Response to comments and suggestions from Reviewer 2

This paper proposes a proximal and remote sensing data harmonisation framework for input into a Self-organizing map (SOM)-based classification for determining field management zones. It is worthy of publication once the following points are considered and addressed.

We thank the reviewer for the positive evaluation. In the following, we describe how we have addressed the points raised by the reviewer.

1. Materials/Methods: The four sub-sections of section 2.2 need re-ordering to demonstrate the workflow: (1) EMI/EC data, (2) RS/NDVI data, (3) Yield data, (4) Soils data. As only the first two are inputs for the SOM/MCASD clustering. The second two are used to 'validate' and refine the clusters.

We thank the reviewer for this helpful suggestion. We agree that reordering the subsection in Section 2.2 improves the clarity and logical flow of the methodology, particularly in distinguishing between input data for clustering (EMI, NDVI) and data used for validation and refinement (yield, soil). We have revised the manuscript accordingly by placing the subsections in the suggested order.

2. Materials/Methods: A table would be useful to summarise each of these four datasets and their use in the study. The table can list: (a) the period of collection (e.g., 2011-19 for yield data); (b) whether the patchCROP experiment was in operation or not, (c) data processing steps taken (e.g. kriging or some other interpolation, normalisation etc. – see also that stated in section 3), and (d) whether used for SOM/MCASD inputs or used for the (ANOVA-based) validation of SOM clusters (with subsequent merging of clusters) etc.

We thank the reviewer for this very helpful suggestion. We agree that summarizing the role and processing of the four datasets enhances clarity. In response to a similar suggestion from Reviewer 1, we have added a workflow diagram (Figure 2 in the manuscript, Figure R1 below) that provides an overview of all data sources, their processing steps, and their roles in both the clustering and validation stages. We believe this figure addresses the intent of the suggested table in a more integrated and visual format, and improves the overall readability of the Materials and Methods section.

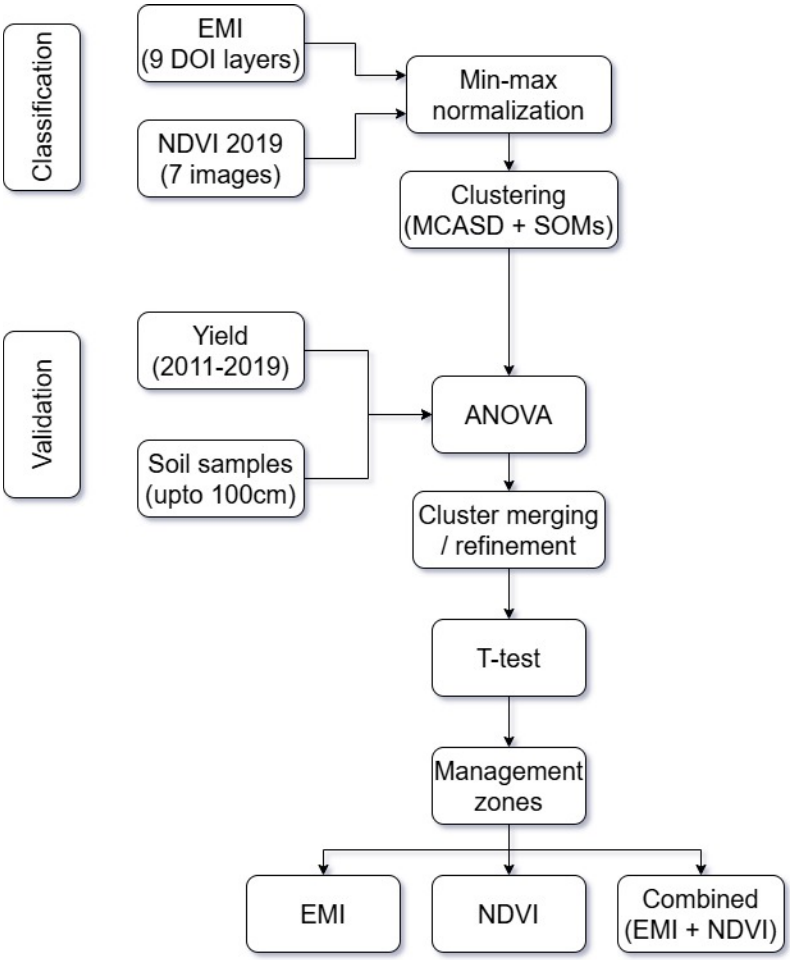

Figure R1. Summary of workflow showing the integration of proximal (EMI) and remote sensing (NDVI) data for unsupervised clustering using MCASD and SOMs. Yield and soil datasets were used for post-hoc validation and refinement of management zones.

