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. SOM exerts numerous positive effects on soil physical and chemical properties, as well as the soil's capacity to provide regulatory ecosystem services.[1] Particularly, the presence of SOM is regarded as being critical for soil function and soil quality.[2]

The positive impacts of SOM result from a number of complex, interactive edaphic factors; a non-exhaustive list of SOM's effects on soil functioning includes improvements related to soil structure, aggregation, water retention, soil biodiversity, absorption and retention of pollutants, buffering capacity, and the cycling and storage of plant nutrients. SOM increases soil fertility by providing cation exchange sites and acting as reserve of plant nutrients, especially nitrogen (N), phosphorus (P), and sulfur (S), along with micronutrients, which are slowly released upon SOM mineralization. As such, there is a significant correlation between SOM content and soil fertility.

SOM also acts as a major sink and source of soil carbon (C). Although the C content of SOM is known to vary considerably,[3][4] SOM is typically estimated to contain 58% C, and the terms 'soil organic carbon' (SOC) and SOM are often used interchangeably, with measured SOC content often serving as a proxy for SOM. Soil represents one of the largest C sinks on the planet and plays a major role in the global carbon cycle. Therefore, SOM/SOC dynamics and the capacity of soils to provide the ecosystem service of carbon sequestration through SOM management have received considerable attention in recent years.

The concentration of SOM in soils generally ranges from 1% to 6% of the total topsoil mass for most upland soils. Soils whose upper horizons consist of less than 1% organic matter are mostly limited to desert areas, while the SOM content of soils in low-lying, wet areas can be as high as 90%. Soils containing 12-18% SOC are generally classified as organic soils.[5]

It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues, and humus: the well-decomposed organic material. Surface plant litter is generally not included as part of soil organic matter.[6][7]

Contents

Sources of soil organic matter

The primary source of organic matter contained in soil is vegetal. In forest or prairies, as well as agricultural fields, dead plants are transformed by different kinds of living organisms. This process involves several steps, the first being mostly mechanical, and becoming more chemical as it progresses. The small living beings that work on that decomposition chain are themselves part of the soil organic matter, and form a food web of organisms that prey upon each other and are preyed upon.

There are also other animals that consume living vegetal material, whose residues are passed to the soil. The products from the living organisms metabolism are the secondary sources of soil organic matter that also includes the dead corpses of these organisms. Some animals, like earthworms, ants and centipedes contribute to both vertical and horizontal translocation of organic material.[8]

Additional sources of soil organic matter include plant root exudates[9] and charcoal.[10]

Composition of plant residues

The water content of most plant residues is in the range of 60% to 90%. The dry matter consists of complex organic material composed mainly of carbon, oxygen and hydrogen. Although these three elements make up about 92% of the dry weight of the organic material in soils, there are other elements that are of great importance for the nutrition of plants. They include nitrogen, sulfur, phosphorus, potassium, calcium, magnesium and a range of micronutrients.[8]

Organic compounds found in plant residues include:

- **Carbohydrates** are made up of carbon, hydrogen and oxygen, and range in complexity from rather simple *sugars* to the big molecules of *cellulose*.
- **Fats** consist of glycerids of fatty acids, like butyric, stearic, oleic. They are also made up of carbon, oxygen and hydrogen atoms.
- **Lignins** are complex compounds that form the older parts of wood, and consist also mainly of carbon, oxygen and hydrogen. They are resistant to decomposition.
- **Proteins** contain nitrogen in addition to carbon, hydrogen and oxygen, and also small amounts of sulfur, iron, and phosphorus.[8]
- **Charcoal** is elemental carbon derived from incomplete combustion of organic matter. Charcoal is resistant to decomposition.

Decomposition

The vegetal residues in general are not water-soluble, and they are not usable by the plants. They constitute, nevertheless, the raw materials from which plant nutrients are derived. The decomposition is carried out as enzymatic biochemical processes by soil microorganisms, that obtain the necessary energy from the same residues, and produce the mineral compounds that are apt to be absorbed by plant roots. This process by which organic compounds are broken down and transformed into mineral (inorganic) compounds is also referred to as *mineralization*. A portion of organic material is not mineralized, but transformed into stable organic matter *humus*.[8]

The break down of the organic compounds is done at very different rates, depending on their nature. The ranking, from fast to slow rates are as follow.

1. Sugars, starches and simple proteins.
2. Proteins
3. Hemicelluloses
4. Cellulose

5. Lignins and fats.

The reactions that take place can be included in one of three groups:

- Enzymatic oxidation, that produces carbon dioxide, water and heat. It affects the bulk or major portion of the material.
- The essential elements, nitrogen, sulfur, phosphorus are liberated and mineralized by a series of specific reactions.
- Compounds that are resistant to microbial action are formed by modification of original compounds or by synthesis of new ones by microbes, creating humus.[8]

The list of mineral end products are as follow:

Element	Mineral end products
Carbon	CO_2, CO_3^{2-}, HCO_3^-, CH_4, C
Nitrogen	NH_4^+, NO_2^-, NO_3^-, N_2 (gas)
Sulfur	S, H_2S, SO_3^{2-}, SO_4^{2-}, CS_2
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}
Others	H_2O, O_2, H_2, H^+, OH^-, K^+, Ca^{2+}, Mg^{2+}, etc.

Humus

As vegetal material undergoes decomposition, some microbial resistant compounds are formed. These include modified lignins, oils, fats and waxes. Secondly, some new compounds are synthesized, like polysaccharides and polyuronids. These materials form the basis for humus. New reactions take place between these compounds and some proteins and other nitrogen containing products, incorporating thus nitrogen and avoiding its mineralization. Other nutrients are also protected in this way from mineralization.

Humic substances classification

There is a classification into three groups, based on solubility in acids and alkalis, and also related to stability.

- *Fulvic acid* is the group which contains the materials that have the lowest molecular weight, and are soluble in acids and alkali, and susceptible to microbial attack.
- *Humic acid* group contains the intermediate materials, with medium molecular weight, soluble in alkali, but insoluble in acid, and intermediate resistance to microbial attack.
- *Humin* is the generic name for the materials with highest molecular weight, that are darkest in color, insoluble in acid and alkali, and with the most resistance to microbial attack.[8]

Role in carbon cycling

Soil plays a major role in the global carbon cycle, with the global soil carbon pool estimated at 2500 gigatons. This is 3.3 times the size of the atmospheric pool (750 gigatons) and 4.5 times the biotic pool (560 gigatons). The pool of organic carbon, which occurs primarily in the form of SOM, accounts roughly 1550 gigatons of the total global C pool, with the remainder accounted for by soil inorganic carbon (SIC). The pool of organic C exists in dynamic equilibrium between gains and losses; soil may therefore serve as either a sink or source of C, through sequestration or greenhouse gas emissions, respectively, depending on exogenous factors.[11]

See also

- Biotic material
- Natural organic matter
- Mineralization (soil science)

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