Kansas Soil Health Partnership

C.B. Pires, I.A. Ciampitti, D.A Ruiz Diaz, M.V.M Sarto, and C.W. Rice

Summary

This study was part of a farmer-led initiative that fosters transformation in agriculture through improved soil health, benefitting farmer profitability, supporting a stable food supply, and preserving the environment. This study's objective was to measure the effect of soil management strategies on the soil microbial community distribution and activity. Four farmers in Kansas were accepted into the program to conduct on-farm comparisons of a standard farm practice and an improved practice. This was ongoing research, and for this field research report, we are presenting the study at one of the selected farms. This site was located near Bucyrus, Miami County (38°44'30" N, 94°42'30" W, elevation: 1109 ft), with a Grundy silt loam. The improved practice was the incorporation of cover crops into a long-term no-till corn-soybean rotation. The experimental design was four replicated strips of the farmer standard practice and the improved practice. Soil samples were taken on a GPS coordinated grid at 0 to 2 inches soil depth before implementing the cover crops (baseline), and at the third year of the study. Soil biological health indicators included soil organic matter, soil microbial biomass, total fungi, total bacteria, and β-glucosidase (βG) activity. Soil organic matter and βG activity were compared between initial and third-year. Interpolated maps evaluated the spatial distribution of the soil microbial community. Two years of cover crops increased enzyme activity. Soil microbial biomass and soil organic matter were significantly ($P < 0.001$) correlated. Our results suggest that soil organic matter was a key driver of the spatial distribution of the soil microbial community.

Introduction

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (Doran and Zeiss, 2000; Lehmann et al., 2020). Healthy soils are critical for supporting crops, but also ecosystem services, such as climate regulation, nutrient cycling, flood regulation, carbon sequestration, water purification, and habitats for microorganisms (Rinot et al., 2019). Soil health includes soil attributes associated with the soil microbiome and the range of functions they perform (Doran et al., 1996). Promoting and monitoring soil health is the basis for sustainable agriculture. According to Karlen and Rice (2015), the most promising strategies to mitigate soil degradation are improving soil management practices, which improves soil health by enhancing soil biological activity and increasing soil organic matter. Soil microbial communities regulate carbon and nutrient cycling in soils. For agricultural soils, the use of cover crops may ultimately increase crop production, carbon sequestration, microbial biomass and activity, and soil health (Bonini Pires et al., 2020; Chavarría et al., 2016). With the purpose of testing different soil management practices, a Kansas soil health network was created between the Kansas State University Soil Microbial Agroecology Lab, Kansas Corn, and the Kansas Soil Health Partnership.

The partnership was a farmer-led initiative that fosters transformation in agriculture through improved soil health, benefitting farmer profitability, supporting a stable food supply, and preserving the environment. The objective of this study was to measure the effect of the farmer soil management practice and an improved practice on the soil microbial community distribution and activity.

