REVIEWER 1

These are my comments about the paper 'Shifts in controls and abundance of particulate and mineral associated organic matter fractions among subfield yield stability zones', from Sam J. Leuthold et al., submitted to EGUsphere.

It is a good paper, and actually I did not expect otherwise, owing to the already known experience and scientific proficiency of some of the senior authors. Therefore, as you will see, I have very little to add to the text. I have a few comments, however, that may be of help to authors, or perhaps may suggest some improvements in the paper.

RESPONSE: We appreciate the referee's kind comments about the paper, and their efforts in providing suggestions to improve the quality of the manuscript. We have read through and considered each of the comments in turn and have provided our response to them below.

COMMENTS

COMMENT: As I understand, this research is done simultaneously to other ones, namely that of Fowler et al., which is repeatedly cited (as 'in-review': perhaps the term 'submitted' would have been more appropriate?). The fact that this additional information (about the sites, plant production and so on) is not yet available is a pity. However this is a minor drawback in this work.

RESPONSE: We agree that it was challenging to not have the paper by Fowler et al. available at the time of review. However, we are pleased to announce that this paper was published during the intervening time and can now be found at https://doi.org/10.1038/s41598-024-51155-y. In a revised manuscript, we will replace the citations that are listed as "in-review" to the new citation (i.e., Fowler et al., 2024), and add the following citation to the reference list:

Fowler, A., Basso, B., Maureira, F., Millar, N., Ulbrich, R., and Brinton, W. F.: Spatial patterns of historical crop yields reveal soil health attributes in US Midwest fields, Sci Rep, 14, 465, https://doi.org/10.1038/s41598-024-51155-y, 2024.

COMMENT: Line 93. 'Zea mays', not 'Zea maize'.

RESPONSE: Thank you for pointing this out, we will correct this in the revised manuscript.

COMMENT: Line 145. Remove one of the two consecutive 'the'.

REPSONSE: Thank you for finding this typo, we will correct this in the revised manuscript.

COMMENT: Lines 252-255. If I well understood, your results seem contradictory with those of Maestrini & Basso. This is a very interesting result: could you stress it a bit more in the text? It goes almost unnoticed.

RESPONSE: This is a good point, and one that we believe needs to be further clarified in the revised manuscript to avoid any ambiguity. Our results are not in opposition to the work presented by Maestrini and Basso (2018). In the original text, we discuss the observation of both high-yielding, stable zones and unstable yield zones in low-lying areas in our study. However, we discussed the Maestrini and Basso work only in relation to the unstable yield zones in low-lying areas. This was ambiguous and requires clarification, as these findings are not contradictory-- Masestrini and Basso also find high-yielding, stable zones in low-lying areas in their observations, especially in rain-fed cropping systems. We are sorry to have omitted this finding from their work in our discussion, generating confusion, and we are happy to further clarify as necessary. We will address this comment by revising the text as follows—

Original Text: "As characterized by Maestrini and Basso (2018), unstable yield zones are often located in depositional areas that receive downslope contributions of fine soil particles on the decadal time scale (Ampontuah et al., 2006; Thaler et al., 2021). In our study, high-yielding, stable zones had soils with relatively high fine particle content (Fig. 3) and were found mostly in lower areas of the field as well (Fig. 4), which reflects previous observations of crop yield heterogeneity in areas of topographic complexity (Kravchenko and Bullock, 2000; Leuthold et al., 2021)".

Revised Text: "As observed by Maestrini and Basso (2018), both high-yielding, stable zones and unstable zones are often located in depositional areas that receive downslope contributions of fine soil particles on the decadal timescale. Our study finds a similar distribution of stability zones amongst low-lying areas, with both the high-yielding, stable zones and the unstable zones having a relatively high fine particle content (Fig. 3), and being found primarily in lower areas of the field (Figure 4). Our findings thus corroborate previous observations of crop yield heterogeneity in areas of topographic complexity (Kravchenko and Bullock, 2000; Maestrini and Basso, 2018; Leuthold et al., 2021)".

COMMENT: Lines 262-263. Extremely interesting finding, even though it has been observed before (as mentioned in line 265). Note, however, that the relationship is very weak, in the very limit of signification ($p = 0.048$). Please mention this detail.

RESPONSE: The referee is correct that this relationship is somewhat muddled by the variability in cropping system, site characteristics, and climate, leading to the small r^2 value as well as the marginal significance. In the revised manuscript we will acknowledge these factors more explicitly so as not misrepresenting the strength of the relationship, revising the text as follows.

