# Soil health characteristics across a gradient of organic land-use intensity in Mid-Missouri

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## Background

- Missouri and the surrounding Midwestern region are frequently plagued by increasingly variable weather, from warming temperatures to precipitation extremes – conditions that are often interspersed with seasonal drought – leading to delayed planting and crop losses across the region.
- Also, the dominance of specialized crop and livestock farming systems resulted in the on-going regional loss of biodiversity [1], declines in organic matter and soil health [2], and greater nutrient losses to the environment [3,4].
- Thus, there is an urgent need for effective land use and management strategies to build resilience and adapt to changing climate conditions, and to mitigate the more severe outcomes while simultaneously delivering ecosystem services.
- A growing number of producers in the Midwest are grazing species-diverse pastures, which we hypothesize to improve resilience to extreme weather conditions through soil health improvement and other ecosystem services.
- Specifically, rotational grazing, also known as multi-paddock grazing, is management intensive climate-smart grazing that is purported to sequester carbon (C) in soils compared to other agricultural management systems [5].
- However, results from previous research investigating the potential for rotational or multi-paddock grazing to enhance soil C accrual and soil health have been inconclusive, and there is also a paucity of data from certified organic systems.

## Objective

- This work aims to evaluate soil microbial characteristics and labile C and N indicators of soil health under long-term (≥11-years ) contrasting organic pastures including specialty cropping systems of the Midwestern United States relative to a restored native prairie reference.
- We hypothesized that the rotationally grazed organic pastures and cover crop-based no-till specialty cropping systems have enhanced microbial communities and labile C and N indicators of soil health due to the presence of diverse plant species and absence of soil disturbance in these systems.