Procedures

This research project was initiated in 2018 and conducted at four commercial farms across Kansas (Figure 1). This is ongoing research, and for this field report, we are presenting the study at one of the selected farms. This site was located near Bucyrus, Miami County (38°44'30" N, 94°42'30" W, elevation: 1109 ft), on a Grundy silt loam soil. This study consisted of two treatments: an improved practice, which was the addition of cover crops (CC) in a long-term no-till corn-soybean rotation; and the standard practice (NC) was the same rotation, without cover crops. The cover crop planted in 2018 was rye (broadcast), and in 2019 a mix of rye, oats, barley, peas, and vetch. The experimental design was four replicated strips of 6.5 acres each of the farmer's standard practice and the improved practice (Figure 2), for a total of 52 acres. Soil samples were taken on a 1-acre GPS coordinated grid at 0 to 2 inches depth before implementing the cover crops (baseline-2018) and at the third year of the study (2020). Soil samples for microbial properties were kept in a cooler (39°F) and frozen (-4°F) within 2 hours after sampling and stored until analysis. Samples for soil organic matter analysis were cleaned of roots, air-dried, ground, and sieved (2 mm). Soil organic matter (SOM) was analyzed by loss-on-ignition (LOI). Soil microbial community composition was assessed by phospholipid fatty acid analysis (PLFA). The PLFA was performed with modifications to the original procedure (White and Ringelberg, 1998). A total of 30 biomarkers were identified for all samples. Microbial groups were assigned based on characteristics of the biomarkers. Any PLFA abundance was reported as nmol per gram of dry soil (nmol PLFA g^{-1} soil). Total bacteria were the sum of Gram-positive bacteria, Gram-negative bacteria, and actinomycetes. Microbial biomass was the sum of all PLFA biomarkers. The Fungal:Bacterial ratio (F:B ratio) was total fungi divided by total bacteria. The βG activity was measured following a modified fluorometric method using fluorometric substrate 4-methylumbelliferone (Zeglin et al., 2013). Potential βG activity was reported as nanomoles activity per gram of dry soil per hour ($nmol^{-1}$ hr^{-1} g^{-1} soil). As ongoing research, no statistical analyses were performed. All figures presented in this field report are exploratory and preliminary.

Preliminary Results

Soil Microbial Community and Soil Organic Matter Spatial Distribution

Spatial patterns and drivers of soil microbial communities have not yet been well documented (Song et al., 2018); however, the spatial distribution of plants and soil chemical properties have been documented for a long period. Technological advances in precision agriculture have made soil mapping an economically feasible practice for farmers in the last couple of decades. Global positioning system (GPS) equipped machinery allows the collection of georeferenced data, which can generate maps via several interpolation techniques when coupled with a geographic information system (GIS). The interpolated soil microbial community maps (Figure 3A, 3B, and 3C) suggest a correlation between soil microbial biomass, total fungi, and total bacteria, hereinafter referred to as soil microbial community with soil organic matter (Figure 4). This correlation was

confirmed through a simple linear regression between soil microbial biomass and soil organic matter, which had a *P*-value < 0.001 and coefficient of determination (R^2) of 0.43 (Figure 5). Overall, all microbial groups had a similar spatial distribution. Likewise, F:B ratio (Figure 3D) had a similar spatial pattern of their base microbial groups. Intensively managed agricultural soils often have lower F:B biomass ratios compared to more extensively managed soils due to tillage, high rates of fertilization, and decreasing C:N ratio favoring bacteria (Sinsabaugh et al., 2013). A higher F:B ratio is linked to an increased abundance of fungi in the soil, which indicates a higher carbon storage potential and greater aggregations (Malik et al., 2016).

Soil Organic Matter

Soil organic matter is the key driver to improved soil health, to increase yields, and minimize environmental damage (Oldfield et al., 2019). Thus, SOM is crucial to conserve, regenerate, and increase productive soils' resilience. The use of conservation practices such as cover crops, one of the mainstays of conservation agriculture (Pittelkow et al., 2015), is essential to increase SOM and enhance microbial diversity and activity. Although still preliminary, our results indicate a slight increase in SOM levels for the cover crop treatment when comparing the baseline and third-year data (Figure 6). The SOM remained unchanged for the no cover crop treatment.

β-Glucosidase Activity

β-Glucosidase is a hydrolytic enzyme linked to the soil carbon cycle (Bonini Pires et al., 2020). For these reasons, βG has been used as an indicator of soil health due to its rapid response to soil management changes. Our preliminary results had increased βG activity for the CC treatment compared with NC (Figure 7). The cover crop residue is likely to have increased βG activity. Shifts in βG activity in response to management changes have been reported previously in different systems (Sarto et al., 2020), highlighting the sensitivity of enzyme activity as a soil health indicator.

