

Reviewer 1

General comment:

This manuscript addresses an important topic and provides a valuable comparison of soil inventory, RothC modelling, and eddy covariance approaches for estimating long-term SOC dynamics in cropland systems. The study is well designed and based on a unique long-term dataset.

The introduction is clear, well structured, and effectively motivates the study objectives. The methodology is described in a comprehensive and transparent manner, allowing the reader to fully understand the applied approaches and uncertainty analyses. The results are clearly presented and supported by informative figures and tables, while the discussion provides a balanced interpretation of the findings and places them appropriately within the context of previous research. Finally, the conclusions are well supported by the presented results and remain consistent with the scope of the study.

Overall, I consider this to be a good-quality manuscript that is suitable for publication after minor revision. The comments below are intended to further strengthen the presentation and interpretation of the results.

We thank reviewer 1 (R1) for the positive comments regarding the manuscript. Please find below the responses to R1 comments.

Comment 1: EC bias and energy balance non-closure

The manuscript presents a convincing comparison of SOC stock changes derived from soil inventories, RothC simulations, and EC-based carbon budgets, and clearly demonstrates a systematic divergence among these approaches. Furthermore, the discussion of the potential role of energy balance non-closure is thoughtful and appropriately cautious. The inclusion of both the carbon balance ratio (CBR) and energy balance ratio (EBR) provides useful support for the proposed explanation. As a possible avenue to further strengthen the discussion, the authors may consider briefly elaborating on whether the observed magnitude of EBR reduction could plausibly account for the discrepancy between EC-derived and inventory/model-based SOC estimates, even if such a relationship cannot currently be quantified with certainty.

We thank the reviewer for this comment. We agree that elaborating on whether the observed magnitude of EBR reduction could plausibly account for the discrepancy between EC-derived and inventory/model-based SOC estimates would indeed strengthen the discussion. We therefore have tested an EBR-based correction on NEE which consisted of applying a fraction (f) of energy balance non-closure ($1 - \text{EBR}$) to NEE. EBR was calculated based on Volk (2021) and the differences between corrected and uncorrected NEE (ΔNEE) was compared to NBP for f varying between 0 and 100%. It was found that a factor of $f = 52\%$ led to a ΔNEE of a comparable magnitude than NBP (1.45 kgC m^{-2}). In other words, attributing half of the energy balance non-closure would reconcile EC and modelling/inventories approaches.

This following paragraph has been added to the revised manuscript after L681:

“To test whether the discrepancy between the EC-based C budget, the model estimates and the soil C inventories could arise from a fraction of the turbulent CO₂ exchange being missed by EC at the ecosystem surface, we computed the EBR following Volk et al.(2021) and attributed a fraction (α) of the energy balance non-closure to NEE, varying α between 0 and 100%. The optimal α was identified by comparing the resulting gain in C sequestration after correction (Δ NEE) with NBP under the hypothesis of SOC stock equilibrium. An α of 52% yielded a cumulative Δ NEE of the same magnitude as cumulative NBP (-1.45 kgC m⁻²), indicating that correcting NEE for only part of the energy balance non-closure may help reconcile EC, RothC and soil C inventories. This supports the hypothesis that eddy covariance turbulent fluxes are underestimated in absolute value at BE-Lon, while also implying that the degree of underestimation differs between turbulent energy fluxes and CO₂ fluxes. Whether energy balance non-closure can be systematically translated into NEE corrections nevertheless remains uncertain (Mauder et al., 2024; Zhou et al., 2024).”

Comment 2: Visibility of farmyard manure applications in Figure 4

Farmyard manure application is identified as one of the key drivers of SOC accumulation throughout the manuscript. In Figure 4, the caption indicates that vertical lines represent farmyard manure applications; however, these markers are difficult to identify or not readily visible in the current version of the figure. The figure could be improved by displaying manure application events more clearly (e.g., through stronger colours, thicker lines, symbols, or annotations). This would help readers visually relate management events to the temporal dynamics of NBP and SOC stock changes and would further support one of the central messages of the study.

The vertical lines were not displayed on Figure 4. It is now fixed in the revised manuscript. Please keep in mind that FYM application and harvest occurred the same month in 2009, 2015, 2021 and 2024. Therefore, for the NBP curve, the resulting increase in SOC stocks due to FYM application can be compensated by the export of C at harvest.

Minor editorial comment:

Line 68 – CO₂ – the lower index is missing - fixed

Line 106 – Please remove “2” form 20225 - fixed

Line 128. – The dot is at a lower index; please change this format to normal. fixed

Line 134 – Why is this hyphen used differently than the previous ones? Please unify it throughout the whole manuscript. fixed

Line 228 - In my opinion, the paragraph should not begin with a mathematical formula. Please consider making this change throughout the whole manuscript to avoid this. After carefully reviewing the submitted manuscript, we decided to keep the structure as it is.

Line 379 – The version of R and the appropriate citation for this software should be provided. Fixed