Soil Health Gap between Cropland and Uncultivated Soil

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There is substantial interest in both quantifying and improving soil health. To assess soil health, scientists typically measure many soil properties that reflect the soil's ability to support plant growth. These include biological (e.g., enzymes secreted by microbes), chemical (e.g., soil organic matter), and physical (e.g., aggregation and infiltration) properties as described in The Soil Scoop, *Evaluating Soil Health and Quality*. This Soil Scoop describes both the Soil Health Gap - a method to evaluate land management on soil health - and ways to improve soil health.

THE SOIL HEALTH GAP

Because soil health is affected by soil texture and climate, there is no standard optimum that indicates soil health in the same way that we can identify an optimal blood pressure or body temperature for human health. For example, measures of soil health for a sandy soil in an arid region will almost always be lower than those for a silt loam in a wet region. Dry sandy soils produce less plant biomass, therefore they have lower soil organic matter and microbial activity, both measures of soil health.

To assess the effect of management on soil health, we need a relevant site- or property-specific benchmark of healthy soil. This can be provided by minimally disturbed land. We then compare the soil health of this minimally disturbed land with that of the cultivated, disturbed, hayed or grazed land. The difference is called the "Soil Health Gap" (Maharjan et al. 2020). The soil health gap tends to be the greatest on annual cropland largely because less residue is returned to the soil than on perennial grassland. It takes around 1.8 ton per acre of above ground residue per year to maintain soil organic matter levels in Northern Great Plains soils (Jones et al. 2022a).

To learn more about the Soil Health Gap in Montana soils, the top 6-inches of ten paired cultivated and uncultivated fields were sampled near both Forsyth and Fort Benton, Montana, in 2022 and 2023 (Ashford 2024). The uncultivated sites were dominantly intact perennial plant communities and had not been cultivated for at least the past two generations of farming.

The soil was analyzed for soil organic matter (SOM), POxC (a measure of bioavailable carbon), potentially mineralizable nitrogen (PMN), and five soil enzymes related to nutrient cycling. Enzyme activity was summarized as a mean of the five enzymes (Ashford 2024). The decline in these parameters, from uncultivated to cultivated soils, averaged across the ten pairings, was 39% for both SOM and POxC, 51% for PMN, and 59% for mean enzyme activity (Figure 1). In other Northern Great Plains research, the SOM Soil Health Gap averaged 42% (Liebig et al. 2006), similar to our findings.

The fields chosen for this study were from farms that use conservation farming practices, including no-till, crop rotations, leaving stubble on the field, and planting strips of perennials. We would expect the soil health gap to be larger on tilled, mono-crop, annual cropland. In the central Great Plains, SOM was 50% lower in cropland than nearby grasslands, and an additional 18% lower on tilled cropland (Maharjan et al. 2020).

To determine a Soil Health Gap, collect multiple 6-inch-deep soil samples (see The Soil Scoop *Soil Testing: Getting a Good Sample* for sampling instructions) from each of the paired locations - the managed area of interest and a similar, nearby, minimally disturbed site. It is important to closely match the aspect, slope, and soil series (using Web Soil Survey) of the paired locations to make for a comparison where only management is different.

It is difficult to find one or a few simple measures that characterize soil health; soil health parameters are numerous and often correlated. Soil organic matter has often been used as a proxy for soil health. It is more stable than PMN, POxC and enzyme activity, and takes years to respond to management change. Enzyme activity, PMN, and POxC are all more sensitive to change, even from year-to-year.

Recent research from the Soil Health Institute comparing 30 different measures across 124 sites across the U.S. recommends three measures that reflect soil health, are responsive to management practices, and are cost effective:

soil organic carbon (directly related to SOM), aggregate stability, and 24 h C mineralization (Bagnall et al. 2023).

One time soil health measurements are affected by natural year-to-year variations and do not tell us very much. However, tracking the soil health gap every five years over 15-20 years can identify how much soil health may improve with specific changes in field management.

IMPROVING SOIL HEALTH

Should farmers target the soil health measures of adjacent grassland as a standard? Not necessarily. The relatively low residue, especially belowground, of annual cropping systems makes it is nearly impossible to match soil health in an annual system with a perennial system or native grassland. Yet it should be possible to narrow the gap with the following practices:

- Replace summer fallow with a crop
- Grow cover crops
- Add perennials into an annual rotation or add perennial strips into fields
- Grow high residue crops such as cereals and maximize the amount of residue left in the field
- Use no-till
- Diversify crop rotations to increase variety of residue added to the soil
- Use practices that reduce soil acidification such as soil nitrate testing, grow low N need crops (e.g., pulses, malt barley, forages) and use reasonable yield goals to not over fertilize with N. See The Soil Scoops on soil acidification for more information.
- Use stocking rate, grazing intensity, livestock rotation and plant recovery time to promote healthy plant roots and no more than 50% forage removal. See the USDA's *Grazing Management and Soil Health – Montana* for more information.

For more information on the advantages of recrop over crop-fallow in Montana see Jones et al. (2022b). The MSU Extension bulletins *Cover Crops: Soil Health* and *Cover Crops: Management for Organic Matter and Nitrogen* provide information on how cover crops affect soil health.

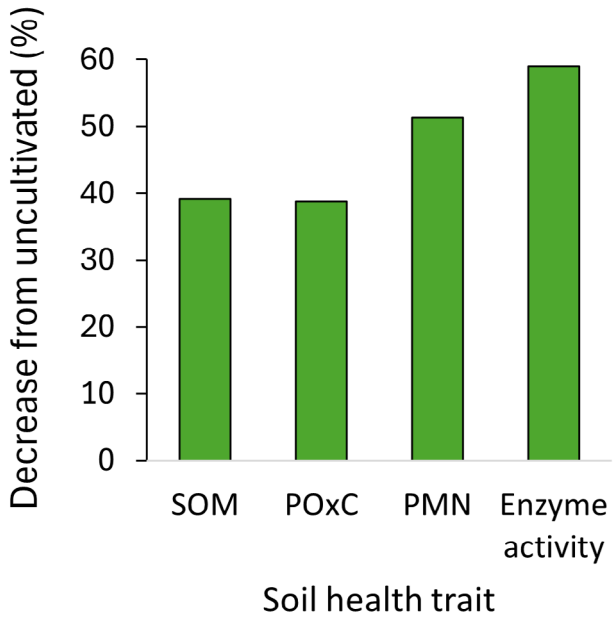

FIGURE 1. Percent decrease for all soil health traits between uncultivated and cultivated soils; soil organic matter (SOM), permanganate oxidizable carbon (POxC), potentially mineralizable N (PMN), and a mean of five enzymatic activities (Ashford 2024).

For more information and references:

The Soil Scoops are available at https://landresources.montana.edu/soilfertility/soilscoop.html

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