Original Text: In addition to these edaphic controls, we also observed an association between increasing yields and increasing MAOM-C content. Linear regression analysis indicated that as mean yield within a stability zone increased, so did MAOM-C ($p = 0.048$, r2 = 0.08; Supplemental Fig. 5). This finding mirrors recent studies that support causal linkages between increasing productivity and increased MAOM-C (Prairie et al., 2023; King et al., 2023; Hansen et al., in-revision).

Revised Text: In addition to these edaphic controls, we also observed an association between increasing yields and increasing MAOM-C content. Linear regression analysis indicated that as mean yield within a stability zone increased, so did MAOM-C. This relationship was weak, likely reflecting the influence of cropping system, soil physicochemical properties, and climate on variability in MAOM-C and yield ($p = 0.048$, r2 = 0.08; Supplemental Fig. 5). However, this result does mirror recent studies that support causal linkages between increasing productivity and increased MAOM-C (Prairie et al., 2023; King et al., 2023; Hansen et al., in-revision).

COMMENT: About the Figure 6. This figure summarizes, to some extent, the results of this experiment. It is nice. Note, however, that at a first glance, it is a bit unconsistent with some of the results mentioned before. For instance: POM-C is, apparently, the most relevant factor in determining Yield stability. Nevertheless, the previous text (lines 274-276, also the following ones) rather suggests that the relationship between POM-C and yield stability is unclear. The key is, perhaps, the sentence(s) 'POM-C content in unstable zones was significantly higher than in all stable zones ($p = 0.019$), which had the same POM-C content independent of yields (Fig. 2C)' (lines 273-274), which suggest rather a negative relationship: POM-C relates negatively to yield stability. In line 284 you state 'we did not observe evidence that POM-C conferred additional stability to cropping systems'. But perhaps the key is in your further sentences (lines 285 and following) that rather suggest that POM-C relates indirectly to yield stability. The reasons that make unstable the crop yield have, as a secondary result, the accumulation of POM (if I well understood). However the heading of figure 6 ('Relative importance of variables in determining yield stability zones') rather suggests that you see POM-C as a cause of yield stability. May Figure 6 give an inexact view about your results? Is there any way to distinguish between 'likely causes' and 'likely consequences' of yield unstability?

RESPONSE: Yes, the referee is correct about this interpretation of the results relating POM-C concentrations to yield stability zone. While our initial hypothesis was that increasing POM-C would lead to increased yield stability, we found instead that unstable zones had significantly higher POM-C than any stable zone, regardless of yield. Our interpretation of these results is consistent with the referee's understanding—the conditions that lead to yield instability and annual fluctuations in yield are also conditions that would lead to the preservation of POM in these areas (i.e., anoxic soil conditions, increased residue inputs). The results presented in figure 6 are the relative importance of variables in predicting whether a zone would be stable or not via a Random Forest (RF) model. The values are computed based on the number of times a given variable is used to split nodes within an RF model, with higher values indicating more influence on the prediction outcome. The referee makes a good point that the figure caption and title could be misleading. In our revision we will reword the caption by replacing "determining," such that it does not refer to a causal mechanism (see below).

COMMENT: An additional detail: because all bars are given in a left-right orientation, it is not possible to distinguish between factors that affect (or are related) positively to yield stability, and those that affect (or are related) negatively to yield stability (which would be the case of POM-C, by the way). Would it be possible to distinguish them? For instance: perhaps the factors that affect negatively could be in the right-left orientation?

RESPONSE: Unfortunately, unlike linear models that have positive and negative coefficients that indicate the direction of a relationship, the variable importance metric does not have an inherent directionality. As detailed above, it instead reflects the structure of the RF model. We will change the figure caption to make this explicit upon revision as detailed below.

Original Text: Figure 6 – Relative importance of variables in determining yield stability zones as determined by the gradient boosted random forest model employed here. Relative importance represents the average of the feature importance over the course of 1000 model iterations. (POM: Particulate organic matter… GDD: Growing degree days).

Revised Text: Figure 6 – Relative importance of variables in predicting yield stability zone as determined by the gradient boosted random forest model employed here. Relative importance represents the average of the feature importance over the course of 1000 model iterations and does not imply a directionality or causal linkage. (POM: Particulate organic matter… GDD: Growing degree days).

FIGURES

COMMENT: Figure 2. Just a question. I observed that the several points for a given 'Stability Zone' are not aligned horizontally. Is this deliberate, to facilitate a good view of these points (thus avoiding their superposition), or does this lack of alignment reflect some property of the points' sets?

