Geoderma 337 (2019) 1077–1085

Contents lists available at ScienceDirect

Geoderma

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

Temporal dynamics and vertical distribution of newly-derived carbon from a C_3/C_4 conversion in an Ultisol after 30-yr fertilization

S. Liu[a,b], Z.B. Zhang[a], D.M. Li[c], P.D. Hallett[d], G.L. Zhang[a], X.H. Peng[a,*]

[a] State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, PR China
[b] University of Chinese Academy of Sciences, Beijing, 100081, PR China
[c] Institute of Red Soil, Jinxian, 331700, PR China
[d] School of Biological Sciences, University of Aberdeen, Aberdeen AB24 3UU, UK

ARTICLE INFO

Handling Editor: Junhong Bai

Keywords:
Soil aggregation
Soil organic carbon fractions
^{13}C natural abundance
Long-term fertilization

ABSTRACT

Long-term fertilization has a considerable effect on the dynamics of soil organic carbon (SOC). However, quantifying the contribution of fertilization practices to SOC is still a challenge. In this study, we selected a 30-yr fertilization experiment planted with a shift from C_3 to C_4 crops. Our objectives were (i) to determine temporal dynamics of SOC and newly-derived C (f_{new}) with the cultivation time and their vertical distribution along with soil profile; (ii) to assess the effect of the fertilization on SOC and f_{new}. Three treatments were involved: no fertilization (Control), NPK application (NPK), and continuously planted with C_3 crops adjacent to the experiment as a reference (NAT). The SOC was physically separated into cPOM, fPOM, iPOM, s + c_m and s + c_f fractions, and their $\delta^{13}C$ values were determined. Our results show the f_{new} in the bulk soil and C fractions presented an exponential increase over the cultivation time in the NPK treatment but this was only observed for the bulk soil and the s + c_f fraction in the Control treatment. The f_{new} had a priority to be stored within microaggregates, and then enriched in the silt and clay sized fraction over time. The SOC and f_{new} in the bulk soil and C fractions decreased with soil depth so that the difference between the Control and NPK treatments was observed only in the 0–20 cm depth. Our results demonstrate that the long-term fertilization increases the new C proportion in the bulk soil and C fractions but this contribution was limited to the plough layer.

1. Introduction

Red soils cover about 30% of China's and 20% of India's arable land area (Zhao, 2002). Globally they are extremely important to food provision, but they suffer from past mismanagement that has depleted soil organic carbon (SOC) to < 1% in many regions. The consequence is severe soil erosion during monsoon rains and poorer soil conditions for crop production. Boosting SOC in these soils is essential for their long-term productive use, but the rapid cycling of SOC under the tropical climate, the highly weathered clays that make up these soils and limited inputs of fresh SOC make this difficult to achieve.

One easily adopted approach is improved fertilization, which can increase yield, crop residues and root biomass, leading to increased SOC (Franzluebbers, 2005; Kong et al., 2005). However, the contribution from new crop residues and roots to the SOC pool is difficult to disentangle from older SOC. This can be accomplished at field scale by measuring changes of natural stable C isotope ($\delta^{13}C$) content in soil to investigate the dynamics of newly-derived C and SOC turnover rate following conversion between C_3 and C_4 plants (Roscoe et al., 2001; Christensen et al., 2011; Gunina and Kuzyakov, 2014). Many studies have used $\delta^{13}C$ to assess the amount of new C in the bulk soil under different soil types (Kristiansen et al., 2005; Wang et al., 2015), C_4 plant types (Garten and Wullschleger, 2000; Roscoe et al., 2001; Schneckenberger and Kuzyakov, 2007), land uses (Zhang et al., 2015a), and fertilization treatments (Zhang et al., 2015b). It has been widely confirmed that the $\delta^{13}C$ values and newly-derived C in bulk soil are closely related to soil depth (Rasse et al., 2006; Kramer and Gleixner, 2008; Liu et al., 2013; Qiao et al., 2015) and cultivation time (Blagodatskaya et al., 2011; Christensen et al., 2011). However, these studies assessed the change in the newly-derived C mainly based on the total SOC. We hypothesized the temporal dynamics of newly-derived C and its vertical distribution along with soil profile may be various in different SOC fractions.

SOC physical fractions play a key role in preserving SOC because it physically hinders the accessibility of organic compounds to microorganisms, extracellular enzymes, and oxygen (Six et al., 2002; Lützow

* Corresponding author.
E-mail address: xhpeng@issas.ac.cn (X.H. Peng).

https://doi.org/10.1016/j.geoderma.2018.11.021
Received 3 May 2018; Received in revised form 20 October 2018; Accepted 12 November 2018