

Geospatial Modeling of Spatiotemporal Variability in Farm-Scale Soil Organic Matter Dynamics

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Background: Soil health impacts the land's ability to cycle nutrients, filter water, and produce crops (Natural Resources Conservation Service, 2024). One key measurable aspect of soil health is soil organic matter (SOM), which includes all decomposing remains of living things in the soil. SOM improves soil structure, water retention, and drought and heat tolerance, among other benefits (Lal, 2016).

Using models rather than soil surveys to map SOM can provide more precise and high-resolution mapping data (cite). Most digital SOM mapping so far focuses on the landscape or plot scale; this study works with the farm scale.

Research Question & Hypothesis:

Research Question: How well do geostatistical and machine learning models predict SOM with varying input sample sizes and spatial distributions over ten years?

Hypothesis: Geostatistical models will perform better because they factor in inherent spatial trends in soil properties. The accuracy of all models will be impacted by input soil sample dataset size and spatial distribution.

Preliminary Conclusions:

- **2021-2022 soil sample data** ($n \sim 570$, soil samples collected in 100-m grid) **led to more accurate model results than 2015 data** ($n \sim 100$, soil sample locations determined by conditioned Latin Hypercube Sampling).
- Half of the predicted absolute SOM change values fall between -10 and 0.58 g SOM / kg soil. Soil properties like SOM typically take more than ten years to show changes, so we expected values within <10 g/kg of 0 here (Paustian et al., 2019). Lower tillage intensity, earlier planting dates, and other changes could cause these SOM level changes (Paustian et al., 2019).

FOR FURTHER READING:

Natural Resources Conservation Service. (2024). Soil Health. <https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health>.

Paustian, K., et al. (2019). Quantifying carbon for agricultural soil management: from the current status toward a global soil information system. *Carbon Management*, 10(6), 567–587.

Heung, B., Saurette, D., & Bulmer, C. E. 2021. Digital Soil Mapping. In M. Krzic, F.L. Walley, A. Diochon, M.C. Paré, & R.E. Farrell (Eds.), *Digging into Canadian soils: An introduction to soil science* (pp. 463–517). Pinawa, MB: Canadian Society of Soil Science.

Lal, R. (2016). Soil health and carbon management. *Food and Energy Security*, 5(4), 212–222.

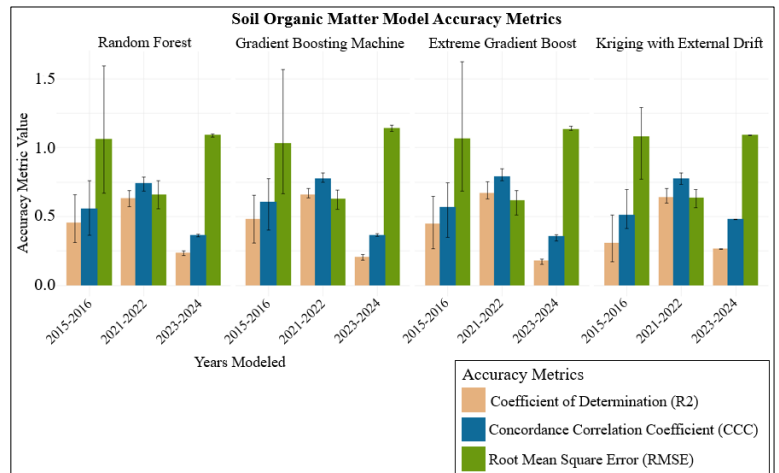


Figure 1. Accuracy metrics from three machine learning models (Random Forest, Gradient Boosting Machine, and Extreme Gradient Boost) and one geostatistical model (kriging with external drift). The models predict Purdue Agronomy Center for Research and Education (ACRE) SOM using soil sample data along with vegetation and soil index data from Sentinel-2 satellite imagery, topographic data derived from a digital elevation model, and soil drainage class data from the USDA NRCS soil survey.

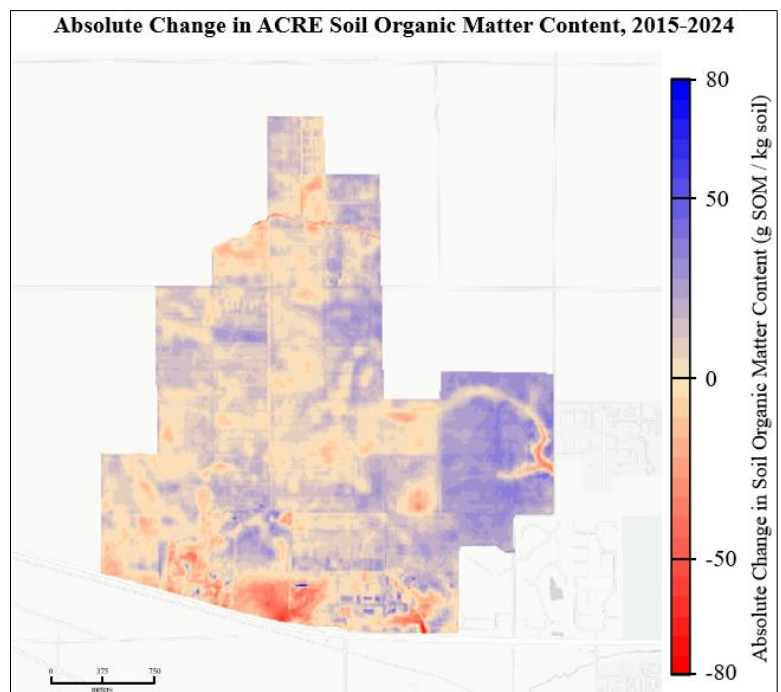


Figure 2. Map showing absolute change (g SOM / kg soil) in ACRE SOM from 2015-2024. 72.8% of ACRE area showed a decrease in SOM levels from 2015-2024, while 26.5% showed an increase and 0.7% showed no change.