White Paper

Soil Carbon

Soil carbon is an important indicator of healthy soil, influencing a range of factors that impact yield and quality.

Forms of Soil Carbon

Like most elements carbon can be present in soils in different forms. Carbon is present as organic or inorganic carbon. Inorganic carbon is mineral based with its most common form being calcium carbonate.

The carbon present in soil organic matter is referred to as organic carbon. Carbon is the main element present in soil organic matter (SOM), on average making up 58% by weight.[i] SOM includes decaying plant material, soil organisms and microbes, and carbon compounds such as sugars, starches, proteins, carbohydrates, lignins, waxes, resins and organic acids.

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Importance of Organic Carbon in Soils

Soil organic carbon is a vital component of productive agriculture and is significantly influenced by management practices. In addition, sequestration of carbon in agricultural soils has been recognised as a tool to mitigate climate change and is at times referred to as ‘carbon farming’.

Organic carbon influences many soil characteristics including, colour, nutrient and water holding capacity, nutrient cycling and availability, improved water infiltration and aeration. Soils can preserve organic carbon, as the main component of organic matter, by forming soil aggregates and mineral-organic complexes. Clay particles are more effective than sand and silt in preserving soil organic matter.[ii]

Examples of soil with less than 1%, 2% and 3% organic matter from left to right, respectively. *Photo – Jodi DiJong-Hughes*[iii]

Soil carbon is a food source for soil micro-organisms and an important bacteria metabolite. Soil microflora form microaggregates in the soil by binding soil particles together with their secretions. Many bacteria produce a layer of polysaccharides or glycoproteins that coat the surface of soil particles. These substances play an important role in binding sand, silt and clay soil particles into stable microaggregates that improve soil structure.[iv]

A well-aggregated soil provides many micro-habitats for soil microbes.
Photo – Caley Gasch[iii]

These microaggregates are like the building blocks for improving soil structure. Improved soil structure increases water infiltration and increases water holding capacity of the soil.[v]

High levels of organic carbon help to maintain agricultural production through its positive role in maintaining soil health, raising fertility, reducing erosion and encouraging soil biota. Higher soil organic matter levels cause greater soil nitrogen retention, greater microbial biodiversity, and promote the presence and growth of arbuscular mycorrhizal fungi that penetrate the roots of crops and facilitate the movement of plant nutrients from the soil into plants improving growth and yields.[vi]

As soil organic matter decreases, problems with fertility, water availability, compaction, erosion, parasites, diseases, and insects become more common, requiring higher levels of intervention from fertilisers, irrigation water, pesticides, and machinery to maintain yields. Too much chemical and mechanical intervention can indeed lead to reduced yields at increased cost. However, biological management of soils, will support a healthy for expensive fixes.

The organic matter content of agricultural topsoil is usually in the range of 1-6%. A study of soils in Michigan USA demonstrated potential crop-yield increases of about 12% for every 1% increase in organic matter. It has a significant influence on the soil's biological, chemical, and physical properties. Humus, which is the well-decomposed portion of organic matter, gives the soil the ability to absorb, and retain moisture, allowing water and air to penetrate through the soil. For Australian agricultural soils, soil organic matter decline in the top 10cm is estimated between 20% and 70%, with average soil organic matter stocks about half that of native system soils.[vii]