Final Considerations and Next Steps

This study is part of a 5-year on-farm soil health project. The ultimate goal is to generate data-driven recommendations that Kansas farmers can use to improve their farms' productivity and sustainability. With our still-growing georeferenced dataset, we will also evaluate the effect of soil health on crop yield and develop strategies to mitigate yield-limiting factors while increasing soil resilience.

References

Bonini Pires, C.A., Amado, T.J.C., Reimche, G., Schwalbert, R., Sarto, M.V.M., Nicoloso, R.S., Fiorin, J.E., Rice, C.W., 2020. Diversified crop rotation with no-till changes microbial distribution with depth and enhances activity in a subtropical Oxisol. Eur. J. Soil Sci. 71, 1173–1187. https://doi.org/10.1111/ejss.12981.

Chavarría, D.N., Verdenelli, R.A., Serri, D.L., Restovich, S.B., Andriulo, A.E., Meriles, J.M., Vargas-Gil, S., 2016. Effect of cover crops on microbial community structure and related enzyme activities and macronutrient availability. Eur. J. Soil Biol. 76, 74–82. https://doi.org/10.1016/j.ejsobi.2016.07.002.

Doran, J.W., Sarrantonio, M., Liebig, M.A., 1996. Soil Health and Sustainability, in: Advances in Agronomy. pp. 1–54. https://doi.org/10.1016/S0065-2113(08)60178-9.

Doran, J.W., Zeiss, M.R., 2000. Soil health and sustainability: managing the biotic component of soil quality. Appl. Soil Ecol. 15, 3–11. https://doi.org/1_107.

Karlen, D.L., Rice, C.W., 2015. Soil degradation: Will humankind ever learn? Sustain. https://doi.org/10.3390/su70912490.

Lehmann, J., Bossio, D.A., Kögel-Knabner, I., Rillig, M.C., 2020. The concept and future prospects of soil health. Nat. Rev. Earth Environ. 1, 544–553. https://doi.org/10.1038/s43017-020-0080-8.

Liu, H., Carvalhais, L.C., Rincon-Florez, V., Crawford, M., Dang, Y.P., Dennis, P.G., Schenk, P.M., 2016. One-time strategic tillage does not cause major impacts on soil microbial properties in a no-till Calcisol. Soil Tillage Res. 158, 91–99. https://doi.org/10.1016/j.still.2015.12.007.

Malik, A.A., Chowdhury, S., Schlager, V., Oliver, A., Puissant, J., Vazquez, P.G.M., Jehmlich, N., von Bergen, M., Griffiths, R.I., Gleixner, G., 2016. Soil fungal: Bacterial ratios are linked to altered carbon cycling. Front. Microbiol. 7, 1–11. https://doi.org/10.3389/fmicb.2016.01247.

Oldfield, E.E., Bradford, M.A., Wood, S.A., 2019. Global meta-analysis of the relationship between soil organic matter and crop yields. SOIL 5, 15–32. https://doi.org/10.5194/soil-5-15-2019.

Pittelkow, C.M., Linquist, B.A., Lundy, M.E., Liang, X., van Groenigen, K.J., Lee, J., van Gestel, N., Six, J., Venterea, R.T., van Kessel, C., 2015. When does no-till yield more? A global meta-analysis. F. Crop. Res. 183, 156–168. https://doi.org/10.1016/j.fcr.2015.07.020.

Rinot, O., Levy, G.J., Steinberger, Y., Svoray, T., Eshel, G., 2019. Soil health assessment: A critical review of current methodologies and a proposed new approach. Sci. Total Environ. 648, 1484–1491. https://doi.org/10.1016/j.scitotenv.2018.08.259.

Sarto, M.V.M., Borges, W.L.B., Bassegio, D., Pires, C.A.B., Rice, C.W., Rosolem, C.A., 2020. Soil microbial community, enzyme activity, C and N stocks and soil aggregation as affected by land use and soil depth in a tropical climate region of Brazil. Arch. Microbiol. https://doi.org/10.1007/s00203-020-01996-8.

