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LETTER TO THE EDITOR

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Climate change mitigation through soil carbon sequestration in working lands: A reality check

As global anthropogenic emissions of greenhouse gases keep rising, there is increased pressure to utilise so-called natural climate solutions. Sequestration of additional organic carbon in agricultural soils is one such approach but it continues to provoke much debate. Published estimates for the potential magnitude of soil carbon sequestration (SCS) vary dramatically, from very modest to very substantial (Moinet et al., 2023). The estimations recently published by Almaraz et al. (2023) are of the latter category and we question here the validity and realism of their claims.

Almaraz et al. (2023) use a modelling approach to estimate the impact of six land management practices on SCS. They consider all practices to be additive and to "offer an immediate negative emission technology (NET) for deployment" as opposed to those less practically or economically feasible in the short-term. Their approach is helpfully transparent in some respects. For example (a) stressing the importance of SCS being *coupled* to deep emission reductions; (b) only considering areas not already using SCS practices as contributing to climate mitigation; and (c) clearly stating that they ignore socioeconomic barriers, focusing on *technical* potential. Nonetheless, we contend that the values presented by Almaraz et al. (2023) are considerable over-estimates. This is due to methodological inaccuracies and overly optimistic assumptions. We have listed our three main concerns below.

1 | SERIOUS OVERESTIMATION OF THE AVAILABILITY OF ORGANIC MATTER FOR COMPOST AND BIOCHAR

All organic inputs to soil are ultimately limited by photosynthesis (Janzen et al., 2022), which creates competition for biomass resources. A European study revealed that compost availability currently limits its use by farmers (Hijbeek et al., 2019) and biomass availability for biochar production is limited (Schlesinger & Amundson, 2019). Consequently, composting and biochar production are in competition for organic matter, so their SCS potentials cannot be regarded as additive. Moreover, Almaraz et al. (2023) seem to have made an error when trying to take this availability issue into account. Specifically, they calculate that the feedstock requirement for applying compost and biochar across 1132 million ha of global cropland and 2800 million ha of global pasture equates to 53 Gt (14 Gt for compost and 39 Gt for biochar). This is almost nine times higher than the feedstock availability of 6 Gt from the study they cite (Matovic, 2011). In fact, feedstock requirements would even be higher, because substantial amounts of carbon are lost during composting or biochar production. In view of uncertainty regarding biomass availability, and the logistics and cost of establishing pyrolysis infrastructure for production at scale globally, it seems overly optimistic to promote these practices as major contributors to climate change mitigation in the short-term.

2 | METHODOLOGICAL INACCURACIES IN INTERPRETING C SEQUESTRATION RATES

Compost and biochar additions to soil represent spatial redistribution of organic C already removed from the atmosphere by photosynthesis, not additional removal. Although Almaraz et al. (2023) account for this issue for biochar, their table S2 suggests that they do not consider it for compost. Furthermore, they used a single rate of SCS for each practice which they applied globally, irrespective of soil type, land use, climate, and initial soil C stock. This broad-brush approach is highly inaccurate and hardly seems acceptable in a study designed to give advice to policymakers. For example, the authors cite a unique SCS rate of 1.0 $Mg\,C\,ha^{-1}\,year^{-1}$ for the first 20 years of compost addition, quoting Powlson et al. (2012). However, this rate was for farmyard manure added annually to a cropland soil with a low initial soil C stock. Many grassland soils will likely have a relatively high C stock, potentially close to saturation, and thus limited potential to accumulate additional C, as recently re-emphasised (Moinet et al., 2023; Muleke et al., 2023). The actual rate of SCS for grassland soils (which would receive 71% of the globally available compost according to table S2 of Almaraz et al., 2023) will therefore be much lower than the rate used. Another example of the shortcomings of their approach is the lack of considerations regarding climates and growing seasons when estimating land suitable for cover cropping; in many (sub-)tropical regions, there is virtually no opportunity to grow cover crops outside the rainy seasons.

This article is a Response to the Letter by Almaraz et al, https://doi.org/10.1111/gcb.16884 and https://doi.org/10.1111/gcb.17011.

3 | PREMATURE ASSUMPTION ABOUT THE APPLICABILITY OF ENHANCED ROCK WEATHERING

Modelling studies show considerable promise for enhanced rock weathering. However, the practice is in its infancy and much remains to be understood (Vicca et al., 2022), which the authors themselves admit, stating: "this is a very new practice and is rarely applied, even in field-scale research trials". This contrasts with their claim to only consider practices that offer immediate NET for deployment.

4 | CONCLUSION

To summarise, we contend that Almaraz et al. (2023) seriously overestimate the contributions of two of the three main SCS practices (compost and biochar), and the third (enhanced rock weathering) is far from practical application at large scale. We fully agree that it is appropriate to consider novel practices and urgently promote research to evaluate their SCS potential. We add that it is equally critical to quantify any potential trade-offs and to provide realistic evaluations of the practical, infrastructural, social, or financial limitations to the uptake of such practices. Overly optimistic estimates for current *technical* potential such as those provided by Almaraz et al. (2023) can be highly misleading for policymakers and may hamper rather than aid the fight against global warming.

AUTHOR CONTRIBUTIONS

Gabriel Y. K. Moinet: Writing – original draft; writing – review and editing. **Ronald Amundson:** Writing – original draft; writing – review and editing. **Marcelo V. Galdos:** Writing – original draft; writing – review and editing. **Peter R. Grace:** Writing – original draft; writing – review and editing. **Stephan M. Haefele:** Writing – original draft; writing – review and editing. **Renske Hijbeek:** Writing – original draft; writing – review and editing. **Jan Willem Van Groenigen:** Writing – original draft; writing – review and editing. **Kees Jan Van Groenigen:** Writing – original draft; writing – review and editing. **David S. Powlson:** Writing – original draft; writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

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

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