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Soil Organic Matter

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Soil organic matter (SOM) is the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. Living organisms (especially those smaller than 2 mm) are generally regarded as part of SOM.

What is humus?

Some scientists view humus as being synonymous with soil organic matter (Stevenson, 1999), but others define humus as being the natural organic matter in soil excluding identifiable plant and animal tissues and live organisms (Chen *et al*., 2004). Because humus has different meanings for different people, most soil scientists prefer to use the term 'soil organic matter'.

The composition of soil organic matter

Traditionally SOM was thought to be comprised mostly of a unique category of cross-linked structures termed humic substances and that the long residence times of soil organic carbon in soils was due to the ability of these substances to resist microbial and enzymatic degradation.

However, recent studies have shown that soil organic matter exists mainly in the form of complexes of molecules (supramolecular associations) held together by non-covalent bonds (weak chemical bonds). These bonds bind together fragments of organic material produced through the degradation of biomolecules. The fragments are derived primarily from lipids, lignin, non-lignin aromatic species, peptidoglycans, lipoproteins, carbohydrates, peptides and proteins (Sutton & Sposito 2005; Simpson *et al*. 2007).

Controversy

The debate regarding the true nature of soil organic matter continues today; in their paper "The contentious nature of soil organic matter", Lehmann & Kleber (2015) outline most of the issues involved. The debate is important because our understanding of soil organic matter affects our thinking with respect to several important issues. These include:

- Rates of carbon dioxide (CO_2) evolution from soils, and the response of this process to increased temperature
- Effects of SOM on soil structure and on nutrient and water storage and provision in soils
- Water quality studies.

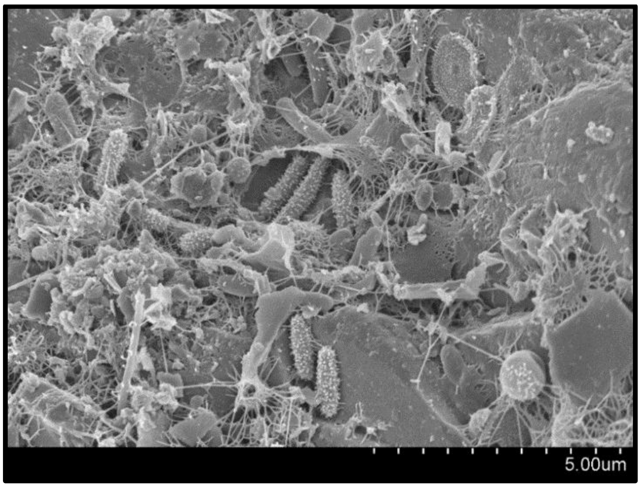

FIGURE 1: A scanning electron micrograph showing how a variety of bacteria have attached themselves to a grain of sand. Image courtesy of the Lewis Lab at North-eastern University. Image created by Anthony D'Onofrio, William H. Fowle, Eric J. Stewart and Kim Lewis.

How does the "emergent view" of SOM affect our management of soil and water?

The persistence of organic matter in soil is now thought to be a result primarily of physical protection of organic matter rather than as a result of the resistance of SOM to decomposition due to its chemical composition (chemical recalcitrance). This has implications for soil management:

- Carbon (C) storage. Labile C compounds (such as glucose) are efficiently stored as mineral-associated microbial residues, whereas carbon compounds that are more difficult to decompose (such as lignin) generate more CO_2 per unit C decomposed (Cotrufo *et al*., 2013; Haddix *et al*., 2016).

  The source of microbial C has been thought to impact its stability in soil; it has been suggested that fungal cell wall components and pigments are more chemically recalcitrant than bacterial residues, thereby contributing to longer C residence times. Throckmorton *et al*. (2012) found, however, that residues from three groups of micro-organisms (fungi, Gram-positive bacteria (including actinobacteria) and Gram-negative bacteria) have similar turnover rates; this was true in both temperate and tropical soils. In general, their results did not support the hypothesis that fungal-dominated soils stabilize more C than bacterial-dominated soils.

FIGURE 2: A basalt-derived soil from the Drakensberg. These soils typically contain more than 6% organic carbon. Photo: Alan Manson.

- Nutrient storage in SOM and release from SOM. There is no chemically recalcitrant fraction because long-term storage depends largely on protection by sorption, occlusion (envelopment) and aggregation. It is, therefore, very difficult to improve on total N as an index of potentially mineralizable N – over a growing season, all forms of organic N are potentially mineralized, depending on their exposure to microbes.
- Soils with a higher clay content can protect more organic matter from decomposition than more sandy soils. This is because clay particles have highly reactive surfaces that promote sorption and aggregation. An organic carbon content of 1% is therefore regarded as high (and possibly practically unattainable) in a sandy soil (such as that in Figure 3), but would be regarded as very low in many of our highly weathered, high-clay KZN soils (Figure 2).

FIGURE 3: A sandy subsoil (Fernwood form). The wavy horizontal lines are clay-rich lamellae that hold much higher concentrations of organic matter than the very sandy matrix. Photo: Alan Manson.

- Maintaining infiltration. Water that is unable to enter the soil contributes to surface runoff, reducing the soil storage of water for plant growth and increasing the risk of flooding and soil erosion. We need to promote aggregation of soil particles at the soil surface, increase the stability of large soil pores, and reduce surface sealing. How does the new paradigm affect that? We need to: keep feeding microbes that hold together both micro-aggregates and macro-aggregates; avoid conditions that promote dispersion, especially high sodium combined with low electrical conductivity (EC); avoid intermittent waterlogging (this pushes up pH, reduces iron oxides and releases organic-N at an optimal time for loss by leaching and denitrification); avoid high pH because deprotonation decreases the strength of both electrostatic and hydrogen bonding that stabilize OM-OM and OM-mineral complexes.

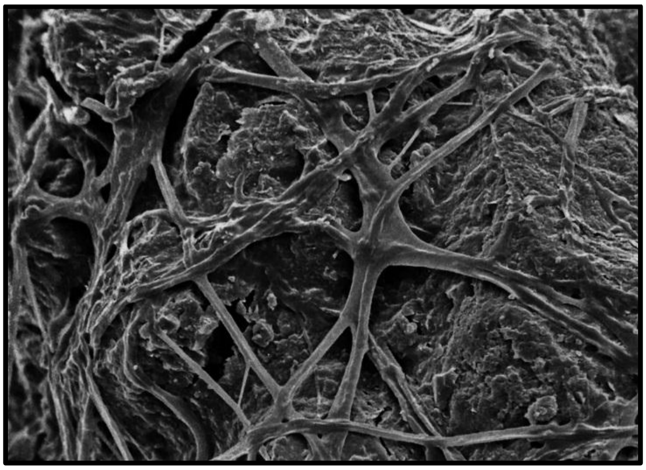

FIGURE 4: Fungal hyphae enmeshing a soil aggregate. Image courtesy of Soil Microbial Ecology, University of Bremen. http://www.microped.uni-bremen.de (with permission).

- Water quality. Although SOM has a positive impact in soil, when eroded from soils into surface waters organic matter has a negative effect on most parameters of water quality. Organic forms of phosphorus and nitrogen may be stable, slow-release stores of these nutrients in soils, but in water they are susceptible to rapid mineralization causing eutrophication (algal blooms) and reduced oxygen concentrations. High concentrations of organic matter also increase the cost of water purification.
- The importance of continuous input of organic matter into soils. The key functions of SOM will decline unless there is continuous turnover of plant and microbial C. More attention should be given to the management of carbon flows rather than carbon stocks.

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