3. Results: Maps and workflow narratives should be in this order: (1) EMI/EC data (Figs. 3, 4), (2) RS/NDVI data (Fig. 5), (3) Yield data (Fig. 2), (4) Soils data graphic (new), (5) SOM/MCASD clustering maps of EMI/RS plus refinements via yield/soils (Fig. 6).

We thank the reviewer for this helpful recommendation regarding the logical flow of the Results section. We agree that reordering the narrative and associated figures to match the data processing workflow enhances clarity. As suggested, we have revised the Results section to follow this order: (1) EMI/ECa maps, (2) NDVI maps, (3) Yield data, and (4) SOM/MCASD clustering and refinement maps.

We decided not to add a new figure presenting the soil data, as we prefer to present them as part of the validation of the zonation.

4. Limitations: When describing the caveats to the methodology (section 3.5), refer to the new Table suggested in (2) for challenges due to different data collection timeframes, patchCROP, data processing, etc.

We thank the reviewer for this observation. The methodological caveats related to differences in data collection timeframes, patchCROP implementation, and dataset-specific processing steps are already discussed in the Limitations section (Lines 668–690). While we did not include a table as initially suggested, we opted to incorporate a workflow diagram (Figure X), which summarizes the sequence and role of each dataset. We believe that the combination of this figure and the existing discussion adequately addresses the reviewer's concern.

5. Limitations: What would be the likely consequences of using free, 10m resolution imagery from sentinel 2 say, to that used with the 3m resolution of Planetscope for the NDVI data?

We thank the reviewer for raising this interesting point. The 3 m spatial resolution of PlanetScope imagery provided a more detailed representation of within-field variability, which was essential for our study's goal of delineating high-resolution management zones. In contrast, using 10 m resolution data from Sentinel-2 would likely result in a less detailed representation of the horizontal heterogeneity in NDVI, which could obscure narrow or patchy features, especially in highly heterogeneous fields like that of this study. This could reduce the sensitivity of the clustering algorithm to subtle spatial transitions and affect the precision of zone delineation. However, for larger fields or regions with less spatial variability, Sentinel-2 could be a valuable, freely available alternative. We have now included these considerations in section 3.5 (lines 685-693). The new text reads:

"Similarly, the NDVI dataset was limited to the 2019 growing season due to the availability of PlanetScope imagery, which became accessible for this field only in 2019. The choice of PlanetScope imagery (3 m resolution) enabled to capture detailed within-field variability in NDVI, which was particularly important in our study area due to the spatial heterogeneity introduced by soil variation and the patchCROP experiment. If coarser-resolution imagery such as Sentinel-2 (10 m) were used instead, smaller-scale patterns in crop development or soil-related variation would have been less detectable due to spatial averaging. This could reduce the effectiveness of the SOM clustering in identifying distinct management zones. However, for more homogeneous or large-scale fields, Sentinel-2 could be a practical and freely accessible alternative."

6. Limitations: More on the sensitivity of the SOM-based clusters and their refinements using yield and soil information – from no data available to that available here (as shown in rows 3 and 4 in Fig.6).

We thank the reviewer for raising this point. It is true that the availability of yield and soil data can influence the refinement of the SOM-based clusters. In our study, these datasets were used to validate and occasionally merge clusters that were not clearly different in terms of agronomic performance. While such validation improves the interpretability of the zones, we acknowledge that in cases where such data are not available or are sparse, the clustering process can still be applied—although some clusters may remain less interpretable. We have now included these considerations in section 3.5 (lines 709-716). The new text reads:

"The availability of yield and soil data supported the refinement of SOM-based clusters, enabling the merging of groups that were not agronomically distinct. These datasets helped to ensure that the final management zones were both data-driven and interpretable. However, in scenarios where such ground-truth data are limited or unavailable, the initial clusters may still offer useful insights, albeit with greater uncertainty in their agronomic interpretation. The post-hoc validation step adds confidence, but is not strictly required for the SOM-based clustering to be applied."

