Building Soil Organic Matter

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Soil Organic Matter (SOM) is the fraction of the soil that consists of plant and animal residues in various stages of decomposition. It contains organic carbon and nitrogen. For soil microorganisms, such as fungi and bacteria, carbon is used as a source of energy whereas nitrogen is used as a source of protein. In healthy soils, the vast majority of soil microorganisms are beneficial or neutral and can help prevent organisms such as plant pathogens from becoming dominant.

SOM is important because it improves many physical, chemical, and biological characteristics of soil. When SOM is well-decomposed, it enhances biological activities in the soil, improves soil structure by increasing aggregation and aggregate stability, and slowly releases nitrogen and phosphorus, reducing the need for synthetic fertility amendments. Additional SOM benefits include increased ability of the soil to hold water, reduced erosion, stabilized (buffered) pH, and increased availability of micronutrients. A loss of SOM can lead to negative effects such as soil erosion, loss of fertility, compaction, and land degradation. Because SOM contains an average of 58% carbon by volume, building soil organic matter significantly contributes to carbon sequestration. Therefore, farming practices that increase amounts of SOM, or reduce its loss, are ideal.

Building SOM is a very slow process that begins with photosynthesis. During photosynthesis, plants take carbon from the atmosphere and form sugars. As much as 40-44% of these sugars are then released from plant roots as root exudates. These sugars help feed the soil microbial communities, and the sugars become a part of the microbes' bodies. In return, these microbes can increase soil fertility and health by suppressing plant diseases, delivering nutrients, and increasing water use efficiency. Likewise, when plants die or when manure is added to the soil, the microbes can decompose these materials. Thus, soil organic matter is found in three states:

1. Living: microbes and other soil biology
2. Dead: plant residues and manures added to the soil
3. Very Dead: this is what we call humus. The living SOM digests the dead SOM to make the very dead SOM. The very dead SOM is also formed through chemical processes.

Increasing Soil Organic Matter – Let's Do the Math

When we want to increase SOM, we must set reasonable expectations about how quickly this will occur. Let us suppose that you want to increase your SOM by 1%. First, we must know that

one acre of soil to a depth of 6 inches (acre furrow slice) weighs approximately 2,000,000 lbs. One percent of 2,000,000 is 20,000 lbs. of SOM.
It is necessary to convert SOM to carbon to continue our equation. To convert between soil organic matter to soil organic carbon, the Van Bemmelin conversion factor of 0.58 is used. This number assumes that all SOM is approximately 58% carbon. There is variation in this number, but this conversion factor is widely used and is an accepted estimate. With this conversion factor, 20,000 lbs. of SOM equals 11,600 lbs. of carbon. This means that approximately 11,600 lbs. of carbon from plant or manure residues is required to increase soil organic matter by 1%.

However, 11,600 lbs. of carbon means a lot of plant matter or manure is needed. For example, the carbon content by mass of tall fescue, a common pasture and hay grass, is 47%. Thus, to increase SOM by 1%, you would need to add 24,680 lbs. of fescue dry matter (0.47x=11,600, solve for x).

Yet, in reality, it is estimated that only 10-20% of plant residue converts into SOM. The remaining components are lost back to the environment in the breakdown process. Adding this value into the calculations, you would need 123,400 to 246,800 lbs. of fescue dry matter to increase SOM by 1% (0.1x=24680 to 0.2x=24680, solve for x). In a productive season of well managed pasture or hay, tall fescue may yield around 9000 lbs. of above ground dry biomass per acre. It would take years of biomass incorporation to reach the desired 1% SOM increase.

It is critical to point out that this calculation only considers the aboveground biomass of tall fescue. In reality, the roots of the fescue and the root exudates can also convert into SOM. In some crops, the root contribution can be nearly half of the total annual crop residues for that crop. In others, root contributions can even be 2.3 times the aboveground biomass amount. The root residues provide important inputs up to 8 inches deep in the soil to feed soil organisms. If we estimate that the roots contribute the same amount of carbon and SOM as the above ground biomass, it would take 6 years of fescue growth – with all the aboveground biomass being returned to the system instead of harvested or grazed – to reach a 1% increase to SOM.

Table 1: How many pounds of dry cover crop biomass is needed for 1% increase in SOM, assuming a 10-20% conversion rate. Roots are not included in these estimates.

Crop/Biomass Input	Carbon Content	Lbs. Dry Matter for 1% Increase in SOM
Annual rye/winter rye	42%	138,095-276,190
Tall fescue	47%	123,400-246,800
Vetch	38%	152,631-305,263
Vetch and rye	39%	148,718-297,436

Rule of Thumb for SOM Increases

A series of similar calculations and estimates, based on field research, have lead to the generalization that we can expect a 0.1% increase to SOM per year in a well-managed system. Yet, in-field variation when we take soil samples, coupled with the margin of error on laboratory analysis of SOM, means it is very difficult to reliably identify increased to SOM in the short term. Therefore, it is recommended that changes to SOM be measured after a period of 3-5 years for a reliable indicator. Large, sudden increases to SOM are best explained by errors, not real change in the soil.

Gaps in Knowledge

Currently, more research is being conducted on how much root biomass and exudates convert to SOM. This will improve our estimates in the future. Plant roots have a different chemical composition than aboveground biomass, but have close association with soil microorganisms. Therefore, roots decompose at different rates compared to aboveground biomass like leaves. Likewise, roots and their exudates are already in the soil, whereas aboveground biomass must work its way into the soil. This can of course be affected by the tillage method chosen to manage agricultural land.

Take Home Message:

Roots have long been undermeasured due simply to the difficulty of removing roots from the soil and washing them in order to estimate biomass. However, this work is expected to increase in the immediate future. In the meantime? Emphasize practices that build SOM, set reasonable expectations, and give it time.

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