Dear Editor

We thank the reviewer 1 for their feedback on the manuscript. Our response to reviewer comments is in green font. The line numbers correspond to the manuscript file with track changes.

1. **Abstract**

Line 12: It is better to correct sample size to "a dataset of 1490 topsoil samples" or "a dataset of 1490 post-filtered topsoil samples" here.

Authors: Agreed and done.

Line 23: The statement "Remaining soil management variables (cover crop use, tillage intensity, and organic amendments) had less influence" is vague (e.g., "less influence" relative to what?) and conflicts with two key sources. Table 1 shows tillage intensity explains 18.0% of variance in Cmin-96h and 22.3% in ACE; Table 2 further demonstrates tillage significantly affects POXC in fine-textured soils (P=0.0210). The Introduction cites Sun et al. (2023) and Balota et al. (2004), who show reduced tillage and cover crops increase SOC and C mineralization.

I suggest revising vague "less influence" to "weaker influence than texture/cropping systems"

Authors: Thank you. The edit was made at line 24 as per reviewer suggestion.

1. **Introduction**

Line 41: The Introduction cites Weil et al. (2003) for POXC, while Section 2.2 references Moebius-Clune et al. (2016) for POXC methods. The former is the original POXC protocol, the latter is the revised method? Please reconcile the two citations.

Authors: We have deleted the citation "Weil et al. 2003" and have replaced it with "Moebius-Clune et al. (2016)" for clarity at line 43.

1. **Materials and Methods**

Lines 101–102: The original description "Soil samples were collected …… terminated at 30 cm" is ambiguous. Confirm and revise to: "Soil samples were collected from the Ap horizon (agricultural tilled layer). To ensure all samples were restricted to this horizon, sampling was terminated at 30 cm if the Ap horizon exceeded this depth; the median thickness of the sampled Ap horizons across all sites was 25 cm."

Authors: Agreed and done at line 105. "Soil samples were collected from the Ap horizon (agricultural tilled layer). To ensure all samples were restricted to this horizon depth, the sampling depth was terminated at 30 cm if the Ap horizon exceeded this depth. The median thickness of the sampled Ap horizons across all the sites was 25 cm."

Line 112: Overlapping soil texture ranges

The current texture classifications (coarse: 52–94% sand; medium: 2–78% sand; fine: 1–45% sand) have overlapping ranges, leading to ambiguous categorization. Why did the Ref. Moebius-Clune et al., 2016 do like this?

Authors: The categories were designed for soil health scoring functions and not classifying soil textural classes and taxonomy. The reference Moebius-Clune et al. (2016) did not intend these ranges to be exclusive soil textural classes. Having a broad range of soil textural classes allows for smooth transitions of soil health scoring curves. Therefore, no changes were made to the ranges used to categorize soil textural classes in our study.

Line 130: Explain ACE (n=151) was measured only on the 151 pyrolysis subsamples (representative of full dataset), tell the reader they are the same 151 samples.

Authors: Agreed. This comment was addressed at line 139"As described above, 151 soil samples used to measure ACE protein and pyrolysis parameters were representative of the full dataset and refer to the same set of soil samples."

Line 153-162: Programmed pyrolysis (Section 2.2) is central to the study's novel insights, but key parameters are omitted: helium flow rate (critical for hydrocarbon capture), sample weight precision (±0.1 mg?), and calibration standards used for S1/S2/S3 quantification.

Authors: Thank you for your suggestion. We did not add these parameters as the programmed pyrolysis was conducted as per the standard manufacturer recommended Rock-Eval operating procedures. Since these parameters are well documented in the existing Rock-Eval literature, we believe that including the suggested parameters would not have added any additional information to our study results. To further clarify this comment, we have added that the analyses were performed under standard manufacturer-recommended settings. Line 165 "The standard manufacturer recommended settings (with the helium flow rate at 100 mL/min) were followed to conduct the programmed pyrolysis."

Lines 163–164: the definition of T50 ("temperature at which 50% of the SOC was pyrolyzed") conflicts with the cited reference (Gregorich et al., 2015), which defines T50 for pyrolyzable C (not total SOC).

Authors: We have removed Gregorich et al. (2015) for clarity.

