The Living Soil

& Carbon Sequestration

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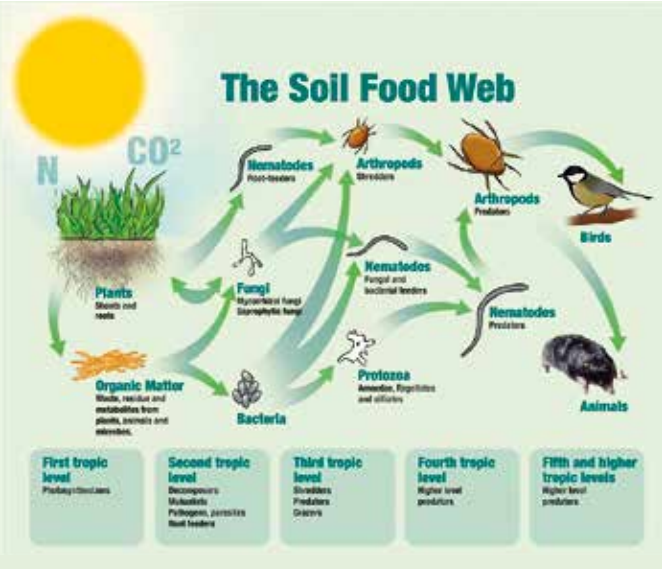
Joel Williams describes the biology of healthy soil and why fungi play such an important role in carbon sequestration

Soils are vast and complex living ecosystems, teeming with an incredible diversity of micro and macro-organisms that function together and comprise the underground bionetwork often referred to as the soil food web. These living organisms range in all shapes and sizes from the smallest virus, bacteria and algae to the more complex nematodes and up to the visible earthworms, insects and plants. As these organisms grow, eat and move their way through the soil, they perform a vast array of beneficial functions including:

- Decomposing organic materials, including composts and plant residues.
- Fixing atmospheric nitrogen and solubilising soil minerals into plant available form.
- Storing and recycling soil nutrients.
- Enhancing soil aggregation and porosity.
- Building soil humus and hence increasing nutrient and moisture retention.
- Preying on crop pests and even being consumed themselves by higher level predators from the intertwined soil food web.



Above:
A pictorial representation of the soil food web from photosynthesizers to high level predators.

Feeding the Masses

The soil foodweb is fuelled by the primary producers: plants, algae, lichens, moss and certain groups of bacteria that have the ability to fix carbon from the atmosphere. Other soil organisms then obtain their energy by consuming those primary producers and their waste products. In agro-ecosystems, organic matter inputs such as composts, crop residues and manures also provide a carbon source to feed into and fuel this living system. As organisms decompose organic materials or consume other organisms, nutrients are converted from one form to another and some are made available to plants and other soil organisms. All crops – grass, vegetables and orchard crops – depend on these microbial interactions of the food web to obtain their nutrition from the soil.

Who's Who in the Soil Food Web

Bacteria are single celled organisms and reside in the soil in vast numbers. Most bacteria are decomposers of simple carbon compounds but they also hold nutrients in the root zone and filter and degrade pollutants.

Above:
Artist's impression of bacteria. They exist in the soil in vast numbers and play a vital role in breaking down carbon compounds.

Fungi are multi celled organisms that grow as long threads or strands called hyphae. Fungal hyphae can span in length from a few cells to many yards. Saprophytic fungi perform important services related to soil-water dynamics; they physically bind soil particles into aggregates thereby improving soil structure.

Protozoa are single celled animals that feed primarily on bacteria, but also eat other protozoa, organic matter and sometimes fungi. As protozoa eat bacteria, excess nutrients are released into the soil in plant available form.

Nematodes are non-segmented tiny worms and many growers are familiar with the nematodes that cause crop losses, when in fact, there is an incredible variety of beneficial nematodes. These beneficial nematodes consume bacteria, fungi or even other nematodes and in doing so (similarly to protozoa) release nutrients in plant available form.

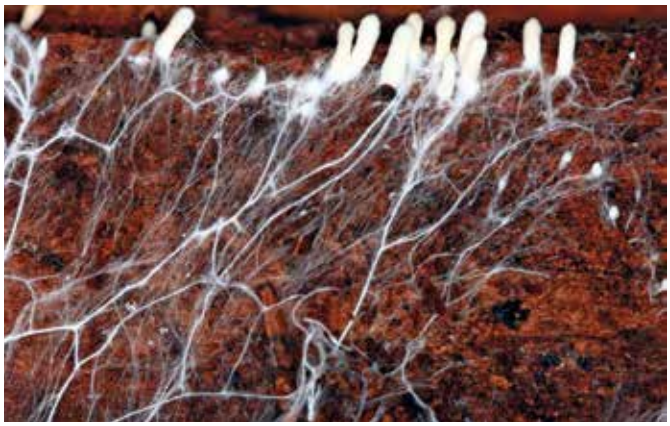
Soil insects are important shredders of organic materials while *earthworms* also grind up organic materials in the soil and redistribute them from the soil surface throughout the soil profile.

Above:
Nematodes consume bacteria and fungi and in so doing release nutrients to plants.

It is this interaction of predators consuming lower hierarchical organisms and recycling nutrients in which highly productive natural ecosystems can maintain their fertility in the long-term without the application of fertiliser year after year.