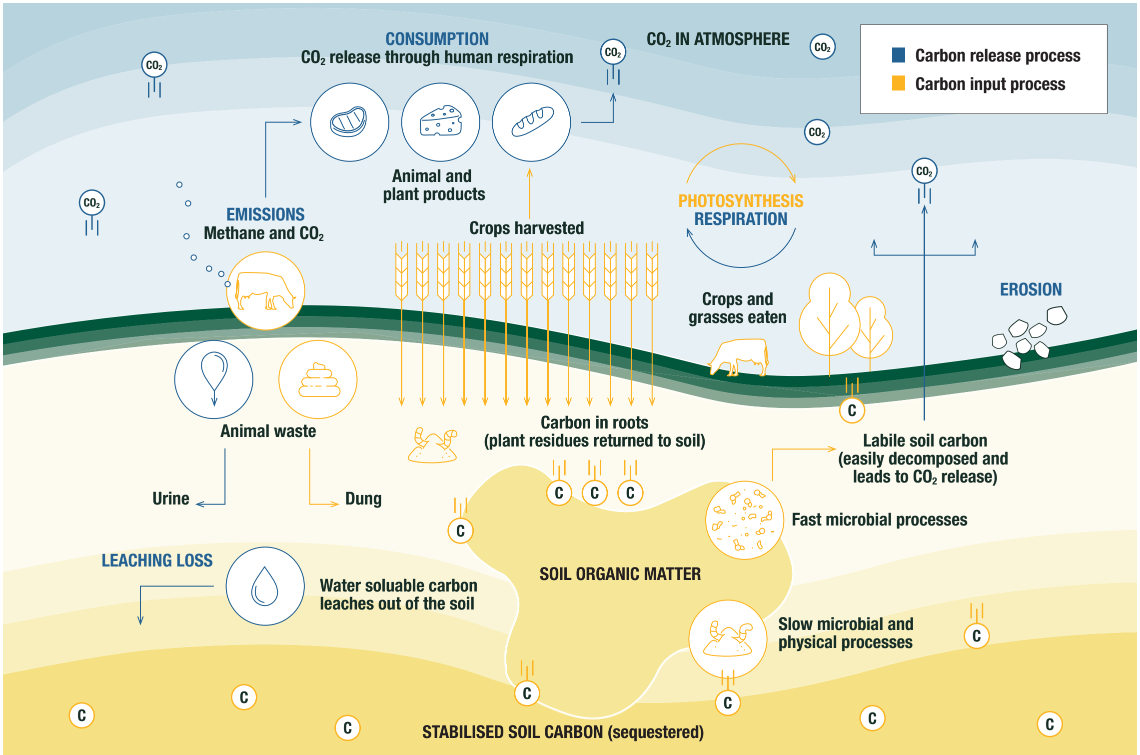
Carbon Sequestration

Sequestering carbon in soils is about increasing SOM.

It is estimated that SOM stores four times as much carbon as living plants and that carbon stored in all the world's soils is two to three times the amount in the atmosphere.

Soil carbon sequestration is a normal part of farming, however when it becomes a focus it is known as 'carbon farming', which focuses on adopting land management practices that increase the amount of carbon stored in soils. The practice of carbon farming is often done by landowners who are given incentives through policies created by government programs and there are independent consultants who specialise and can advise on this. BioAg's focus is purely on working with farmers to improve their soil health for the long term, for improved yield and quality.

Carbon naturally enters and leaves the soil through a range of complex processes occurring simultaneously. The amount of carbon stored in soils can be increased or decreased by changing and adapting land management practices.



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Increasing Soil Organic Matter / Soil Organic Carbon

Soil carbon levels increase when carbon-based inputs are greater than the losses. The main losses of carbon from the soil are through organic matter decomposition, soil erosion, biomass burning.[viii]

To build carbon levels in soils requires plant material to be accumulated in soils. Recycling residues from all types of harvested crops (trees, cereals, grazed pastures, orchards and vineyards) is beneficial for maintaining or increasing soil carbon.[ix]

A pasture phase in any crop rotation is an efficient way to build soil carbon.[x] Productive perennial pastures incorporating grass species with extensive root zones are known to improve soil carbon levels. Dry matter from pastures will decay in the soil and when pasture is grazed or harvested, for hay or silage, plants will shed roots which will decay into organic carbon. The more crop residue (straw, leaf matter, cuttings, stubble and roots) that can be returned to the soil, the better.[ix]

The process whereby plants extract carbon (CO_2) from the atmosphere via photosynthesis and deposit organic carbon in the soil is described as carbon sequestration. To optimise sequestration, look to minimise soil disturbance and maximise plant growth.

Disturbing the soil enables existing soil carbon to oxidise into CO_2 and enter the atmosphere. Maximising plant growth maximises the production of organic matter which in combination with appropriate crop residue management will maximise sequestration.

In Australian soil typically the greatest impediment to growth is nutrient availability (notably in grasslands) and moisture availability.