1. **Results and Discussion**

Soil texture explains 60.5% of SOC variance (Table 1)—the largest driver—but the manuscript only attributes this to "inherent soil characteristics" without linking it to specific processes (e.g., clay mineral adsorption, aggregate protection of C). I suggest expanding discussions to: "Soil texture was the strongest driver of SOC (explaining 60.5% of variance; Table 1), primarily due to texture-mediated C stabilization processes: fine-textured soils (high clay content) enhance C retention via clay mineral adsorption (e.g., smectite and illite bind organic molecules) and aggregate protection (microaggregates physically isolate SOC from microbial decomposition). This aligns with Figure 1B, where fine-textured soils had the highest T50 (greater thermal stability), likely due to increased clay-C binding capacity compared to coarse/medium-textured soils."

Authors: Thank you for your comment. We have added the discussion related to soil textural influences on soil C protection in the revised version of the manuscript. Line 204 "Our results of strong dependence of soil texture on SOC confirm the texture mediated soil C stabilization processes. For instance, soil C retention is higher in fine textured than coarse textured soils mainly due to mineral-organic associations and through the formation of microaggregates which physically protect the soil C from microbial decomposition. This finding also aligned with Figure 1 where fine textured soils exhibited greatest T50 values (i.e. indicating greater thermal stability); thus, further highlighting the role of clay induced protection of SOC."

Table 1: "Model R^2" values (0.16–0.37) are low, indicating unaccounted variance? Other potential variables (e.g., crop residue input rates, microbial community composition, or historical land use,……)? The manuscript does not address this, leaving readers to question if key drivers were omitted.

Authors: We have added the discussion related to this comment at line 231 in the manuscript. "It is important to note that the model R^2 values in our study were relatively low ranging between 0.16 to 0.37 (Table 1). This is not unexpected for agronomic studies on SOC that integrate variable land use management practices and complex biochemical processes. The unexplained variance likely reflects the additional variables which were not captured in our model such as the crop residue inputs, soil microbial community composition, and/or the historical land use intensity. Although these variables are known to influence the SOC dynamics, the data on these factors were not consistently available for all the sites studied. Incorporating these variables in the future research might improve the model R^2 values; however, the current results still clearly highlight the importance of soil texture as the major predictor of SOC in our study."

Line 193: "Tillage intensity was not found to be an important predictor" contradicts Table 2, where tillage affects POXC in fine-textured soils (P=0.0210). Qualify this statement.

Authors: We have clarified this comment at line 218 "While tillage intensity was not found to be an important variable impacting soil C indicators when the bulk dataset was used, its effects were detected for some soil C indicators when the data were categorized based on soil textural classes. In particular, tillage intensity significantly influenced POXC in fine-textured soils (Table 2) suggesting that effects of tillage are more pronounced on labile soil C pools in soils with high clay content than the stable fractions of soil C."

Line 201: Perennials and forages had greatest SOC aligns with Table 3, but Table 3 shows coarse-textured perennial SOC (19.4ab) is not statistically distinct from annual grain (16.9ab). Soften the claim to "greater or comparable concentrations."

Authors: Agreed and done at line 243. "Perennial and forages when grown with annual crops exhibited greater or comparable SOC concentrations relative to the other cropping systems in all soil textural classes (Table 3)."

Line 213: "Diversification of cropping systems... critical for building soil C"—no data on residue inputs to support "quantity/quality of C inputs" as the mechanism. Add a discussion linking cropping systems to measured C inputs (if available) or cite literature on residue differences.

Authors: We have added the discussion related to this comment at line 259 "While our findings suggest that diversification of cropping systems results in greater soil C, we did not measure the quantity and quality of crop residue inputs, which limits our ability to confirm the exact mechanisms of soil C accumulation in our study. Nevertheless, previous studies by King and Blesh (2018), McDaniel and Grandy (2016) have reported that diversifying crop rotations with cover crops, perennials, or forages tend to increase the quantity and biochemical diversity of soil C inputs than the conventional monocultures (e.g. simple annual grain systems)."

Line 253: "In coarse-textured soils, Cmin-96h, POXC... were significantly impacted by tillage"—Figure 2 (boxplots) for these indicators shows overlapping ranges between tillage intensities, weakening the "significant" claim. Discuss effect size alongside statistical significance.