A Sum of the Parts

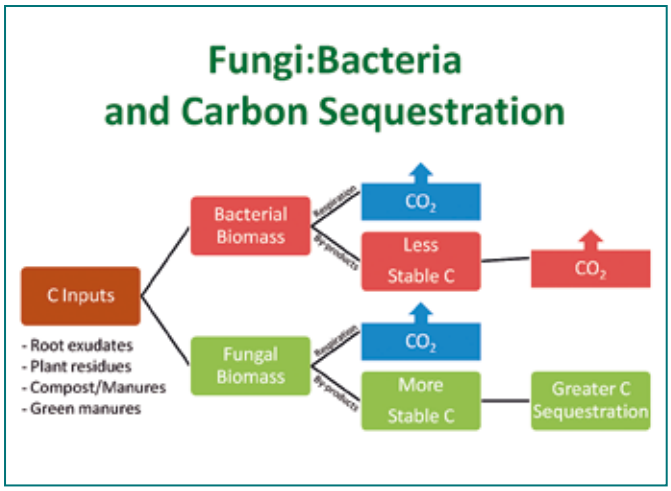
The soil food web is a perfect example of the permaculture viewpoint regarding collaboration and synergy whereby the whole is greater than the sum of its parts. The focus need not necessarily be on any particular organism, but rather the relationship between organisms and how they function as a whole system. The relationship between bacteria and fungi is a noteworthy example. These two organisms are the primary decomposers of organic materials and hence play a crucial role in the flow of carbon (energy) into the soil food web. The balance between bacterial and fungal abundance plays an important role in soil carbon sequestration. If bacteria dominate the soil environment and 'eat at the table first' (thereby consuming a majority of carbon inputs), then the flow of that carbon into the soil food web takes a very different pathway than when fungi consume the majority of that carbon.



Above:
Fungi, like bacteria, also consume carbon. Healthy soil relies on having the right balance of both.

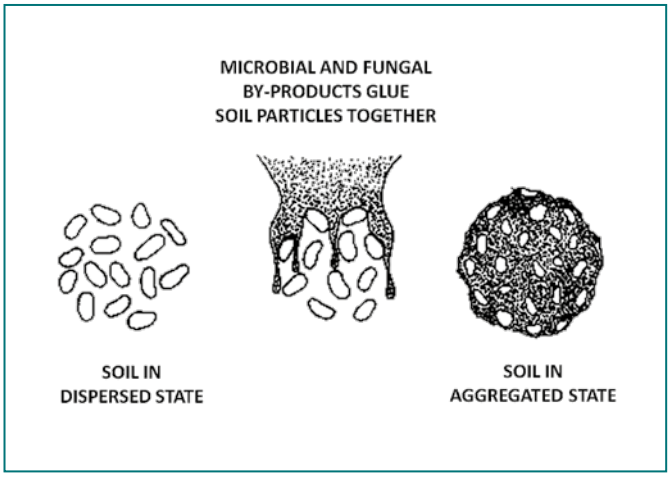
Fungi:Bacteria Ratio

As both bacteria and fungi feed on carbon and via their metabolism, they exude a range of carbon based by-products and waste products and also respire CO_2 during this process. On one hand bacteria produce small chain by-products and breathe out relatively more CO_2 while fungi produce larger chain by-products and respire less CO_2. These larger carbon chain products produced by fungi are more resistant to decomposition in the environment thereby remaining stable in the soil for longer periods of time than bacterial by-products which are smaller and degrade more easily, ultimately into CO_2. This means a greater proportion of fungi present in the soil ultimately leads to greater carbon sequestration via the synthesis of these stable forms of carbon with longer residence times.



Above:
Diagram showing the influence of the fungi:bacteria ratio on carbon flows in soils.

In addition to this, as fungi grow, their fine filaments excavate their way through the soil environment creating channels and tunnels. The physical action of this growth habit thrusts soil particles together; clumping and aggregating these particles and binding them with glue like substances. Highly aggregated, structured soils contain invaluable pore spaces for the most important element for all living organisms, oxygen. The vast array of beneficial microbes that reside around the plant root system and



Above:
Fungal hyphae and their sticky by-products bind soil particles together forming stable aggregates – the sites of optimised carbon sequestration.

throughout the soil environment require this precious, life giving oxygen for their growth and survival. Aerobic, structured soil provides the optimum conditions for microbial proliferation, which leads to a healthy soil food-web, increased nutrient cycling, greater nutrient supply to growing plants and maximum carbon sequestration.

In Conclusion

Fungi are truly wondrous and most farm soils are desperately lacking an abundance of these and many other beneficial soil organisms at large. Soil disturbance in particular, but also excess moisture, surplus soluble nutrients and pesticide applications, all suppress fungal and general microbial activity in the soil. Minimising these harmful practices and ensuring there are adequate carbon based inputs (food) for fungi will help ensure they remain active in the soil environment. A deeper understanding of the soil characteristics that optimise microbial abundance and activity in order to improve carbon sequestration would improve the overall health and resilience of our agro-ecosystems

Joel Williams is a soil health educator and crop advisor for chemical free food production systems. He is also an urban farmer and through teaching food growing, strengthens connections between consumers and food.

Recommended Reading

The Soil Will Save Us: How Scientists, Farmers and Foodies Are Building Healthy Soil to Heal the Planet by Kristin Ohlson. RRP £16.99 on offer for £15.50

The Carbon Farming Solution: A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security by Eric Toensmeier. RRP £51.50 on offer for £46.00

Both titles are available to order from *PM*'s online independent bookstore at: **www.green-shopping.co.uk** or in the US from **www.chelseagreen.com**