particles and organic constituents to form stable aggregates (Caravaca, Lax, & Albaladejo, 2004). Thus, the recognition of soil aggregate size distribution and soil aggregate stability is important to properly interpret soil structure. Soil aggregation is a complex phenomenon, which is a product of interactions of the soil microbial community, mineral and organic compositions and is influenced by many factors such as soil environment, management practices, land use patterns, etc. (Seybold & Herrick, 2001; Wei, Ni, Gao, Xie, & Hasegawa, 2006). Recent studies mainly concentrate on analyzing the relationship between soil organic matter and soil aggregate stability under different cultivations. Land use and landscape position have an interactive effect on water-stable aggregates and aggregate carbon concentration (Natalia & Nicholas, 2005), and high variability of aggregate stability and soil C has important implications for C sequestration (Bird, Herrick, Wander, & Wright, 2002). Meanwhile, long-term soil cultivation increases organic matter turnover due to differences in the amount of aggregation and aggregate turnover, and aggregates in tilled soils cycle more rapidly in a cultivation loop (Six, Elliott, & Paustian, 2000). These studies focus on soil water-stability aggregates and soil materials, but little attention is paid to mechanics and chemical stability.

Purple soils are mainly distributed in Sichuan Basin of southwestern China, and are classified as Regosols in FAO Taxonomy or Entisols in USDA Taxonomy (He, 2003). Purple soils, which typically developed by the physical weathering of red or purple parent materials or rocks, inherit many of the characteristics of parent materials or rocks. But other changes in soil properties have taken place as a result of land use change,

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agricultural practice, or eco-environment disturbances (Wei, Xie, & Che, 1989; He, 2003). The objectives of the present work were (a) to analyze the effects of land use on the soil aggregate distribution, and (b) to discuss the effects of land use on water stability, mechanics and chemical stability of soil aggregates.

2. Materials and methods

2.1. Sites, soils and sampling

Sichuan Basin is located in southwestern China with an area of 165,000 km^2 and an elevation varying from 200 to 500 m above sea level. The climate is subtropical humid monsoon with an average annual precipitation of 1000–1200 mm and the average annual temperature is 14–19 °C. This basin is well known as the "Red Basin" due to being covered by a red or purple rock series of the Trias-Cretaceous system, from which the purple soils are developed and formed (He, 2003).

A stratified sampling design, based on land use patterns and principal rock types, was used to collect the soil samples. Four land use patterns, namely cropland, orchard, forestland, barren land were selected. Cropland means land covered with temporary crops followed by a bare soil period after harvesting, and lands dominated by fruit trees were orchard. Barren land denoted lands with exposed rock and never had more than 5% vegetated cover and forestland was dominated by woody plants (Liu, Zhuang, Luo, & Xiao, 2003). Rock types studied include dark purple shale of Feixianguan Formation of the Trias system (T_1f), brown purple sandy mudstone of Penglai Formation (J_3p), red brown purple mudstone of Suining Formation (J_3s), and gray brown purple sandy mudstone of Shaximiao Formation (J_2s) of the Jurassic system (Wei, Gao, Shao, Xie, & Pan, 2006). In each sampling area, soil samples were taken randomly at 0–20 cm depth with five replicates in July 2004, and each of the replicates was 5 m apart from each other. The land use, rock types, and basic properties of those tested soils are given in Table 1. Soil pH was determined by using a glass electrode (1:2.5, soil:water) and soil particle composition by the pipette method (Dane & Topp, 2002). Organic matter was measured using the Walkley–Black method (PCARRD, 1980).

2.2. Methods

2.2.1. Soil macroaggregate size distribution and stability

Soil aggregates were broadly classified as macroaggregates (>0.25 mm) and microaggregates (<0.25 mm) (Oades & Water, 1991). A common method used for describing soil macroaggregate distribution was manual dry sieving method (Dane & Topp, 2002). After air-drying of soil samples, stones and litter with size more than 2 mm were removed. Air-dried soil samples of 500 g were placed on the uppermost of a set of graduated sieves 20 cm in diameter and 5 cm in height, on the top of a nest of seven sieves with openings of 10, 5, 3, 2, 1, 0.5, and 0.25 mm. The sieves were then oscillated vertically and rhythmically by hand for 5 min. Aggregates remaining in each sieve were collected and weighed to get macroaggregate size distribution, i.e. aggregates of 10–5, 5–3, 3–2, 2–1, 1–0.5, 0.5–0.25, and

Table 1
Selected basic properties of the soils in this study

Land use	Rock type	Organic matter (g/kg)	pH	Clay (g/kg)	Soil particle composition (g/kg)					
					1–0.25 mm	0.25–0.05 mm	0.05–0.01 mm	0.01–0.005 mm	0.005–0.001 mm	<0.001 mm
Cropland	T_1f	18.93	7.48	42.1	328.2	192.8	105.3	184.2	147.4	42.1
	J_3p	11.15	8.10	41.5	338.8	112.3	127.3	169.8	197.1	54.7
	J_3s	12.28	7.88	31.7	331.6	73.6	148.7	174.4	239.9	31.8
	J_2s	12.33	6.72	146.5	310	22.9	148.6	194.9	298.0	25.6
Orchard	T_1f	22.39	7.14	254.7	22.6	210.1	331.8	165.9	198.1	71.5
	J_3p	14.01	7.80	62.3	21.4	143.4	313.2	187.0	252.3	82.7
	J_3s	19.96	7.88	63.4	10.8	173.0	344.9	176.4	221.7	73.2
	J_2s	25.99	6.87	126.5	16.3	206.7	315.0	136.5	251.5	74.0
Forestland	T_1f	29.8	7.63	201.8	53.7	142.8	338.3	148.0	235.5	81.7
	J_3p	23.77	7.79	63.2	37.0	202.4	274.7	190.2	202.3	93.4
	J_3s	32.79	7.77	141.2	27.8	233.5	249.9	119.5	228.1	141.2
	J_2s	33.70	6.22	200.4	51.0	243.3	299.4	117.6	203.2	85.5
Barren land	T_1f	27.12	7.14	95.6	18.8	232.6	292.9	183.7	115.5	156.5
	J_3p	22.91	8.00	84.0	22.6	271.2	284.6	126.5	158.6	136.5
	J_3s	31.47	7.88	85.5	29.7	172.3	295.3	123.8	252.5	126.4
	J_2s	21.28	7.59	62.5	35.4	235.4	305.0	135.0	166.7	122.5