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# Methodological uncertainty in estimating carbon turnover times of soil fractions

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ABSTRACT

Improving predictions of soil organic carbon (SOC) dynamics by multi-compartment models requires validation of turnover times of different SOC pools. Techniques such as laboratory incubation and isotope analysis have been adopted to estimate C turnover times, yet no studies have systematically compared these techniques and assessed the uncertainties associated with them. Here, we tested whether C turnover times of soil fractions were biased by methodology, and how this changed across soil particle sizes and ecosystems. We identified 52 studies that quantified C turnover times in different soil particles fractionated either according to aggregate size (*e.g.*, macro- versus micro-aggregates) or according to soil texture (*e.g.*, sand versus silt versus clay). C turnover times of these soil fractions were estimated by one of three methods: laboratory incubation (16 studies), $\delta^{13}C$ shift due to $C_3$–$C_4$ vegetation change (25 studies), and $^{14}C$ dating (19 studies). All methods showed that C turnover times of soil fractions generally increase with decreasing soil particle size. However, estimates of C turnover times within soil fractions differed significantly among methods, with incubation estimating the shortest turnover times and $^{14}C$ the longest. The short C turnover times estimated by incubation are likely due to optimal environmental conditions for microbial decomposition existing in these studies, which is often a poor representation of field conditions. The $^{13}C$ method can only be used when documenting a successive $C_3$ versus $C_4$ vegetation shift. C turnover times estimated by $^{14}C$ were systematically higher than those estimated by $^{13}C$, especially for fine soil fractions (*i.e.*, silt and clay). Overall, our findings highlight methodological uncertainties in estimating C turnover times of soil fractions, and correction factors should be explored to account for methodological bias when C turnover times estimated from different methods are used to parameterize soil C models.



## 1. Introduction

Uncertainty in predicting carbon–climate feedbacks largely stems from poor representation of soil organic carbon (SOC) pools. This is an important consideration as SOC is the largest C pool in terrestrial ecosystems and perturbation of it strongly modulates climate change (Todd-Brown et al., 2013; Koven et al., 2015; Luo et al., 2016). SOC is heterogeneous in terms of composition, structure, location, and stabilization mechanism (Stevenson, 1994; Sollins et al., 1996; Schmidt et al., 2011; Lehmann and Kleber 2015). Conventional soil C models classify SOC into multiple conceptual pools with different turnover times based on their resistance to microbial decomposition (Jenkinson and Rayner, 1977; Parton et al., 1987). A growing body of research calls for mechanistic representations of SOC processes in Earth System Models, such as protection by physical isolation and mineral sorption (Sulman et al., 2014; Wieder et al., 2014; Tang and Riley, 2015). Therefore, attention should be paid to physically fractionated SOC fractions which are measurable and could represent soil organic matter (SOM) protection mechanisms (Christensen, 1996; von Lützow et al., 2007; Schmidt et al., 2011). Quantifying C turnover times of these soil

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