



Integrated aggregate turnover and soil organic carbon sequestration using rare earth oxides and ^{13}C isotope as dual tracers

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ABSTRACT

The formation, stabilization and breakdown processes of soil aggregates determine soil organic carbon (SOC) sequestration, in turn, soil aggregate dynamics are mediated by SOC changes. However, the interactions between them remain elusive. Herein, three types of ^{13}C -labelled residues were added to two textured soils. Rare earth oxides (REOs) and ^{13}C isotope were used as dual tracers to simultaneously track aggregate transfer pathways and SOC sequestration during a 56-day incubation period. Residue-derived CO_2 followed the sequence of Vetch > Maize > Decomposed maize during the first two weeks. Residue-derived CO_2 was significantly negatively correlated with the aggregate turnover time in both investigated soils ($P < 0.01$), indicating that aggregate turnover was a controlling factor of residue decomposition in addition to its inherent features. Generally, residue addition decreased the aggregate turnover time in the sequence of Vetch < Maize < Decomposed maize. In Red clay soil, macroaggregates attained a higher turnover rate than that of microaggregates, while a similar change pattern was not observed in Sandstone soil with residue application. Aggregates turnover occurred faster in Sandstone soil than in Red clay soil under a given residue application. The aggregate turnover time was significantly reciprocally correlated with the residue-derived C sequestration rate ($P < 0.01$), suggesting that aggregate turnover was the key factor in C sequestration. A C flow conceptual model was proposed, residue-derived C firstly accumulated in macroaggregates in the formation process, and then relocated from macroaggregates to microaggregates with the breakdown processes at the mid-to-late stage. This study highlights the importance of aggregate turnover in SOC sequestration and demonstrates that these interactions are further affected by residue features and soil texture.

1. Introduction

The soil organic carbon (SOC) pool (~1550 Gt) is approximately three times the biotic pool (~560 Gt) and two times the atmospheric pool (~760 Gt) (Lal, 2004). SOC sequestration involves capturing and storing atmospheric carbon, which exerts notable impacts on global climate change and feedback processes (Lal, 2004; Lehmann and Kleber, 2015). The physical protection of soil aggregates is considered an important mechanism of C stabilization (Dungait et al., 2012; Garland et al., 2018). It has been widely confirmed that macroaggregates physically protect fresh organic matter from microbial attack (Six et al., 2002), while microaggregate fractions tend to be involved in long-term storage and stabilization of newly-derived carbon (Chaudhary et al., 2014; Liu et al., 2019b). Moreover, the aggregate size distribution

determines soil microbe activity (Mummey and Stahl, 2001; Ebrahimi and Barati, 2016), nutrient cycling (Bossard et al., 2008; Nesper et al., 2015) and water movements (Gong et al., 2018), thus indirectly impacting SOC dynamics. In turn, soil aggregation is mediated by SOC sources. Microbial synthesis products influenced by residue biochemical features function as binding agents for soil aggregate formation (Puttaso et al., 2013). Therefore, the interaction between SOC sequestration and soil aggregation has attracted much attentions.

The dynamics of C sequestration in soil aggregates have been evaluated via ^{13}C isotope technology. Following the conversion between C_3 and C_4 plants (Gunina and Kuzyakov, 2014; Liu et al., 2018; Liu et al., 2019b; Atere et al., 2020;) or lab/in situ incubation with labelled organic residues (Majumder and Kuzyakov, 2010; Jin et al., 2018), the pathways of carbon sequestration in aggregates can be tracked.

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