## Materials and Methods

### Study Site

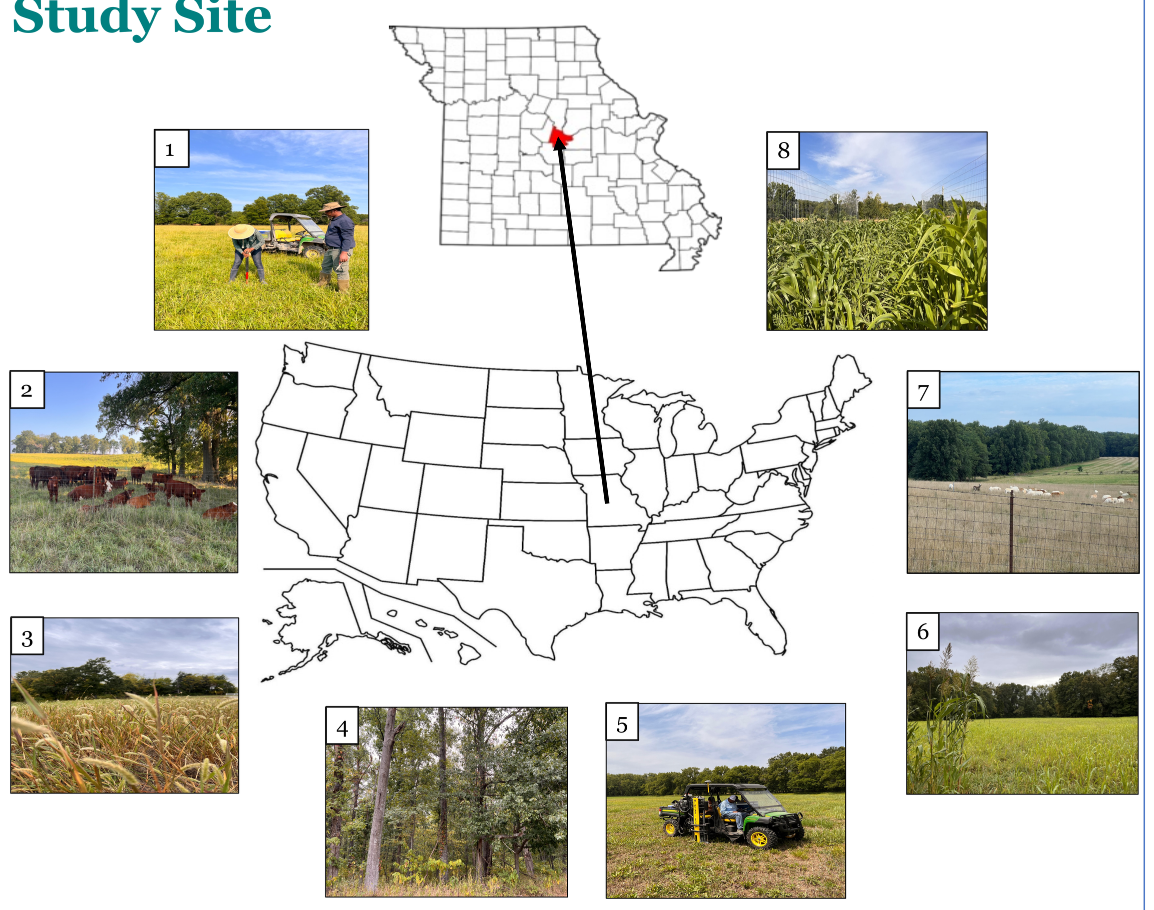

*Fig. 1. Location of the Alan T. Busby Organic Research Farm, Missouri, USA.*

### Experimental design and soil sampling

- Four management systems (annual cropping, rotationally grazed pasture, hayed pasture, silvopasture) located at Lincoln University Busby Organic Farm were compared against a restored native prairie reference.
- Across systems, a total of 11 fields representing contrasting land use types were sampled in fall 2021. Four sampling points were established within each field and sampled at 0-20 and 20-40 cm depth increments.
- Multiple soil health indicators were analyzed including soil organic C (SOC), total soil N, phospholipid fatty acids (PLFAs), permanganate-oxidizable C (POXC), and enzyme assays [6].

