Organic matter and soil functions

Soil health is the ability of the soil to function as a living ecosystem in relation to its natural capacity. A healthy soil sustains biological activity, maintains environmental quality, promotes plant, animal and human health, and is productive, resilient and profitable.

How do we measure soil function?

Traditionally, soils have been assessed on a single function such as plant yield or productivity. This ignores the fact that healthy systems involve multiple soil properties that are often interconnected and support the overall function of the system.

Soil organic matter - more than just organic carbon

A key property that influences soil function is the organic matter content. Soil organic matter (OM) is the fraction of the soil that consists of any animal and/or plant material, living or in any stage of decomposition. OM is not just organic carbon, it also consists of various other chemical compounds and materials. Soil organic carbon (SOC) refers just to the carbon component of OM, and is simpler to measure than OM content, so SOC is more commonly measured and reported.

There are many key soil functions that rely on organic matter in agricultural systems. Some of these include:

Productivity – growing biomass for food, fibre and energy

Soil productivity is the ability of soil to support plant growth and produce yields,, and is affected by climatic conditions, soil properties, nutrition and plant species selection. Increasing plant production provides food security but much of the biomass produced in agricultural systems is removed, reducing the amount of OM returned to the soil. This can lead to a decrease in soil functionality and SOC.

Increased production can be achieved whilst maintaining or improving the soil resource . Improving production efficiency and yield , selecting species to grow more root mass, and maximising ground cover can increase OM inputs.

Nutrient cycling

Nutrient cycling refers to the movement and exchange of inorganic and organic nutrients in soil, and is affected by soil texture,mineralogy, cation exchange capacity, soil moisture and temperature, soil organisms, microbial activity, and supply of mineral and organic nutrients.

Nutrient supply to plants relies on soil organisms breaking down organic or mineral sources to provide nutrients in a form suitable for plants and microbes to use. Diverse plant or crop rotations, growing multi-species mixes or addition of composted organic amendments can increase the diversity of soil organisms and supply a wider range of nutrients. Nutrients such as N, P and S are required to feed soil organisms that break down plant residues (particulate OM) and form more stable humus-like or mineral associated OM.

Using practices such as minimum or no tillage, increasing plant diversity, growing cover or summer crops, growing plants that have longer growing periods (e.g. perennials) and applying organic amendments (e.g. plant or animal residues, composted products) will increase the supply and cycling of nutrients in the soil.

Water circulation and storage

Water circulation through soil is influenced by soil texture, arrangement of soil particles, soil disturbance, soil compaction, soil moisture, water repellence and OM content. The arrangement of sand, clay and silt particles create pore spaces that allow water and gas to move into and through the profile. Management practices can affect the particle arrangement creating compacted layers or high soil strength, in turn affecting water movement and root growth.

Increased OM content can improve soil structure as microbes break down OM to produce carbon-rich secretions that act as glues, binding soil particles together and creating aggregates that can increase pore spaces. Water storage and circulation can be improved by reducing compaction or high soil strength where possible, addressing water repellence, maximising ground cover (e.g. retain stubbles), and minimising soil disturbance to protect aggregates.

Soil biological organisms

Soil organisms consist of microflora, microfauna, mesofauna and macrofauna and play an essential role in decomposing organic matter, cycling nutrients and fertilising the soil. Increased activity and diversity of soil organisms leads to more resilient systems that are more likely to suppress diseases and be more carbon efficient (less CO_2 gas released to the atmosphere with decomposition of OM).

The amount and diversity of OM and soil organisms can be increased through crop diversification, addition of organic amendments including fertilisers, avoidance of chemical fungicide use, reduced soil disturbance and optimiisation of ground cover

Soil organic carbon storage

Organic matter comes in different forms with different longevity in the soil that is commonly measured in terms of SOC storage. Particulate OM consists of lightweight fragments that are relatively undecomposed, and is important as an energy and nutrient source for soil organisms. Particulate OM generally has a mean residence time in the soil of <10-10s of years. Mineral-associated OM describes single molecules or microscopic fragments of organic material attached to clay particles, iron or aluminium complexes in the soil. Mineral associated OM has a residence time of 10s to 100s of years and, therefore, is important for long term stabilisation and storage of SOC.

