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Response to 'Stochastic and deterministic interpretation of pool models'

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Abstract

We concur with Azizi-Rad et al. (2021) that it is vital to critically evaluate and compare different soil carbon models, and we welcome the opportunity to further describe the unique contribution of the PROMISE model (Waring et al., 2020) to this literature. The PROMISE framework does share many features with established biogeochemical models, as our original manuscript highlighted in Table 1, and our work builds upon model innovations developed by many different groups, including that of Azizi-Rad and colleagues. Yet, the PROMISE framework is distinctive due to where it places mechanistic emphasis, and how these mechanisms are formalized in the mathematical model structure.

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Comments

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RESPONSE TO EDITOR

Response to 'Stochastic and deterministic interpretation of pool models'

We concur with Azizi-Rad et al. (2021) that it is vital to critically evaluate and compare different soil carbon models, and we welcome the opportunity to further describe the unique contribution of the PROMISE model (Waring et al., 2020) to this literature. The PROMISE framework does share many features with established biogeochemical models, as our original manuscript highlighted in Table 1, and our work builds upon model innovations developed by many different groups, including that of Azizi-Rad and colleagues. Yet, the PROMISE framework is distinctive due to where it places mechanistic emphasis, and how these mechanisms are formalized in the mathematical model structure.

The biogeochemical model inspired by the PROMISE framework is individual-based and stochastic. This gives it two important advantages: (1) PROMISE generates a distribution of residence times for particles in any given chemical state, and (2) PROMISE allows the user to explore the microbial mechanisms that shape this distribution. As Azizi-Rad and colleagues point out, even standard first-order decay models (e.g., CENTURY) yield a distribution of particle transit times through any particular pool. However, in such deterministic models, the shape of the distribution is entirely determined by parameter selection. By contrast, PROMISE incorporates stochasticity in particle movement. It also simulates microbial control over soil carbon cycling by linking the likelihood of chemical transformations to the proximity of decomposers. Thus, the user can explore how assumptions about microbial ecology, soil texture, and the chemistry of organic matter inputs influence carbon residence times in a given chemical state or pore size class. PROMISE is not the first soil carbon model to adopt a probabilistic approach (e.g., see Sierra et al., 2018). Nor is it the first model of its kind to represent direct microbial control over carbon fluxes—by now, such an approach is well established in the literature (e.g., see Sulman et al., 2014; Wieder et al., 2014; Woolf & Lehmann, 2019; among others). However, we contend that the PROMISE model is novel because it combines a probabilistic, individual-based simulation model approach with ecological mechanisms of organic matter transformation, which are directly inspired by empirical observations.

Azizi-Rad and colleagues also make the observation that no soil carbon model can truly be pool-independent. Obviously, the PROMISE model does store individual carbon atoms "in one or many state variables that account for its change through a mass balance," to quote their definition. However, for a significant portion of the terrestrial ecology community, the term "pool" has a more specific meaning: it represents a cohort of substances or compounds with shared properties, specifically with shared carbon turnover dynamics. Accordingly, membership in the pool is not just a question of having a certain mass, but also a matter of having a certain property: for instance, a predetermined chemical composition, an association with a certain aggregate size, or a particular turnover time. With this latter definition in mind, we promulgate our core argument in Waring et al. (2020): to predict the belowground fate of a particular organic matter compound, it is not especially important which conceptual pool it belongs to. What truly matters are the things that happen to the carbon compound on its way through the system, and the frequencies at which those things happen.

Thus, we contend that it is not the *existence* of modelled pools, but rather their definition, interpretation, and mathematical representation that distinguishes PROMISE from its counterparts. As Azizi-Rad et al. (2021) point out, a pool in PROMISE could be defined as "chemical type *X* in pore size class *Y*." Yet a particle's residence time in this state is not determined simply by the chemistry of *X* or by the dimensions of pore *Y*, but also by the particle's proximity to a microbe with appropriate enzymatic machinery. Thus, the dynamics of a given pool are not defined by parameters specific to that pool, but rather represent an emergent property of the whole model. In this way, the PROMISE framework directs our focus away from the definition of discrete pools, and onto the mechanisms that influence the physical movement and chemical transformation of specific fragments or molecules of organic matter.

DATA AVAILABILITY STATEMENT

No data are associated with this submission.

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This article is a Response to the Letter by Azizi-Rad et al., https://doi.org/10.1111/gcb.15581 about the article by Waring et al., 26, 6631–6643.

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