Soil & Tillage Research 167 (2017) 73–79

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Aggregate stability and size distribution of red soils under different land uses integrally regulated by soil organic matter, and iron and aluminum oxides

Jinsong Zhao[a,b], Shan Chen[a], Ronggui Hu[a,c,*], Yayu Li[a]

[a] College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, PR China
[b] Department of Ecology, Evolution and Marine Biology, University of California at Santa Barbara, Santa Barbara, CA 93106, USA
[c] Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtse River), Ministry of Agriculture, Wuhan 430070, PR China

ARTICLE INFO

Article history:
Received 19 March 2016
Received in revised form 9 October 2016
Accepted 21 November 2016
Available online xxx

Keywords:
Soil aggregates
Stability
Size fraction
Land use
Soil organic matter
Iron and aluminum oxides

ABSTRACT

The stability and size distribution of soil aggregates is profoundly affected by land use, but the influencing mechanisms of land use are not clear. A study was carried out to investigate and attempted to interpret the effects of land use on soil aggregates from types of land use and soil properties in soil samples and size fractions of soil aggregates. Soil samples were taken from 9 sites under paddy, forest, and upland in southern China. The wet-sieving method was used to obtain 6 size fractions of soil aggregates: >5, 5–2, 2–1, 1–0.5, 0.5–0.25, and <0.25 mm. The stability and size distribution of soil aggregates was measured as mean weight diameter (MWD), the percentage of water-stable aggregate (WSA) and the percentage of each size fraction (PSA). The quantities of soil organic carbon (SOC), humic substances, dithionite-citrate-bicarbonate (DCB) and oxalate extractable iron (Fe) and aluminum (Al) oxides were also measured. The results showed that types of land use solely explained 66.6% variation of soil aggregates; SOC, DCB-extractable Fe and Al oxides, and oxalate-extractable Al oxide caused 84.3% variation, in which SOC contributed 29.0%, Fe and Al oxides contributed 33.8%, and their interactions contributed 21.4%. The multiple linear regression and partial correlation analysis showed that soil organic matter and Fe and Al oxides had significant effects but played different roles on the stability and size distribution of soil aggregates. The study suggests that land use affects the stability and size distribution of soil aggregates through the integration of soil organic matter and Fe and Al oxides.

1. Introduction

Soil structure has important influences on edaphic conditions and the environment. The structure is often measured by the stability of soil aggregates (Six et al., 2000; Bronick and Lal, 2005). Soil aggregation sustains soil fertility because it reduces erosion and mediates soil aeration as well as water infiltration and retention. Furthermore, soil aggregation protects soil organic matter (SOM) from mineralizing because it physically reduces the accessibility of organic compounds for microorganisms, extracellular enzymes, and oxygen (Oades, 1984; Six et al., 2002a; von Lützow et al., 2006; Spohn and Giani, 2010). The size distribution and stability of soil aggregates are under the control of various mechanisms. Generally, the size distribution and stability of soil aggregates positively correlates with the main cementing agents, such as SOM, clay minerals, multi-valent cations and their complex in soil aggregates. According to the hierarchical theory of aggregate formation, these materials may be distributed unevenly in different size fractions of soil aggregates, and they may have close relationships with the stability of soil aggregates (Tisdall and Oades, 1982; Six et al., 2004).

Land use and associated management, such as crop sequencing, fertilization, soil conditioning, drainage and irrigation, are the most important and direct ways to affect soil structure and properties, through its impact on destruction forces and aggregate forming processes (Haynes et al., 1991; Besnard et al., 1996; Jastrow, 1996; John et al., 2005; Ashagrie et al., 2007; Lehrsch et al., 2012). However, the extent of the impact and the associated mechanisms of land use on soil aggregates remains unclear. Studies on the stability of soil aggregates under different land use rarely focus on the effects of various soil organic components, Fe

---

* Corresponding author at: College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, PR China.
E-mail address: rghu@mail.hzau.edu.cn (R. Hu).

http://dx.doi.org/10.1016/j.still.2016.11.007
0167-1987/© 2016 Elsevier B.V. All rights reserved.

and Al oxides in different size fractions of soil aggregates, and their interactions.

In southern China, the red soils cover approximately 1.14 million km^2. Because of intensive weathering and leaching, the soil is rich in Fe and Al oxides, and the dominant clay mineral is kaolinite (He et al., 2004). In recent years, soil structure has degraded rapidly, due to strong human intervention and high cultivating intensity (Iqbal et al., 2009), and the sustainability of the agricultural ecosystem is under serious threat.

Therefore, for soils that are rich in Fe and Al oxides, we hypothesize that the stability and size distribution of soil aggregates is controlled by SOM, which is heavily affected by the land use, while Fe and Al oxides and their interactions with SOM manifest another important regulating mechanism for the stability and size distribution of soil aggregates. In order to test this hypothesis, in this study, the stability and size distribution of soil aggregates of red soils in southern China were investigated from different types of land use, which were treated as a factor that represents the comprehensive effects brought about by the land use and its associated management, and the soil properties in soil samples and size fractions of soil aggregates.