## Results

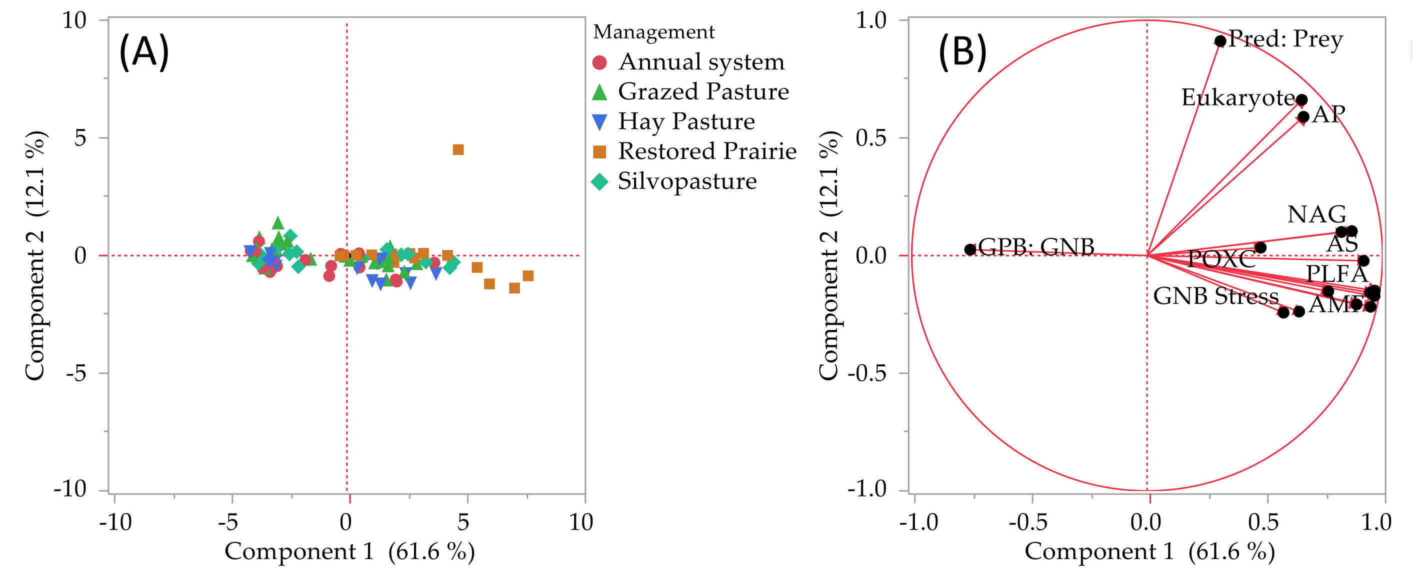


*Fig. 2. Principal component analysis (PCA) map of soil health indicators across five management systems representing contrasting organic land use types.*

- The PCA biplot shows that component 1 explained majority of variation (62%) in the whole dataset in the entire sampling depth (0-40 cm), with POXC, total PLFA, and aryl sulfatase showing close association (2B).
- The multicolored eigenvectors (2A) showed superimposed management systems, indicating similarity among sampled fields except for the native prairie field.

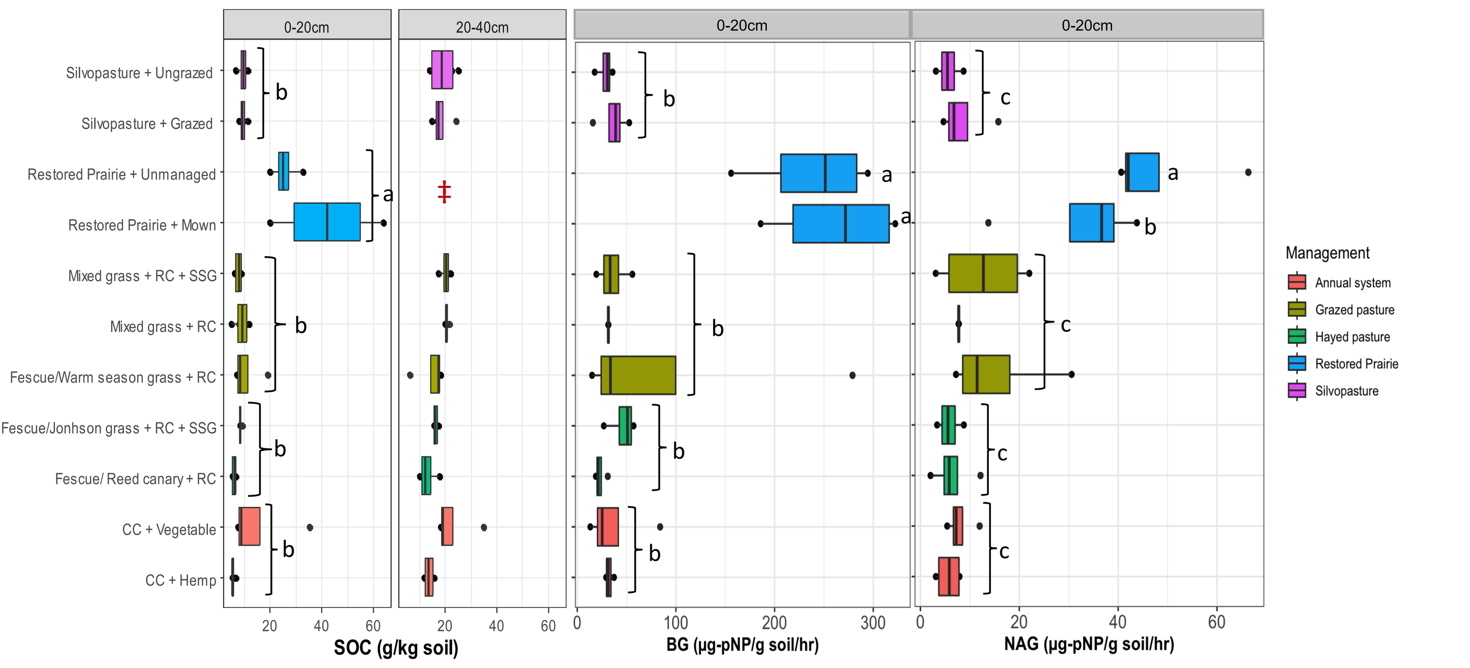


*Fig. 3. Soil organic C (SOC; left), β-glucosidase (BG; middle), and N-Acetyl β-D-glucosaminidase (NAG; right) as influenced by organic land management. ‡ = data unavailable.*

- In the 0-20 cm depth, SOC, BG and NAG were significantly higher in the restored native prairie fields compared to all other fields, with the latter being statistically similar to each other (Fig. 3).

