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Effect of tea plantation age on the distribution of soil organic carbon and nutrient within micro-aggregates in the hilly region of western Sichuan, China

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ABSTRACT

Pool of micro-aggregate-associated carbon (C) play a highly accurate and general diagnostic role for change in soil organic C pool in response to changes in management practices. However, effects of different chronosequence phases on the pools of organic C and nutrient (nitrogen, phosphorus, and potassium) in micro-aggregates of different sizes in tea (*Camellia sinensis* L.) plantations have not been studied in detail. This study was to investigate the organic C and nutrient pools in micro-aggregates of different sizes as affected by age of tea plantation. Surface (0–20 cm) soil samples were collected from four tea plantations with different ages (16, 23, 31, and 53 years) in Zhongfeng town of Mingshan county, which is in the hilly region of western Sichuan, China. Micro-aggregates were isolated from samples through a standard wet-sieving procedure and then separated by ultrasonic dispersion into five fractions (250–50, 50–10, 10–5, 5–1, and <1 μm). For all tea plantations, the distribution of micro-aggregate fractions showed that the dominant class was 250–50 μm fractions with a mean value of 52.98%, and these fractions were the predominant pools of organic C and nutrient in micro-aggregates. Mean weight diameter (MWD) in 53 years of tea plantation was the highest in all tea plantations, suggesting that micro-aggregates in 53 years of tea plantation had more stability than other tea plantations. More important fractions for organic C and total nitrogen (N) retention would be the 250–50 fractions, and higher levels of available phosphorus (P) and potassium (K) were observed in the <1 μm fractions. Successive planting of tea (from 16 years to 53 years) induced a significant increase in pools of organic C and nutrient in whole soils, except for the available K pool that showed an inverse trend. These changes were reflected in parallel and predominant changes in pools of these elements in micro-aggregates, especially in the 250–50 μm fractions, which validated the importance of micro-aggregates (in particular the 250–50 μm fractions) as soil organic C and nutrient protection and stabilization sites in such tea plantations.

1. Introduction

Soil structure is a key factor that regulates many physical and biological processes in soils (Mikha and Rice, 2004). Soil aggregates are heterogeneous assemblages of organic and mineral particles operationally distinguished by size as macro- (>250 μm) and micro- (<250 μm) aggregates (Tisdall and Oades, 2012). Macro-aggregates are formed by temporary associations of micro-aggregates, minerals, and particulate organic matter, predominantly through enmeshment by fungal hyphae and plant roots (Mummey and Stahl, 2004). Micro-aggregates, on the other hand, typically form by microbially mediated processes within macro-aggregates and are largely dependent upon persistent organic binding agents for structural stability (Tisdall and Oades, 2012). Physical disturbance of soils generally results in decreased macro-aggregate stability and the release of relatively stable micro-aggregates, which may then become building blocks for the next cycle of macro-aggregate formation (Mummey and Stahl, 2004; Denef and Six, 2006). According to the concept of aggregate hierarchy (Six et al., 2004), increases in soil organic carbon (C) contents are attributed not only to an increased amount of C-rich macro-aggregates, but also to a reduced rate of macro-aggregate turnover. The slower turnover of macro-aggregates is suggested to enhance the formation of highly stable micro-aggregates in which organic C is stabilized and sequestered in the long term. A previous study with three conventional tillage and no-tillage experiments in widely varying soil types (Alfisol, Oxisol, Mollisol)

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and environments (Kentucky, Brazil, Nebraska) supported this theory by finding that over 90% of the difference in soil organic C between conventional tillage and no-tillage could be accounted for by the micro-aggregate-associated C difference (Denef et al., 2004). Therefore, the micro-aggregate-associated C may play a highly accurate and general diagnostic role for change in soil organic C in response to changes in management practices.

The distribution of organic C and nutrient (nitrogen, phosphorus, and potassium) in soil aggregates can influence both soil aggregation and microbial degradation of soil organic matter, so quantifying their locations within aggregate sizes will improve our understanding of mechanisms for sequestering soil organic matter (Jiang et al., 2011). Also, as different aggregate fractions are selectively removed during erosion, characterization of eroded versus retained aggregates will improve our understanding of nutrient dynamic. Some researchers (Mikha and Rice, 2004; Kong et al., 2005) reported a decrease in organic C contents with decreasing aggregate size, but others (Li et al., 2007; Mao et al., 2014) obtained an inverse relationship between organic C contents and aggregate sizes. The findings by Christensen and Sorensen (1985) showed that organic C and total nitrogen (N) were associated with finer soil particles, and these particles may vary among different aggregate fractions. Generally, most studies have examined soil aggregate-associated C with little attention given to nutrient, especially phosphorus (P) and potassium (K). Also, these researches on soil chemical properties with respect to management practices have concentrated on macro-aggregate analysis. While this approach gives a generalized overview of the organic C and nutrient contents in whole soils, a comprehensive understanding of soil organic C sequestration and nutrient dynamic requires an evaluation of the locations of these elements in micro-aggregates of different sizes.