Authors: Thank you for your comment. We would like to clarify that Figure 2 represents the pooled data of soil C indicators across all soil textural classes. The data in Table S1 represents the interaction of cropping system and tillage intensity on soil C indicators within each soil textural class. Because the figure aggregates the data from all the soil textures, the visual overlap in the boxplots does not directly reflect the within texture patterns which were observed in Table S1. Therefore, no edits were made to this sentence to avoid confusion.

Line 260: "Medium and fine textured soils had more interactions than coarse"—no explanation for this pattern (e.g., texture-mediated microbial activity). Add a mechanistic hypothesis.

Authors: Agreed. We have added discussion related to this comment at line 316 "One possible mechanism might be that fine textured soils have high clay content which stabilizes soil C via mineral adsorption and formation of microaggregates. Fine textured soils also promote and support diverse soil microbial communities which play a critical role in supporting the complex microbial mediated soil C transformation processes (Six et al., 2002). In contrast, coarse textured soils have lower surface area, lower water holding capacity, and less soil microbial activity, which perhaps contributed to lesser number of detectable interactions between the management practices on soil C indicators."

Line 262: Inconsistent terminology: "tillage intensity" vs. "tillage treatments" (Line 262). Standardize to "tillage intensity."

Authors: We have revised the sentence at line 324 for clarity.

Line 268: "Vegetable systems... less advanced decomposition" is supported by Figure 3 (high HI, low OI), but Table 3 shows vegetable OI in coarse soils (147) is lower than orchard (203) but not statistically distinct from annual grain (168). Clarify this nuance.

Authors: We have clarified this comment at line 335 "Interestingly, the OI values for vegetable systems were not significantly different than the annual grain systems in coarse textured soils (Table 3), suggesting that the slow decomposition of organic matter in vegetable systems is dependent on the soil texture and agronomic management practices followed."

Figure 6: "Cover crop" is negatively associated with C indicators, but Table 1 shows cover crops explain <5% variance. Discuss why this association is weak (small sample size: n=55?).

Authors: We have addressed this comment at line 404 "Additionally, cover crops were negatively associated with soil C indicators (Figure 6) but explained <5% of the variance in the dataset (Table 1) confirming a very small response of soil C indicators to cover crops (Table S6). It is not entirely clear but might be attributed to a smaller number of observations with cover crops in our study (n=55). The cover crop effects on soil C indicators are largely dependent on the cover crop management factors such as type of cover crop species grown, frequency and duration of cover cropping, planting date, and termination time of cover crops (Blanco-Canqui et al., 2015; Peng et al., 2024). Due to the unavailability of the cover crop management factors in our study, the interpretation of cover crop effect is challenging but clearly demonstrates that other management factors (cropping system and tillage system) have a greater effect on soil C indicators.”

Table 4: "HI vs. ACE (r=0.59***)"—ACE is a labile N/C proxy, but no discussion of why hydrogen-rich labile C correlates with protein. Link this to microbial metabolism of fresh organic matter?

Authors: Agreed. We have added a discussion related to this comment at line 433 “The positive association of ACE with HI confirms that H-rich aliphatic C and protein like N compounds are concomitantly present in fresh organic matter and are co-metabolized by the soil microbes during the early stages of organic matter decomposition.”

1. **Conclusion**

It is better to explicitly add methodological limitations, e.g. (1) Tillage intensity categories (e.g., 'light disturbance,' 'no disturbance') relied on producer self-reporting of descriptive terms, with no objective metrics (e.g., plowing depth, number of tillage passes) to standardize classification—introducing bias, as 'light disturbance' may vary by grower interpretation; (2) The small sample size for cover crops (n=55) and orchards (n=33) limits the generalizability of results for these management systems. Future studies should adopt objective tillage measurements and balance sample sizes across management categories to strengthen conclusions.

Authors: Agreed. These limitations were added at line 464 “Additionally, tillage intensity categories in our study were based on subjective producer descriptions and lacked standardized metrics such as tillage depth, number of passes which might have introduced a potential bias in the interpretation of study results. The small sample sizes of cover crops (n=55) and orchards (n=33) limit the generalizability of results for these management practices. Future studies should employ more standardized tillage measurements and ensure a more balanced sample sizes across the agronomic management categories to improve the robustness of study results.”

Best regards

Dr. Chao Song