Sinsabaugh, R.L., Manzoni, S., Moorhead, D.L., Richter, A., 2013. Carbon use efficiency of microbial communities: Stoichiometry, methodology and modelling. Ecol. Lett. https://doi.org/10.1111/ele.12113.

Song, M., Peng, W., Zeng, F., Du, H., Peng, Q., Xu, Q., Chen, L., Zhang, F., 2018. Spatial patterns and drivers of microbial taxa in a karst broadleaf forest. Front. Microbiol. 9. https://doi.org/10.3389/fmicb.2018.01691.

White, D.C., Ringelberg, D.B., 1998. Signature lipid biomarker analysis, in: University, O. (Ed.), Techniques in Microbial Ecology. Oxford University Press, New York, pp. 255–272.

Zeglin, L.H., Bottomley, P.J., Jumpponen, A., Rice, C.W., Arango, M., Lindsley, A., McGowan, A., Mfombep, P., Myrold, D.D., 2013. Altered precipitation regime affects the function and composition of soil microbial communities on multiple time scales. Ecology 94, 2334–2345. https://doi.org/10.1890/12-2018.1.

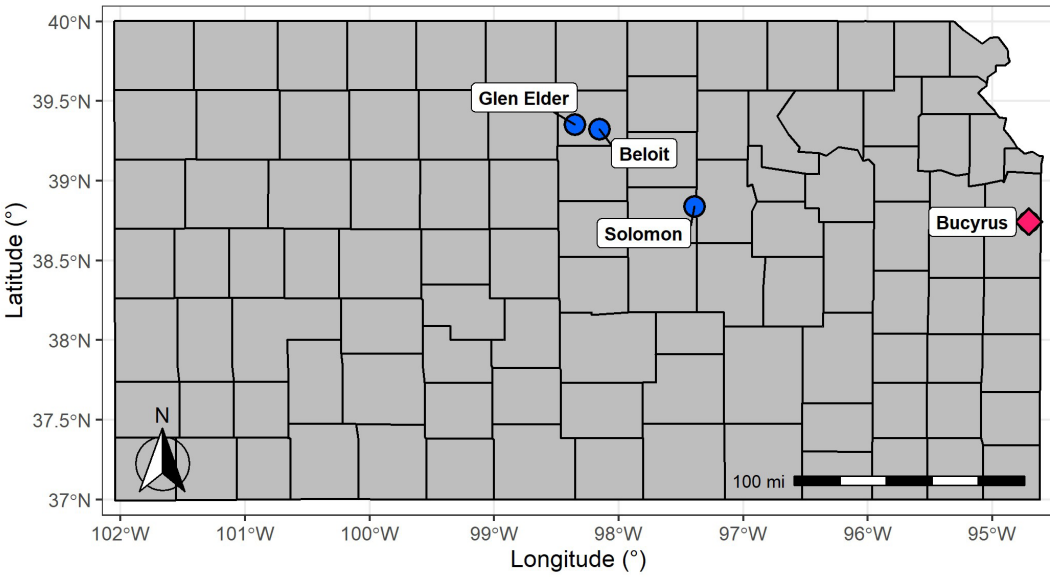

Figure 1. Kansas Soil Health Partnership Network.