In addition to plants needs for nutrients, the microbes that convert organic residues such as roots, leaf matter, stubble and composts, into forms of organic carbon (humus) require nitrogen, phosphorus and sulphur and other trace elements.[x]

Moisture retention typically requires capture and infiltration of available rainfall. This can be improved by improving soil structure. Soil structure is greatly influenced by the presence and ratio of Calcium to other cations. Calcium can also be applied as lime, reducing soil acidity and reducing the impact of antagonistic elements such as iron, aluminium and manganese.

Per the above maintaining your soil structure and nutrient profile are key components in improving organic carbon levels in soils.

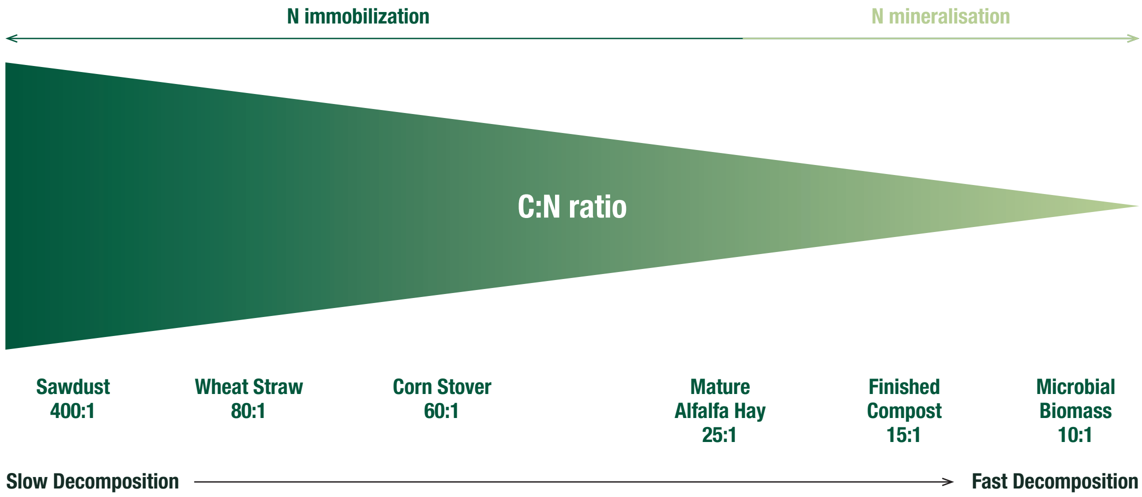
Soil Carbon Nitrogen Ratio

Addressing the content of soil organic carbon requires an understanding of the influence of the Carbon to Nitrogen ratio (C:N ratio).

Soil microbes utilise carbon (whether in soil or supplied through carbohydrates from plants) to generate energy. Available nitrogen in the soil is consumed by microbes to produce enzymes some used to burn carbon that supplies energy[xi] others as building blocks to proteins.

The C:N ratio is the mass of carbon to the mass of nitrogen in a particular substance. For optimum health microbes require approximately 16 parts of carbon for energy and then 8 parts for maintenance. This is why a C:N ratio of 24:1 is ideal for soil health.[xii]

When composting or breaking down plant matter it is commonly recommended that nitrogen be applied to aid the process. This is because microbes require energy to break down organic matter and to do this, they need to produce enzymes (which contain nitrogen).



C:N ratio's supporting composition of varying plant materials.

However, when available nitrogen is high (e.g. after application of nitrogen fertilisers) microbes will look to convert the nitrogen by consuming carbon. When there is insufficient carbon supplied from plants or from the breakdown of plant materials; microbes will consume the carbon stored in the soil.

In soils low in carbon (typical of many Australian soils) the application of nitrogen fertilisers can be a major factor in the loss or failure to build soil carbon levels.

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Building Soil Organic Carbon with BioAg

BioAg's philosophy of soil analysis and developing programs to improve soil structure and nutrient levels is a key step in sustainably increasing levels of soil carbon. By addressing issues of structure and nutrient availability with each seasonal application of ameliorants or nutrients, growers are continually building their soils capacity to grow, capture and hold carbon. BioAg's programs are focused on continual improvement and structured to fit the operational and financial needs of farmers.

