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Biology

HOW MUCH CARBON CAN SOIL STORE?

Key points

- Increasing the total organic carbon in soil may decrease atmospheric carbon dioxide and increases soil quality.
- The amount of organic carbon stored in soil is the sum of inputs to soil (plant and animal residues) and losses from soil (decomposition, erosion and offtake in plant and animal production).
- The maximum capacity of soil to store organic carbon is determined by soil type (% clay).
- Management practices that maximise plant growth and minimise losses of organic carbon from soil will result in greatest organic carbon storage in soil.

Background

Recent interest in carbon sequestration has raised questions about how much organic carbon (OC) can be stored in soil. Total OC is the amount of carbon in the materials related to living organisms or derived from them. In Australian soils, total OC is usually less than 8% of total soil weight (Spain *et al.*, 1983) and under rainfed farming it is typically 0.7–4%. Increasing the amount of OC stored in soil may be one option for decreasing the atmospheric concentration of carbon dioxide, a greenhouse gas.

Increasing the amount of OC stored in soil may also improve soil quality as OC contributes to many beneficial physical, chemical and biological processes in the soil ecosystem (figure 1) (see Total Organic Carbon fact sheet). When OC in soil is below 1%, soil health may be constrained and yield potential (based on rainfall) may not be achieved (Kay and Angers, 1999).

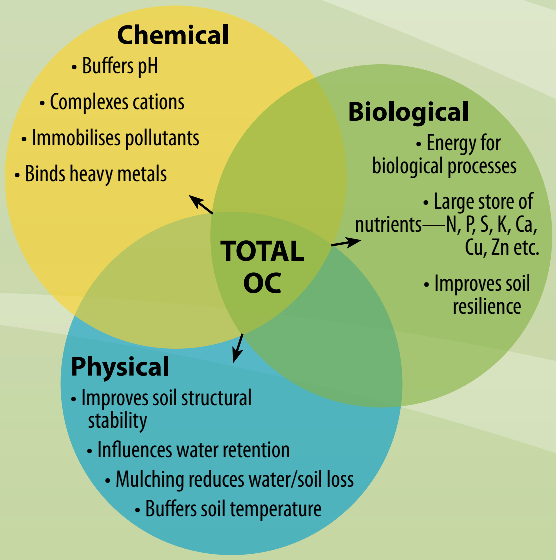

Figure 1: *Some of the beneficial physical, chemical and biological processes in soil that total OC contributes to.*

Carbon budgets in soil—Inputs and losses of organic carbon

The amount of OC stored in soil is the difference between all OC inputs and losses from a soil. The main inputs of OC to soil in rainfed farming systems are from plant material, such as crop residues, plant roots, root exudates and animal manure. Inputs of plant material are generally higher when plant growth is greater.

Losses of OC from soil are from decomposition by microorganisms, erosion of surface soil and offtake in plant and animal production. Decomposition occurs when microorganisms use OC in soil to obtain the carbon, nutrients and energy they need to live. During decomposition, OC is lost from soil because microorganisms convert about half of the OC to carbon dioxide gas (CO_2). Without continual inputs of OC, the amount stored in soil will decrease over time because OC is always being decomposed by microorganisms.

Losses of OC from erosion of surface soil can have a large impact on the amount of OC stored in soil. This is because OC is concentrated in the surface soil layer as small particles that are easily eroded. In Australian agriculture, erosion can cause the annual loss of 0.2 t/ha of soil from a pasture, 8 t/ha from a crop and up to 80 t/ha from bare fallow.

Offtake of OC in plant and animal production is also an important loss of OC from soil. Harvested materials such as grain, hay, feed and animal grazing all represent loss of OC (and nutrients) from soil.