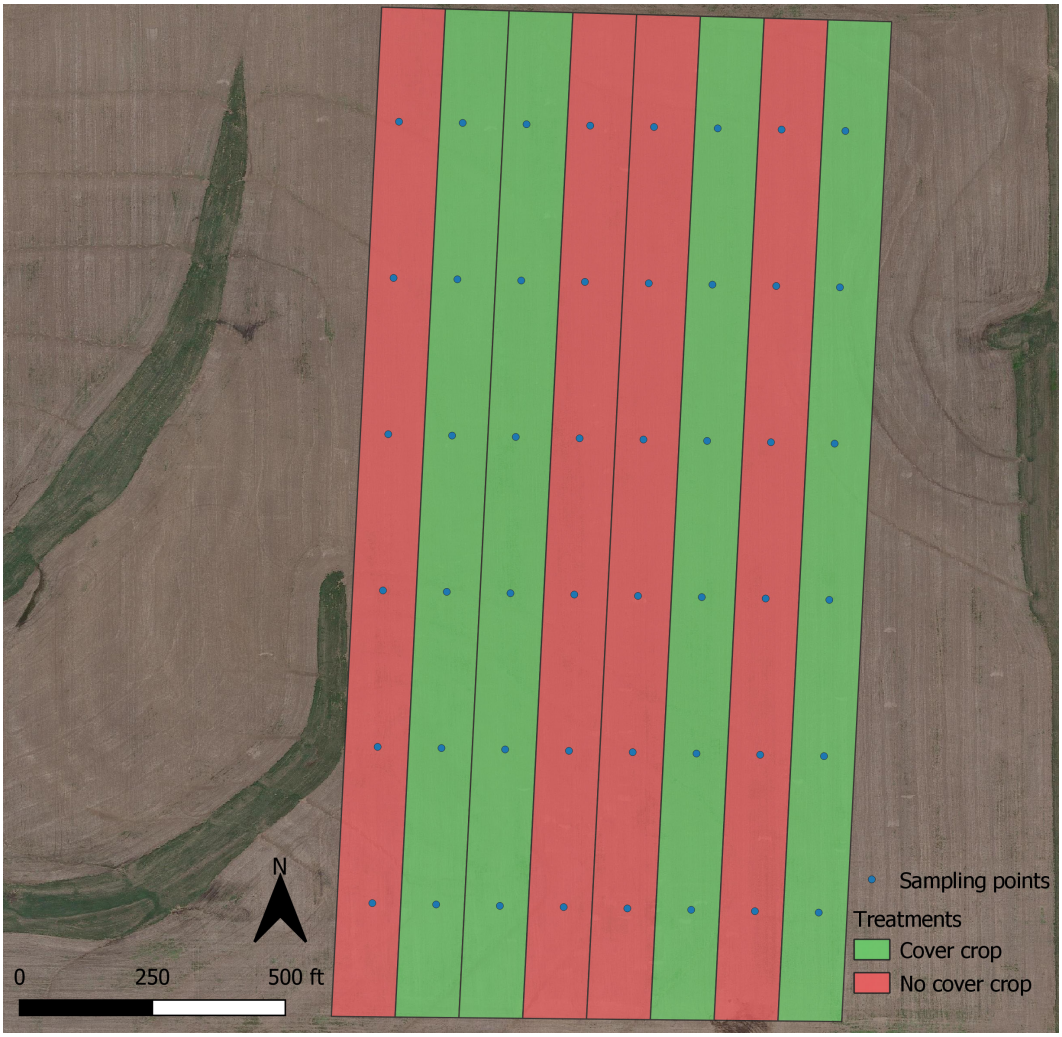

Figure 2. Experimental design and soil sampling scheme.