7. Limitations: For the clustering methods described (in the introduction) and the SOM method applied (p.6 to p.7) – none implicitly capture spatial effects, such as spatial autocorrelation. Further, the statistical analyses using ANOVAs/Tukey's HSD and t-tests are similarly non-spatial. What are the consequences of this? What methods could be applied for future work to investigate this?

We thank the reviewer for this thoughtful observation. It is true that the clustering and statistical validation methods used in this study do not explicitly consider spatial autocorrelation, which may influence both the clustering output and the interpretation of statistical significance. While our use of multi-year yield data and soil samples helped support the robustness of the final zones, we recognize that spatial dependence remains an important factor. We have now included a paragraph in the Limitations section suggesting that future work could apply spatially-aware clustering methods or spatial statistical approaches to better account for this aspect (Section 3.5, lines 715-725). The new text reads:

"Another aspect to consider is the spatial nature of the input datasets. The SOM algorithm and the statistical methods used in this study (ANOVA, Tukey's HSD, and t-tests) do not explicitly account for spatial autocorrelation, which is inherently present in interpolated geospatial datasets such as EMI, NDVI, and yield maps. This may influence statistical outcomes or lead to less spatially coherent clusters in some cases. However, the use of multi-year yield trends and high-resolution soil data helped reduce uncertainty in post-hoc validation. Future studies may benefit from incorporating spatially explicit methods, such as spatially constrained clustering, variogram-based diagnostics, or spatial ANOVA, to better account for spatial dependence during both classification and validation stages. In addition to these methodological considerations, future studies should focus on improving the temporal consistency of data collection and increasing the density and depth of soil sampling."

8. Limitations: Given all the above - something on the capture of uncertainty in the demarcation of the management zones for current and future work?

We thank the reviewer for raising this relevant point. While this study did not explicitly quantify uncertainty in the delineation of management zones, we agree that this represents an important direction for future work. A sentence has been added to the Limitations section 3.5 (lines 725-727) to acknowledge this. The new text reads:

"Future studies should also consider quantifying uncertainty in management zone delineation, for example through ensemble clustering or incorporating uncertainty from spatial inputs such as EMI interpolation."

9. Conclusion: More should be said on the choice made for the proximal sensing and the choice made for the satellite remote sensing. For the former, EMI/EC essentially does soil physics /

structure / water, while for latter, NDVI does crop health. This is OK but what of the alternatives? For example, using indices from radar-based missions (e.g., sentinel 1) rather than imagery based missions (e.g., sentinel 2). Insights on how the choice of sensors will ultimately affect the SOM/MCASD clustering and resultant management zones would be useful. For example, in some cases, the precision management of soil water may be more of a focus than the precision management soil nutrients – each requiring specific sensing technologies, etc. Essentially expand discussions in the introduction (p.5-6) and conclusions.

We thank the reviewer for this interesting point and we agree that the choice of sensing technology (e.g. optical, radar-based, or thermal imagery) can significantly influence the types of variability captured and the resultant management zones. It is also clear that the zones of management may depend on the type of management considered. However, we do not feel that a repetition of these points is fruitful in the conclusions. The objective of this study was to evaluate a harmonized, scalable workflow using widely available and well-established data sources: EMI for subsurface soil properties and NDVI for above-ground crop performance. Exploring the use of alternative sensors such as Sentinel-1 radar or hyperspectral imagery would indeed be valuable, but was beyond the scope of the present work. We prefer to not elaborated on this further in the conclusion section, as different sensors are now also addressed while discussing the limitations of the present study.

10. Consider changing the title to either: 'Combining Proximal and Satellite Remote Sensing Data for Improved Determination of Management Zones for Sustainable Crop Production' or 'Combining Electromagnetic Induction and Satellite Sensed NDVI Data for Improved Determination of Management Zones for Sustainable Crop Production' – the former is general, while the latter is specific.

We thank the reviewer for the helpful suggestions regarding the title. We agree that a more descriptive title improves clarity and scope. Accordingly, we have revised the title to: "Combining Electromagnetic Induction and Satellite-based NDVI Data for Improved Determination of Management Zones for Sustainable Crop Production." This title reflects the specific sensing methods used in our study and aligns with the reviewer recommendation.