SOC storage is affected by soil texture, mineralogy, structure and aggregates, soil disturbance, rainfall, temperature, soil moisture (plant and microbial activity), OM inputs (plant and animal residues) and losses (decomposition and erosion). The SOC storage of a soil can be increased through growing and retaining more soil OM, increasing species diversity (plant and soil organisms) and sources of OM to maximise carbon efficiency, minimising soil disturbance to protect SOC in aggregates, and identifying and rehabilitating areas of low productivity.

Organic-based fertilisers have potential to increase SOC as they contain more OM, decompose more readily and release less CO_2 to the atmosphere than non-organic fertilisers.

Healthy soils mean productive, resilient and profitable systems

More information

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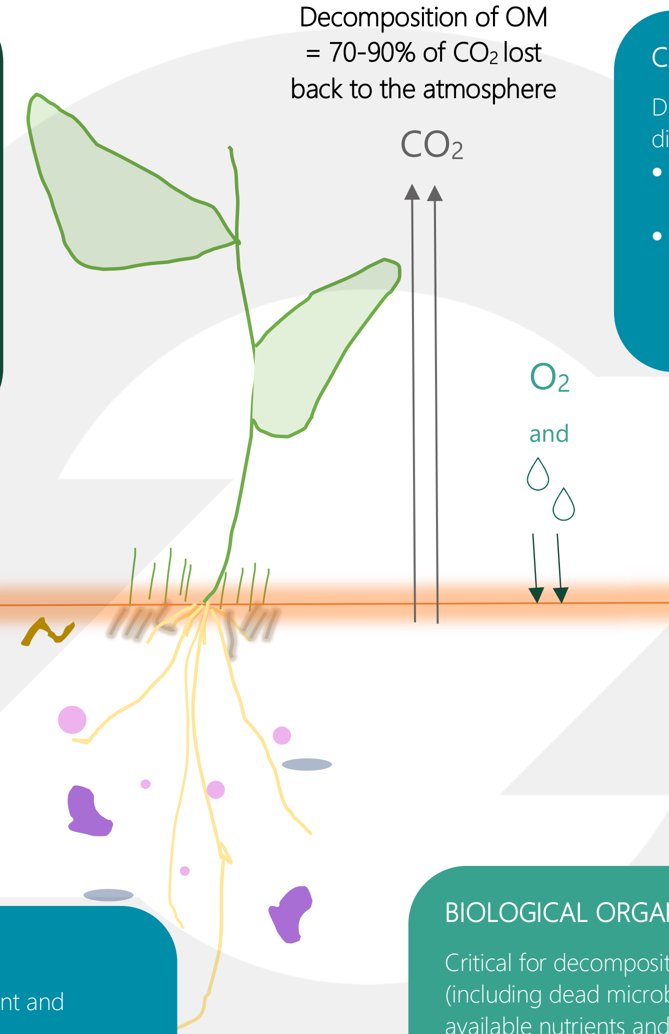
CLIMATIC FACTORS - Rainfall, temperature, evaporation and solar radiation influence all functions

SOURCES OF OM

- Plant – shoot and root residues, root exudates
- Animal and manures
- Offsite composted products
- Living soil biology 1-5%
- Microbial necromass 30-50%
- Organic amendments containing carbon



CARBON

Different forms of SOC have different roles in soil

- Particulate OM = food source (function)
- Mineral associated OM = long-term storage (Green house gas offsets)

PRODUCTIVITY

Improved productivity results in

- More productive and efficient systems
- Increased shoot and root OM inputs
- Less bare ground at the surface modifying climatic conditions that affect microbial activity and soil C

WATER CIRCULATION

Improved soil structure from aggregate formation (mainly by microbial glues and SOC), creating pore spaces for water and air movement. This increases infiltration and storage capacity (bucket size) for water and gases.

NUTRIENT CYCLING

- Needed for successful plant and microbial productivity.
- Functioning soils retain and recycle nutrients in a form suitable for plants and microbes to use for growth and conversion of particulate OM to mineral associated OM **decomposition**

BIOLOGICAL ORGANISMS

Critical for decomposition of organic matter (including dead microbes) releasing plant-available nutrients and secretions used as glue in soil aggregates (soil structure).

More diversity improves disease resilience and, we are learning, can reduce the amount of CO_2 released back to the atmosphere

OM + soil biology = C, H, O, N, P, S + CO_2 as gas

SOIL PROPERTIES - Texture (clay concentration), pH, salinity, limitations to root growth affect all functions

Figure 1: Functions in agricultural systems that influence, and are influenced by soil organic matter.