REPSONSE: Yes, the "jittering" of the points was done to avoid excessive overall and improve readability of the figure. We will revise the figure caption as follows to make this explicit.

Original Text: Figure 2 – Normalized concentrations of total soil organic carbon (SOM-C) (a.), mineral associated organic matter carbon (MAOM-C) (b.), and particulate organic matter carbon (POM-C) (c.) among the various stability zones. Different colored points represent different farms. To account for edaphoclimatic differences among farms, we scaled all data using z-scores prior to analysis, with the mean and standard deviation calculated at the farm level, yielding a unitless metric to compare by. Different lower-case letters indicate significant differences ($p < 0.05$).

Revised Text: Figure 2 – Normalized concentrations of total soil organic carbon (SOM-C) (a.), mineral associated organic matter carbon (MAOM-C) (b.), and particulate organic matter carbon (POM-C) (c.) among the various stability zones. Different colored points represent different farms. To account for edaphoclimatic differences among farms, we scaled all data using z-scores prior to analysis, with the mean and standard deviation calculated at the farm level, yielding a unitless metric to compare by. Different lower-case letters indicate significant differences ($p < 0.05$). Points are offset horizontally to improve readability of the plot.

COMMENT: Figure 5. Should be improved. I noticed that, in the small icons, there is an area in light violet colour, and another in a blue-greenish colour. The relative area of each one changes. I deduce that the blue-greenish means 'unfair condition', but it is not clear. The legend of the figure does not say anything about it: the meaning of these two colours should be added to the legend, otherwise the precise meaning of the figure remains unclear. Besides this problem, these small icons may be impossible to read in a printed version: would it be possible to enlarge them a bit?

RESPONSE: This is a wonderful point, and one we did not consider during the initial iteration of this figure. We will update the figure in the revised manuscript to include a legend for the conditions within the icon boxes that makes the interpretation explicit. We will also increase the size of the icons and text throughout the figure to improve the readability of the figure, especially when printed.

COMMENT: Figure 6. Nice figure. That said, please correct 'Mehlic' to 'Mehlich'. See also my previous comments about this figure, which perhaps summarizes the whole results of this paper.

RESPONSE: We appreciate the reviewer pointing out this typo, and will fix it upon revision. In addition, please see our response above in further reference to this figure.

REFERENCES

COMMENT: The following cites are missing from the 'references' section:

Castellano et al 2015

Just et al 2023

King et al 2023

Prairie et al 2023

Van oost and Six 2023

RESPONSE: We apologize for the oversight and will ensure that the references section is complete upon revision. The citations for the papers the referee indicated will be added and are listed here:

Castellano, M. J., Mueller, K. E., Olk, D. C., Sawyer, J. E., and Six, J.: Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept, Glob Change Biol, 21, 3200–3209, https://doi.org/10.1111/gcb.12982, 2015.

Just, C., Armbruster, M., Barkusky, D., Baumecker, M., Diepolder, M., Döring, T. F., Heigl, L., Honermeier, B., Jate, M., Merbach, I., Rusch, C., Schubert, D., Schulz, F., Schweitzer, K., Seidel, S., Sommer, M., Spiegel, H., Thumm, U., Urbatzka, P., Zimmer, J., Kögel-Knabner, I., and Wiesmeier, M.: Soil organic carbon sequestration in agricultural long-term field experiments as derived from particulate and mineral-associated organic matter, Geoderma, 434, 116472, https://doi.org/10.1016/j.geoderma.2023.116472, 2023.

King, A. E., Amsili, J. P., Córdova, S. C., Culman, S., Fonte, S. J., Kotcon, J., Liebig, M., Masters, M. D., McVay, K., Olk, D. C., Schipanski, M., Schneider, S. K., Stewart, C. E., and Cotrufo, M. F.: A soil matrix capacity index to predict mineral-associated but not particulate organic carbon across a range of climate and soil pH, Biogeochemistry, https://doi.org/10.1007/s10533-023-01066-3, 2023.

Prairie, A. M., King, A. E., and Cotrufo, M. F.: Restoring particulate and mineral-associated organic carbon through regenerative agriculture, Proceedings of the National Academy of Sciences, 120, e2217481120, https://doi.org/10.1073/pnas.2217481120, 2023.

Van Oost, K. and Six, J.: Reconciling the paradox of soil organic carbon erosion by water, Biogeosciences, 20, 635–646, https://doi.org/10.5194/bg-20-635-2023, 2023.