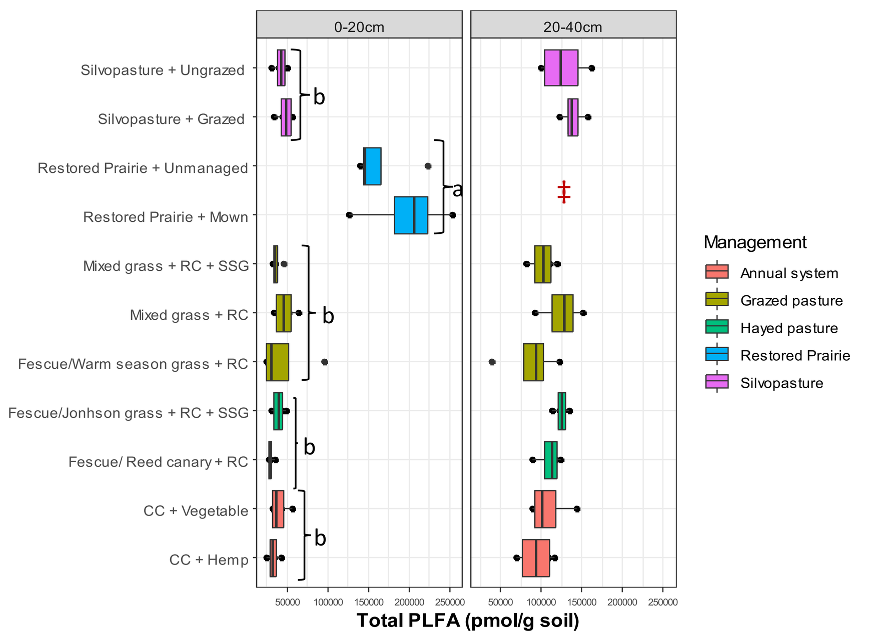


*Fig. 4. Total PLFA across the five contrasting organic land use types.*

- ‡ *Total PLFA, GPB:GNB ratio, GNB stress, AMF, and total data unavailable for the restored native prairie field at 20-40 cm depth.*