2. Materials and methods

2.1. Study sites and soil samplings

Nine sites located in Jinxian, Jiangxi Province, Changsha and Taoyuan, Hunan Province, and Xianning, Hubei Province, southern China, were chosen, taking into account the variability of soil type (Inceptisols and Ultisols), in order to compare how the land use (paddy, forest, and upland) and the associated soil properties affected the stability and size distribution of soil aggregates. All sampling sites are in the subtropics and share similar climate. Those regions are humid and have a monsoon climate, with an annual mean temperature above 15 °C and annual mean precipitation above 1300 mm. The paddy sites have been used for planting rice for more than ten years. The forest sites are secondary forests, with predominance of *Pinus massoniana* in Xianning (F_1), *Cunninghamia lanceolata* in Changsha (F_3), and a mixed forest in Changsha (F_2). The uplands are used for grain or cash crops such as maize (*Zea mays*), rapeseed (*Brassica napus*), soybean (*Glycine max*), and sweet potato (*Ipomoea batatas*). Paddy and upland sites are managed with conventional tillage. The same type of land use shares similar agricultural practices.

At each site, 5 soil monoliths with diameter 10 cm were randomly taken from 0 to 15 cm surface between October and December 2010. All samples were transported to the laboratory in their intact form and broken into small pieces along the natural crack by hand during the air-drying process. The soils from paddies are Endoaquepts, and those from uplands and forests are Plinthudults, according to Soil Survey Staff (2014). All soil developed out of middle Pleistocene (Q2) red clay. The basic soil properties, parent, land use, and soil type are shown in Table 1 and Table 2.

2.2. Water-stable aggregates

To obtain different size fractions of water-stable aggregates, for the 5 samples from each site, 50 g of soil were placed in the top of a set of sieves with mesh sizes of 5 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm from top to bottom. The sieve set was placed on the shock rack of a Yoder aggregates analyzer (Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China), submerged in water, and shaken with an amplitude of 3 cm and a frequency of 30 min^{-1} for a duration of 30 mins. The size fraction at each sieve was then washed into a beaker of known mass and then dried and weighed.

Mean weight diameter (MWD) was calculated as

$$\mathrm{MWD} = \frac{\sum_{i=1}^{6} d_i w_i}{w};$$

the percentage of water-stable aggregate (WSA) was calculated as

$$\mathrm{WSA} = 100 \times \frac{\sum_{i=1}^{5} w_i}{w};$$

and the percentage of each size fraction of soil aggregate (PSA) was given as

$$\mathrm{PSA}_i = 100 \times \frac{w_i}{w};$$

where d_i is the average diameter of i^{th} size fraction of the aggregate, w_i is the mass of i^{th} size fraction of the aggregate, and w is the total mass of all size fractions of the aggregate. $i = 1, 2, \ldots, 6$ represent

Table 1
Location, land use, annual mean precipitation, parent matherial and soil type of study sites.

Location	Code	Coordinates	Land use	Site description	AMP (mm)	Parent material	Soil type
Jinxian	P1	N28°21′31.9″ E116°10′26.8″	Paddy	>50 yrs paddy field	1580	Redeposited Q2 red clay	Endoaquepts
Jinxian	P2	N28°21′02.4″ E116°10′30.9″	Paddy	>20 yrs paddy field	1580	Redeposited Q2 red clay	Endoaquepts
Changsha	P3	N28°13′31.1″ E113°09′94.2″	Paddy	>10 yrs paddy field	1410	Q2 red clay	Endoaquepts
Xianning	F1	N30°00′03.6″ E114°22′38.7″	Forest	>40 yrs horsetail pine forest	1547	Q2 red clay	Plinthudults
Changsha	F2	N28°13′31.9″ E113°09′45.7″	Forest	>10 yrs mixed forest	1319	Q2 red clay	Plinthudults
Changsha	F3	N28°15′40.3″ E113°11′10.6″	Forest	>30 yrs *Cunninghamia lanceolata* forest	1319	Q2 red clay	Plinthudults
Taoyuan	U1	N29°13′43.4″ E111°31′17.8″	Upland	>3 yrs corn with straw return	1510	Q2 red clay	Plinthudults
Xianning	U2	N30°01′18.9″ E114°21′44.4″	Upland	>3 yrs rapeseed and soybean	1547	Q2 red clay	Plinthudults
Changsha	U3	N28°16′06.4″ E113°14′25.9″	Upland	>3 yrs soybean and sweet potato	1410	Q2 red clay	Plinthudults

Note: Q2 means Middle Pleistocene, the second part of Quaternary.