Case study: Pasture for beef, NSW

A long-term customer of BioAg's in the Upper Murray region of NSW has experienced ongoing gradual improvement over 20 years to build resilient healthy soils for the long-term. Spoil test results throughout the two decades clearly show that organic matter has increased more than 1.5 times across various farm sites.

Scan to read the full Case Study.

To overcome issues that may draw down or burn out SOM, such as drought, fallow, high temperatures, excessive applications of nitrogen fertiliser; BioAg has a range of biostimulants which contain organic carbon and provide nutrients and food sources for plants and soil micro-organisms. Supporting soil biology or crops during stress events reduces the consumption of and aids the sequestering of soil carbon.

BioAg *Soil & Seed®* is formulated to improve soil microbial activity. It acts as an excellent soil inoculant, feeds and expands the volume and diversity of beneficial soil micro-organisms as a catalyst to improve plant availability of both soil borne and applied nutrients. Treated soils demonstrate improved structure, water infiltration, tilth and field capacity, along with natural plant pathogen suppression.

Independent trials in a wide variety of crops attest to its efficacy in improving yield and quality.

Creative Innovation Agriculture & Forestry (CIAAF) studied 'The effect of BioAg's *Soil & Seed* on a range of soil samples including sandy soil, loam, clay loam', to ascertain *Soil & Seed* effect on, microbial population in soils (microbial biomass), soil nutrients within the microbial population and soil carbon levels.

The results were a significant increase in microbial levels, with on average, the total number of microorganisms (bacteria and fungi) increased by 77% above the control. In addition, there were increases in nutrients within the soil biomass and in the level of carbon in soils.

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Humus is made up to a great extent of lignins and other high-carbon content material. Or in other words, humus has more carbohydrates than the bodies of microbes, which are extremely high in protein. Humus (organic carbon molecules formed from the breakdown of organic residues) play an important role in the rehabilitation of soils. Increasing soil CEC (cation exchange capacity), improving tilth and porosity, water availability and retention. Humic compounds play a vital role in soil aggregation, making clay more porous, soft, and aerobic, with improved drainage, resulting in deeper root growth of all plants. Humic substances are stable, long-lasting biomolecules.[xiii]

BioAg *HydraHume*® (humic acid) and HydraFuel (humic acid enriched with carbohydrates) directly contribute to an increase in soil carbon. They are efficient promoter's of plant growth and increased root mass, while also improving the effects of fertilisers. Both products rapidly accelerate the microbial activity in soils, developing soil carbon and improving soil properties. The source of Humic acid that is used in *HydraHume* and HydraFuel is derived from Leonardite, one of the richest sources of humic acid available.

BioAg's team of area managers develop programs and provide advice for farmers across the full range of farming approaches to regenerate soils and improve productivity.

i www.dpi.nsw.gov.au/factsheets

ii www.soilquality.org.au/factsheets

iii https://extension.umn.edu/soil-management-and-health/soil-organic-matter-cropping-systems#stableorganic-matter-1388661

iv Hoorman, J.J., Sa, J.C.M., and Reeder, R.C. 2011. The Biology of Soil Compaction (Revised & Updated), Journal of No-till Agriculture, Volume 9, No. 2, Pages 583-587

v Ingham, E.R. (2009). Soil Biology Primer, Chapter 4: Soil Fungus. Ankeny IA: Soil & Water Conservation Society. Pages 22-23

vi Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems David Pimentel, Paul Hepperly, James Hanson, David Douds, Rita Seidel: BioScience, Volume 55, Issue 7, July 2005, Pages 573–582

vii Baldock JA (2019). Nitrogen and soil organic matter decline - what is needed to fix it? GRDC Updates, Bendigo, 2019

viii R.F. Follett, Soil management concepts and carbon sequestration in cropland soils. Soil Tillage Res., 61 (2001), Pages 77-92

ix http://www.futuredirections.org.au/publication/soil-carbon-the-backbone-of-soil-fertility-emeritusprofessor-robert-white/

x www.dpi.nsw.gov.au/factsheets

xi https://www.no-tillfarmer.com/articles/6783-excessive-n-application-burning-the-carbon-pool

xii https://www.nrcs.usda.gov/

xiii https://www.ecofarmingdaily.com/build-soil/humus/humic-acid/