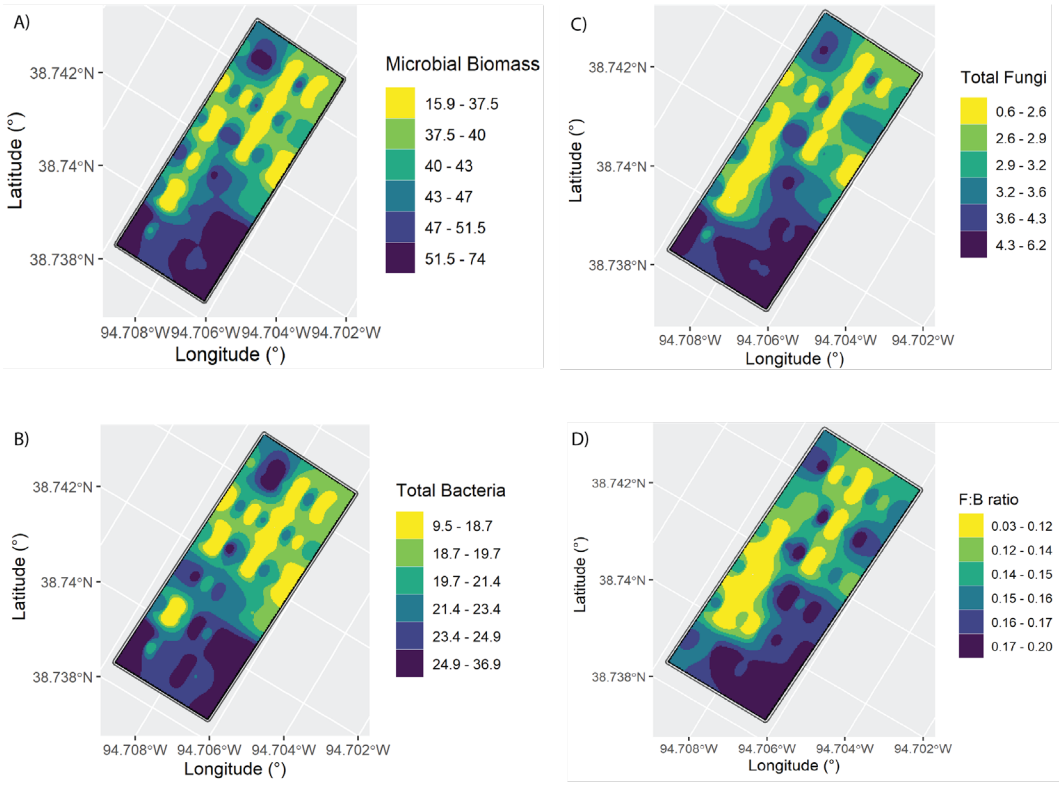

Figure 3. Spatial distribution: (A) microbial biomass, (B) total fungi, (C) total bacteria, and (D) fungal:bacterial ratio. Data are presented in nmol PLFA g^{-1} soil.

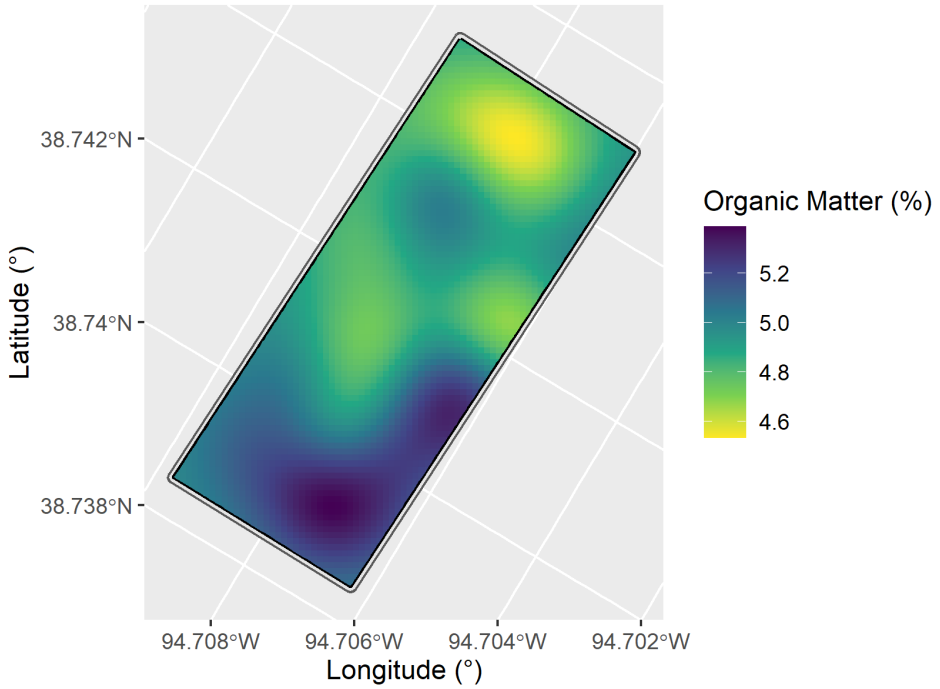

Figure 4. Soil organic matter spatial distribution.

