

RESPONSE

Reply letter to Munoz et al. 'on the importance of time in carbon sequestration in soils and climate change mitigation'— Keep carbon sequestration terminologies consistent and functional

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Munoz et al. (2024) deemed our recent proposal of the definition of carbon (C) sequestration in soils based on a literature review incomplete. They state that including the time that C is stored in soils is required for a proper definition of C sequestration.

1. We based our analysis (Don et al., 2024) on existing definitions of C sequestration, mainly by the IPCC, that does not refer to CO₂ taken out of the atmosphere for a limited period. The term 'sequestration' means 'separation' or 'removal' and thus does not include temporal aspects per se. There is a scientific consensus on the definitions, but it is not followed in practice. We found that most scientific literature was not careful with the use of the term C sequestration in soils. This underlines the need for a uniform, functional definition, as proposed in our review. We provide practical guidance on the use of the terms around C sequestration in soils to help identify measures that result in SOC loss mitigation, C sequestration in soils, climate change mitigation or negative emissions.
2. We agree with Munoz et al. (2024) that the climatic effects of C sequestration have a temporal dimension. In natural systems, such as soils and plant biomass, long-term C storage cannot be completely ensured. Ecosystem disturbances such as a change in land management and climate change can trigger C stock losses. Therefore, we stress this important aspect in our review and oblige stakeholders to take the potential reversibility into account. At the same time, we also acknowledged the climate benefit of shorter lived increases in C storage.
3. Practical application of carbon farming would be extremely difficult with the definition proposed by Munoz et al. (2024). First, non-monotonic SOC changes, such as those depicted in Measure B of their fig. 1, are virtually impossible at time scales relevant for carbon farming projects and hardly measurable. Second, C accounting under such a system can only be done via models, requiring expertise and resources, while still facing challenges and uncertainties due to the multitude of site-specific drivers influencing soil C dynamics (Riggers et al., 2019). This would, in turn, unnecessarily impede carbon farming initiatives.
4. There are different simplified indicators in use to assess the climate impact of land management, including the greenhouse gas balance, tonne-years of carbon storage and also C sequestration rates (Matthews et al., 2023). There are other, more complex methods, such as earth system models, to account for climate

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impacts, but the above-mentioned indicators are compromises between accuracy and practicality. We need indicators with medium complexity, such as C sequestration in soils, to estimate the climate impact of land management.

5. What Munoz et al. (2024) proposed is a possible future next step of complexity beyond current definitions of C sequestration in soils and should be termed differently. Instead of a proposed unit mass C by time, a unit based on radiative forcing would more appropriately approximate the climate effect of ecosystem management by combining C sinks and lifespans of greenhouse gases and changes in albedo (Graf et al., 2023).

We recommend using the terminologies outlined in our review as they are based on scientific grounds, already present in the literature and practical for communication with stakeholders and the society.

AUTHOR CONTRIBUTIONS

Axel Don: Conceptualization; funding acquisition; supervision; visualization; writing – original draft. **Felix Seidel:** Conceptualization; formal analysis; visualization; writing – review and editing. **Jens Leifeld:** Conceptualization; writing – review and editing. **Thomas Kätterer:** Conceptualization; writing – review and editing. **Manuel Martin:** Writing – review and editing. **Sylvain Pellerin:** Writing – review and editing. **David Emde:** Visualization; writing – review and editing. **Daria Seitz:** Conceptualization; writing – review and editing. **Claire Chenu:** Conceptualization; writing – review and editing.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed for the current article.

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