Tea (*Camellia sinensis* L.) is a major economic crop in many developing countries, including China, India, and Sri Lanka. China is the largest tea producing country in the world. By 2013, the tea plantation area in China had reached 2.58 million ha and continues to increase (International Tea and Committee, 2014). As a perennial evergreen crop, tea plantations gradually form a unique regional ecosystem due to leaf and root litters, root exudates, and typical tea plantation management practices (Kamau et al., 2008). Our previous studies suggested that the distribution of macro-aggregate-associated C and nutrient will change with increasing age of tea plantation in the hilly region of western Sichuan, China (Wang et al., 2013a; Li et al., 2015). However, the effects of different chronosequence phases on the pools of these elements in micro-aggregates of different sizes in such tea plantations have not been studied in detail. Therefore, the objectives of this study were to investigate the (i) composition and stability of micro-aggregates, (ii) distribution of micro-aggregate-associated C and nutrient, and (iii) pools of these elements in micro-aggregates as affected by age of tea plantation. Our overall hypothesis was that changing degree of micro-aggregate-associated C and nutrient pools differed with aggregate sizes in the process of tea planting.

2. Materials and methods

2.1. Field site

The study site is located at the Zhongfeng town of Mingshan county of Ya'an city in the hilly region of western Sichuan, China (Fig. 1). The site is under the management of the Sichuan Agricultural University so no special permission was required for the current research and no endangered or protected species were involved in or negatively impacted by this research. The prevailing climate of the study site is a subtropical monsoon climate. Mean annual temperature is 15.4 °C, with the lowest and highest temperatures of 4.3 and 35.2 °C, respectively. Average annual precipitation is 1500 mm with 72.6% of the precipitation occurring during July to September. The exposed layer is sedimentary rocks mainly formed after the Mesozoic age, and the soils were classified

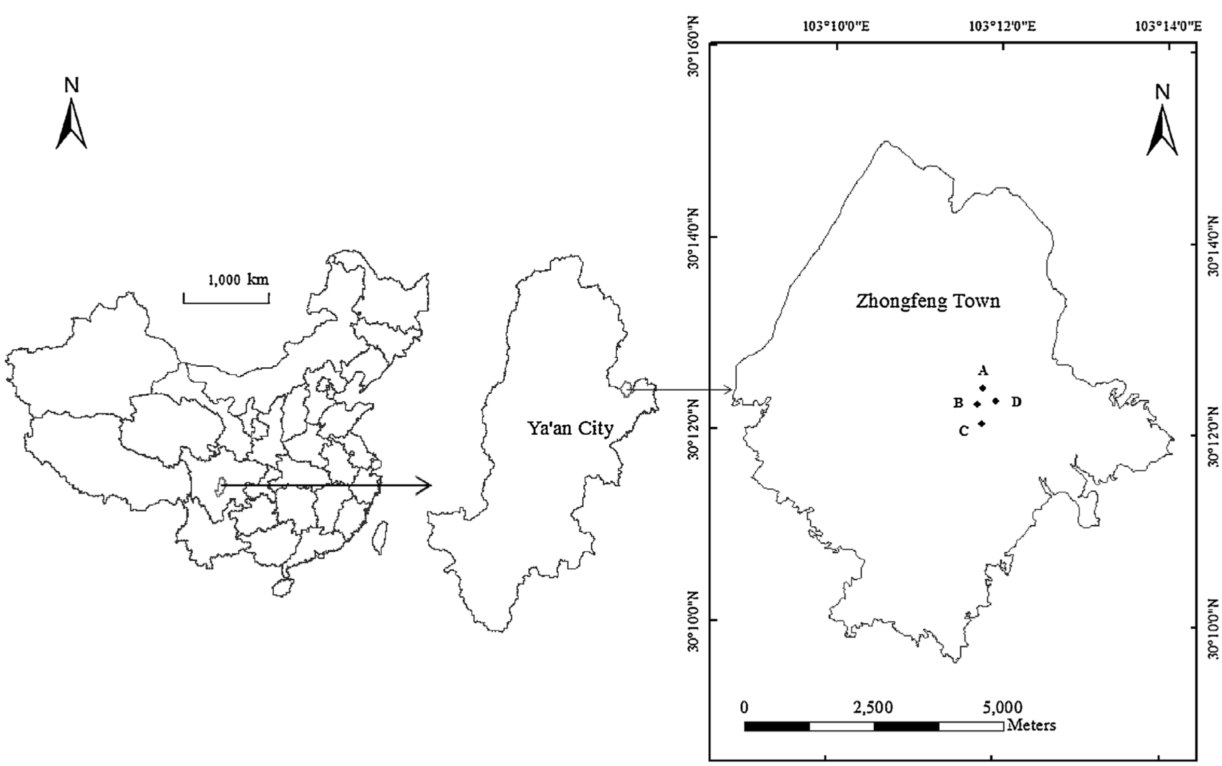

Fig. 1. Location of the study site. (A) 16 years of tea plantation; (B) 23 years of tea plantation; (C) 31 years of tea plantation; D: 53 years of tea plantation.