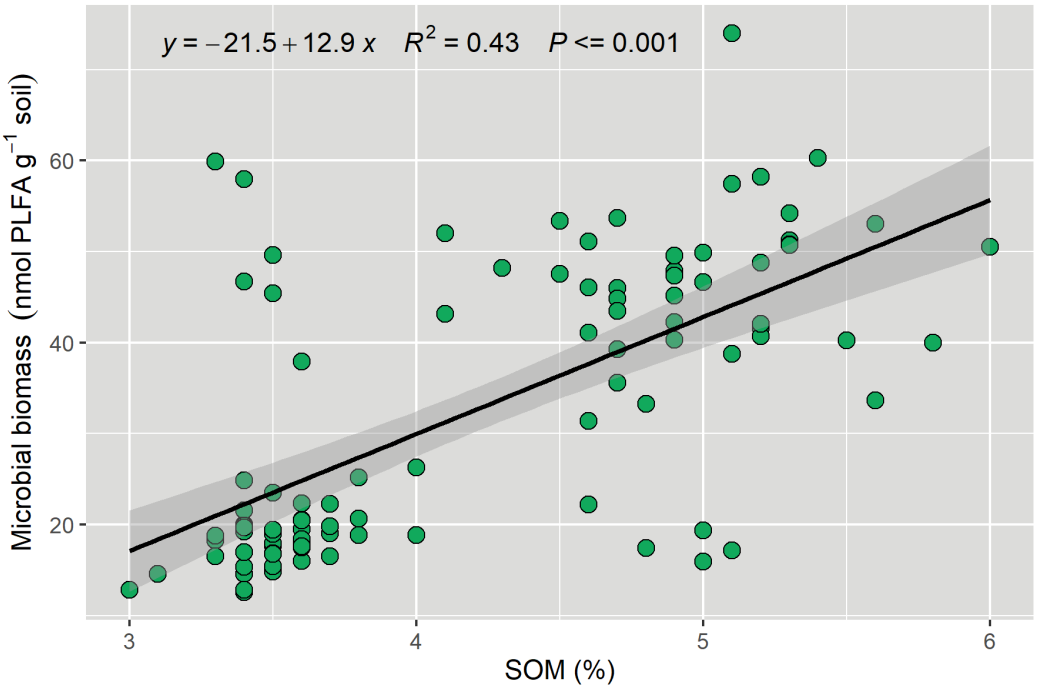

Figure 5. Linear regression between soil organic matter and microbial biomass.