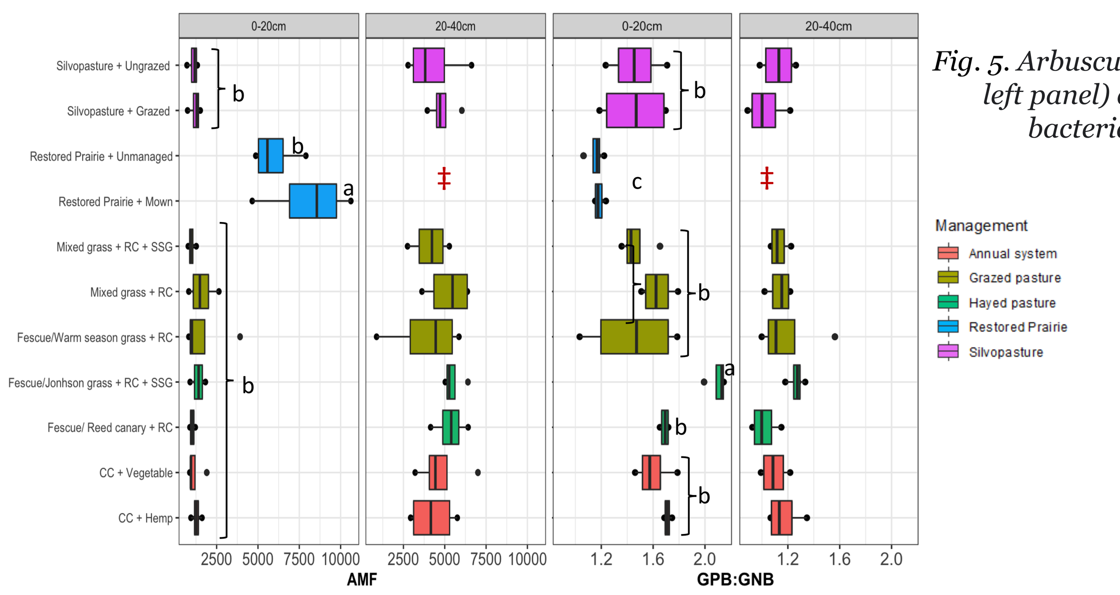


*Fig. 5. Arbuscular mycorrhizal fungi (AMF, left panel) and Gram(+) to Gram(-) bacteria ratio (right, panel).*

- Both total microbial biomass (as measured by the sum of total PLFA biomarkers; Fig. 4) and AMF (Fig. 5, left panel) values in the 0-20 cm depth were significantly higher under mowed restored prairie field than all other fields we sampled in this study.
- Hayed field with Johnson grass and sorghum sudangrass had the highest G+ to G- ratio at 0-20 cm depth, whereas restored prairie fields had the smallest ratio with all other fields being intermediate.

## Results

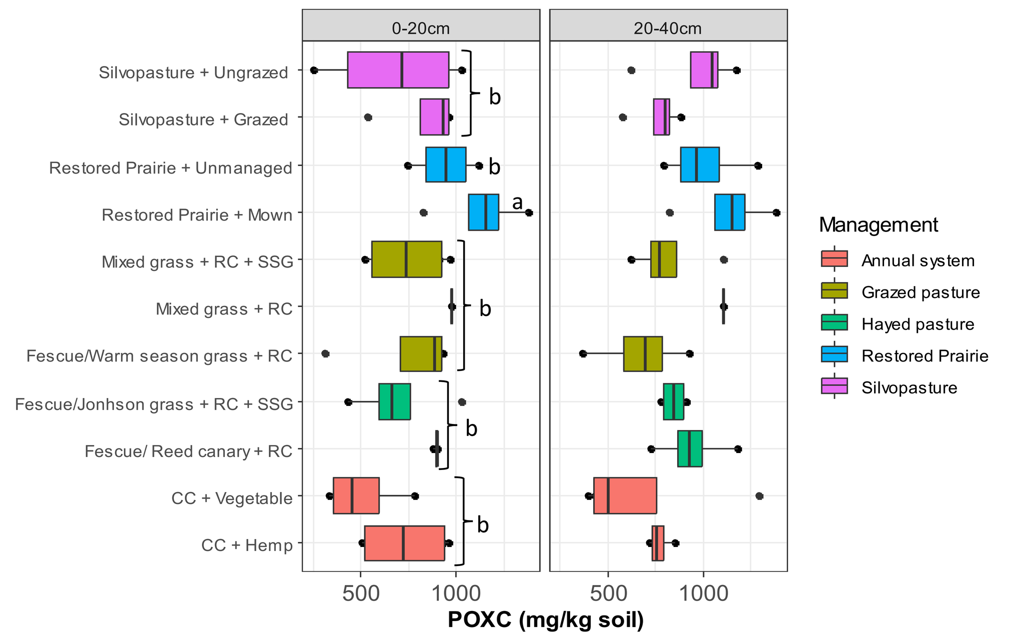


*Fig. 6. Permanganate oxidizable carbon (POXC) across organically-managed fields at two sampling depth.*

- Differences in POXC among the sampled fields followed very similar trends as those observed for the other soil parameters (e.g., SOC, total PLFA, AMF, SOC, β-glucosidase, and N-Acetyl β-D-glucosaminidase) in both sampling depths (Fig. 6).

