Soil Organic Carbon Factsheet 1.1

What is soil carbon?

Carbon is present in soil in inorganic and organic forms. Inorganic carbon (mineral-based material like carbonates) is less responsive to management than soil organic carbon (SOC). SOC makes up about 58% of soil organic matter (SOM) which is known to have many benefits for productivity, climate resilience and ecosystem health. Increasing SOM improves soil structure, increases nutrient cycling and enhances diversity of soil organisms.

Key soil carbon facts

- The amount of organic carbon stored in soil depends on the balance between organic matter inputs and losses.
- Photosynthesis is the dominant pathway of transfer of CO_2 to the biosphere, initially into plant biomass. SOC is added to soil through plant litter, roots, root exudates and soil organisms.
- Loss of organic carbon from the soil occurs through erosion and through decomposition of SOM, mainly via soil microbes action. Most SOM decomposes rapidly releasing CO_2 back to the atmosphere while making nutrients available for plants and improving soil structure for better root growth and air and water flows through soil.
- SOC is a component of the complex mix of organic matter in soil in different states of decomposition, from partially decomposed plant residues and microbial biomass to humus and charcoal. While rapidly cycling organic matter is directly beneficial for plant growth, the slow cycling stable SOM which is protected from decomposition improves soil structure and represents a removal of CO_2 from the atmosphere able to offset an equivalent amount of greenhouse gas emissions.
- The forms and total mass of SOC in soil depend on soil type, climate, landscape, vegetation characteristics and on land management practices.

What is soil carbon sequestration?

Carbon sequestration is the process of removing carbon (in the form of CO_2) from the atmosphere and storing it in sinks such as vegetation and soils permanently (for centuries or millennia). Appropriate management actions can increase sequestration of organic carbon in agricultural soils and contribute to mitigating climate change.

Estimating soil organic carbon sequestration?

In climate change reporting and the Australian Carbon Credit (ACCU) Scheme, SOC sequestration over a period of years from baseline (t_0) to a time (t_1) after implementation of new management is estimated as the change in SOC stocks in units of tonnes C per hectare per year (T C/ha/y), to a depth of at least 30cm.

The potential for soil carbon sequestration in northern grazing lands

Interest in the potential for management strategies to sequester carbon in grazing lands to provide benefits for beef, sheep and goat producers through access to carbon offsets and to contribute to Australia's climate change mitigation targets is high. However, the diversity of soil, climate, landscapes and production systems and limited research and data from long-term field studies or verified modelling on management impacts on soil and soil carbon make predictions complex and uncertain.

1. *Henry, B. (2023) Potential for soil carbon sequestration in Northern Australian grazing lands:*
2. *A review of the evidence. Department of Agriculture and Fisheries, Queensland. (www.futurebeef.com.au) https://era.daf.qld.gov.au/id/eprint/9238/1/Soil-Carbon-Sequestration-in-Northern-Grazing-Lands_B%20Henry.pdf*

Key Soil Carbon Sequestration Facts

- Sequestration means a net gain in stored SOC must be maintained without re-release which requires ongoing inputs of organic matter, in turn depending on rates of photosynthesis and plant growth (or Net Primary Production, NPP). The primary drivers or NPP and the balance of SOC inputs and loss are soil and climate factors, and these variables commonly determine 70 to 90% of change in SOC content. Management strategies have a smaller impact but practices that support strong plant growth and avoid conditions that accelerate loss such as soil disturbance, favour SOC sequestration.
- Sequestration is linked to chemical stabilisation and protection of SOC from loss by microbial decomposition through the formation of soil aggregates and complexes of mineral associated organic carbon (MAOC).
- Clay Content: Soil with higher clay content is more effective than sand and silt in retaining SOC.
- Climate: particularly temperature, influences the rate of decomposition of SOC as well as inputs.
- Baseline SOC: The capacity of soil to sequester additional carbon depends on the initial or baseline SOC content relative to the natural equilibrium for local climate and soil type. Degraded soils that have been depleted of organic matter by factors such as drought or unsustainable management practices have a greater initial capacity for increase towards a new equilibrium condition.
- Understanding SOC sequestration has been hampered by the lack of accurate, cost-effective methods for routine quantification of changes in SOC stocks in managed lands.

What does the evidence show?

- Review of publications and research reports indicated that few long-term field studies had been conducted that provide reliable measurement or model data for SOC sequestration in the grazed savannas and semi-arid/arid rangelands of northern Australia.
- High variability in soil, landscape and climate, and inconsistencies in design and measurement methods contributed to conflicting results between studies and low confidence in estimates of the potential for sequestration. However, based on evidence from past studies the preliminary conclusion is that there is likely to be modest potential for SOC sequestration for some management strategies but that more research is needed to improve confidence for strategies showing inconclusive results:
- Sowing more productive grasses or legumes in existing grass pastures increases SOC stocks, at a rate dependent on baseline soil nitrogen (N) status;
- Prolonged high stocking intensity is associated with net loss of SOC relative to conservative stocking;
- Rotational grazing strategies had negligible impact on SOC stocks relative to continuous grazing;
- Destocking or exclusion of grazing results in modest increase in SOC, especially in degraded sites;
- Conversion from cropping to permanent pasture has limited application in northern Australia but may result in sequestration depending on land management history and baseline soil condition.
- Important gaps in knowledge exist concerning the permanency of reported SOC sequestration rates. How the increase in storage will be affected by climate change is also unknown. Both accumulation and maintenance of SOC stocks reported in published science are vulnerable to global warming and extreme weather events such as drought.

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