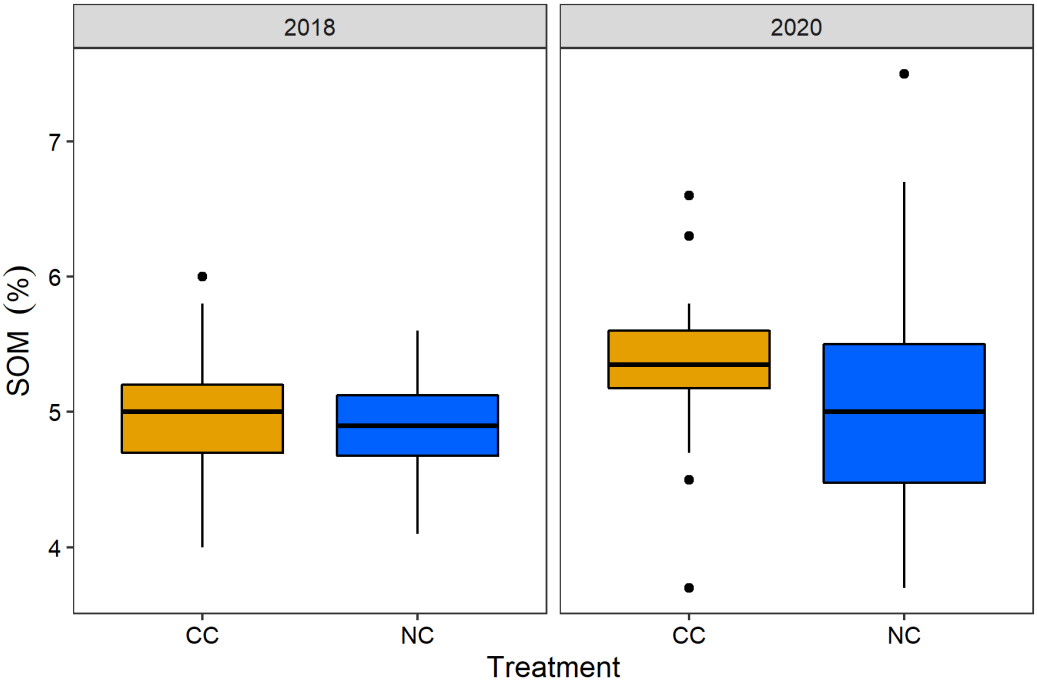

Figure 6. Soil organic matter by loss-on-ignition (LOI). CC = cover crops. NC = standard practice.

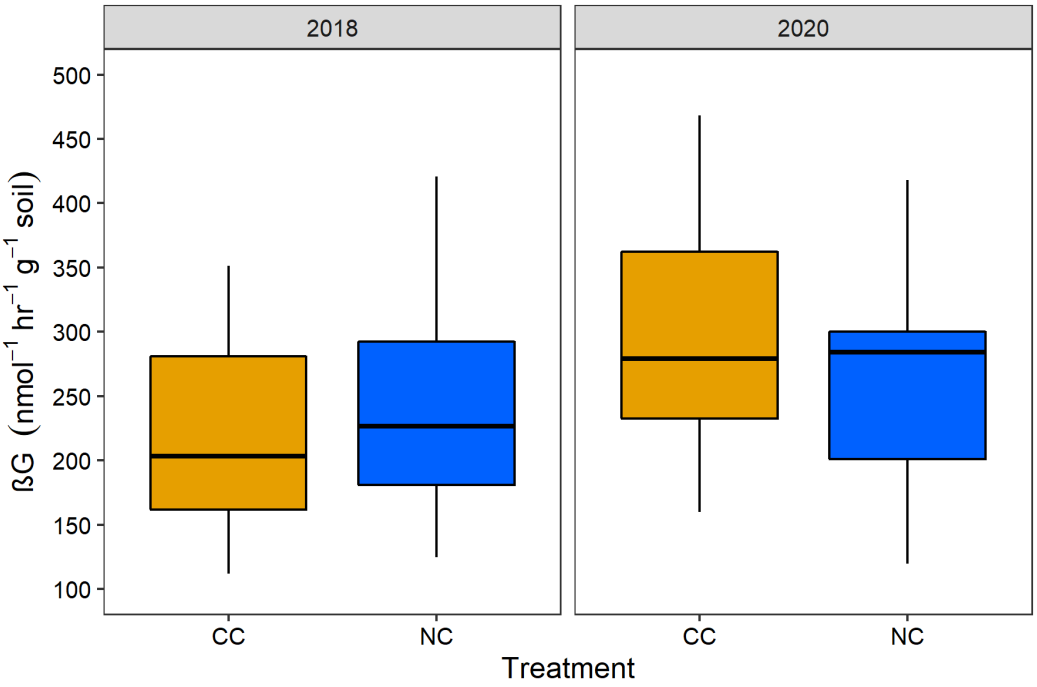

Figure 7. β-Glucosidase activity. CC = cover crops. NC = standard practice.