Soil type determines the potential storage of organic carbon

The potential storage of OC in soil depends on the soil type (figure 2). Clay particles and aggregates can reduce losses of OC by physically protecting organic matter from

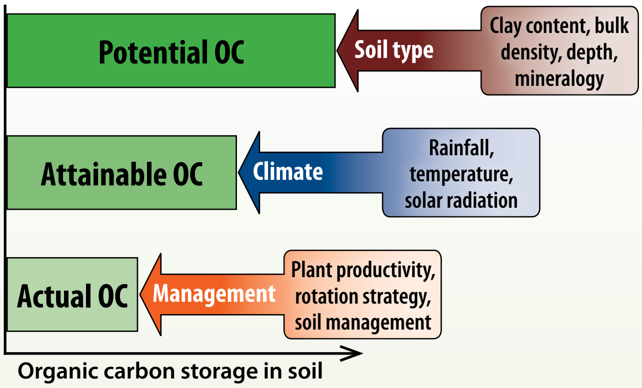

Figure 2: *The influence of soil type, climate and management factors on the storage of organic carbon (OC) that can be achieved in a given soil. Based on Ingram and Fernandes (2001).*

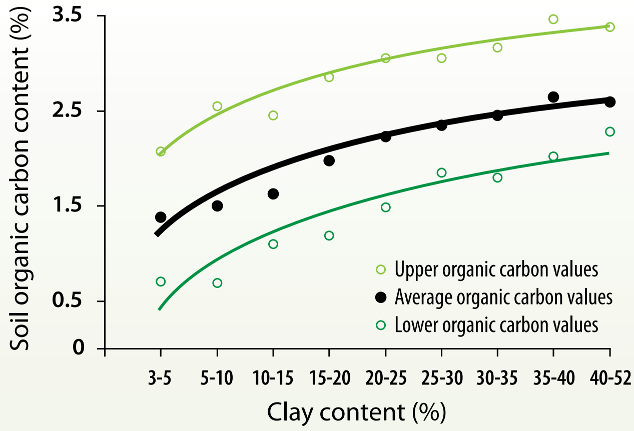

Figure 3: *The relationship between clay content and the organic carbon content of 220 soils in a 10 hectare area of a paddock under cereal-legume rotation in the central agricultural region of Western Australia.*

decomposition. Particles of organic matter can become adsorbed to clay surfaces, coated with clay particles or buried inside small pores or aggregates. All of these processes make it difficult for microorganisms to come in contact with organic matter. Therefore, the amount of OC stored in soil tends to increase with increasing clay content (figure 3). In contrast, in sand soil microorganisms are able to more easily access OC. This causes greater loss of OC by decomposition.

The potential storage of OC in soil is rarely achieved because climate reduces inputs of OC to soil.

Climate determines the attainable storage of organic carbon

Climate determines the attainable storage of OC in soil by regulating plant production (figure 2). Under dryland agriculture, rainfall is the climate factor that has most influence on plant productivity and therefore inputs of OC to soil. In regions with high rainfall, soils tend to have greater attainable storage of OC than the same soil type in a lower rainfall region.

Although it is not possible to increase the attainable storage of OC in soil, management practices determine whether or not the attainable storage of OC in soil is achieved.

Management determines the actual storage of organic carbon in soil

Management practices determine the actual storage of OC in soil by increasing inputs and decreasing losses (figure 2). Practices that can increase the amount of total OC stored in soil include:

- Increased plant growth generally increases inputs of OC to soil in shoot material, roots and root exudates, e.g. optimal nutrition, increasing water use efficiency, decreasing disease.
- Growing plants for longer periods each year generally increases inputs of OC to soil, e.g. shorter fallow, conversion from cropping to pasture, conversion from annual to perennial pasture.
- Improving soil structure can increase the amount of OC stored in soil by reducing losses of OC from soil by decomposition and erosion, e.g. retaining stubble, maintaining ground cover and reducing compaction by vehicles and stock.

References

This factsheet was based on: Hoyle F, Murphy D and Baldock G (2009) Soil organic carbon: Role in Australian farming systems. *Book chapter, in press*.

Ingram JSI and Fernandes ECM (2001) Managing carbon sequestration in soils: Concepts and terminology. *Agriculture, Ecosystems & Environment* **87:** 111-117.

Kay BD and Angers DA (1999) Soil structure. In: 'Handbook of Soil Science' (Ed ME Sumner), pp A-229-276. CRC Press, Boca Raton USA.

Spain AV, Isbell RF and Probert ME (1983) Soil organic matter. In: 'Soils—An Australian viewpoint', pp 551-563. CSIRO, Melbourne Australia. Academic Press, London UK.

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