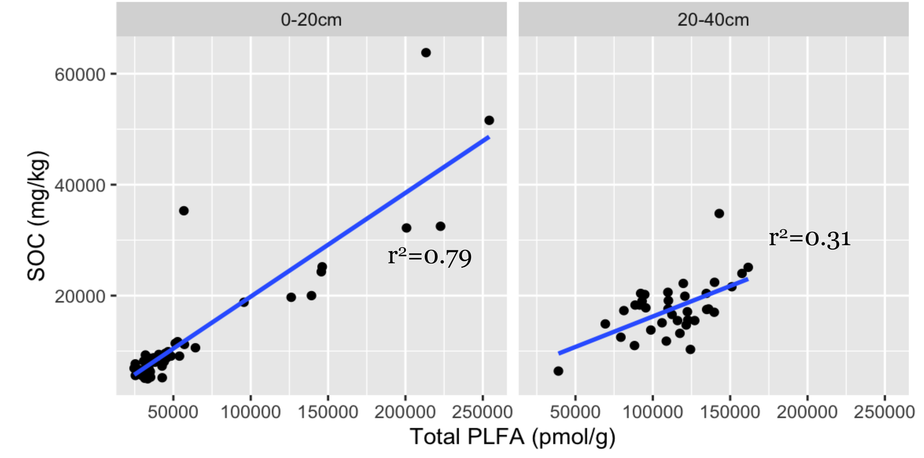


*Fig. 7. Relationship between SOC and PLFA by sampling depth across the entire dataset.*

- SOC and PLFA were positively and significantly related with $r^2$ values of 0.79 and 0.31 for 0-20 and 20-40 cm sampling depths, respectively.

**Table 1**. Coefficients of determination ($r^2$ values) between soil organic C (SOC) and total phospholipid fatty acids (PLFAs) versus enzyme assays in the 0-20 cm depth.

| Enzyme Assays | SOC vs. | PLFA vs. |
|---|---|---|
| β-glucosidase | 0.73*** | 0.86*** |
| N-acetyl-β-glucosaminidase | 0.50** | 0.70*** |
| Acid phosphatase | 0.37* | 0.53** |
| Aryl sulfatase | 0.69** | 0.83*** |

Signif. code: $P < 0.0001$ = ***; $P < 0.01$ = **; $P < 0.05$ = *.

## Summary and Discussion

- In this study, we did not find detectable differences in SOC, total PLFAs including some specific microbial group PLFA (e.g., AMF), POXC, and enzyme activities (β-glucosidase and N-Acetyl β-D-glucosaminidase) among the organic fields at either sampling depth except for restored native prairie fields, which had significantly higher values of these soil parameters compared to all the other fields (Figs. 3-6).
- However, the highest G+ to G- ratio we observed under a hayed field containing Johnson grass and sorghum sudangrass (Fig. 5, right panel) suggests stressful conditions in this field likely due to removal of the aboveground biomass.
- The significant correlations between SOC and microbial (i.e., total PLFA, AMF) and enzymatic (i.e., β-glucosidase, N-Acetyl β-D-glucosaminidase; Table 1 and Fig. 7) demonstrates the importance of microbiological tests for monitoring and assessing the influence of management practices on soil biological health in organic agroecosystems similar to the ones investigated in our study.
- Further research is warranted to better understand factors that contributed to the stressful conditions observed under hayed fields (as shown by the highest G+ to G- ratio; Fig. 5, right panel).

## References

1. Foley J.A., et al. 2005. *Science* 309(5734): 570-574.
2. Thaler, E.A., et al. 2021. *Proceedings of the National Academy of Sciences* 118(8): e1922375118.
3. Park S., et al. 2012. *Nature Geosciences* 5: 261-265
4. Sabo R.D., et al. 2019. *Journal of Geophysical Research: Biogeosciences* 124: 3104-3124.
5. Contosta, A.R., et al. 2021. Agriculture, Ecosystems and Environment 317 (2021) 107471.
6. Stott, D.E. (2019). Recommended Soil Health Indicators and Associated Laboratory Procedures. Soil Health Technical Note No. 450-03. U.S. Department of Agriculture, Natural Resources Conservation Service.

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