Potential for soil carbon sequestration in Northern Australian grazing lands: A review of the evidence

Understanding soil carbon sequestration

Increasing the amount of organic matter in soil has long been recognised by agronomists and farmers as beneficial for soil health and plant growth. Soil organic matter (SOM), comprising plant residues, root exudates and microbial and larger soil fauna biomass, contains around 58% carbon (C) by mass. This C comes initially from atmospheric carbon dioxide (CO2) that is taken up by leaves in photosynthesis and converted to organic molecules for plant growth and function, in turn providing energy for the soil microbial populations and larger soil fauna that feed on them. Through the processes of respiration and decomposition much of the C cycles back to the atmosphere as CO2 in a short time (days to a few years), with only a small fraction (as little as 10% or less) stored or 'sequestered' for more than a century in the soil. This fraction represents a net removal of CO2 (a greenhouse gas, GHG) from the atmosphere and, in carbon crediting schemes such as the Australian ERF, may be issued with carbon credits sold in C markets or used to reduce a farmer's net emissions. The potential for soil carbon sequestration (SCS) is debated but there is broad consensus across both sides of this debate on the value of increasing SOM for soil health, agricultural productivity and climate resilience. Active research in Australia and globally seeks to improve understanding of the complex forms, functions, and dynamics of C in soil and resolve issues on the potential for SCS in different regions.

A review of the evidence from field studies in northern Australian grasslands and woodlands was undertaken to assess the potential for SCS using practical grazing and pasture management strategies. The review found few long-term grazing system studies with robust measurements of soil C stocks, and that there was substantial inconsistency in results across the research, in part due to differences in methods and measurement technologies or procedures. The quality of data for grazing land varied depending on how well sampling protocols accounted for spatial and temporal variability, and the diversity of production systems and management practices.

Surveys have indicated that the amount of SOC stored (standardised for 0 – 30 cm soil layer) is highly correlated with climate factors, particularly rainfall and temperature are major determinants of soil moisture, which, in turn, is a strong determinant of plant growth and, consequently, organic matter added to soil. Another driver of SOC storage is soil clay content, which is a key factor in the stabilisation and persistence of SOC. In some field surveys, the influence of management strategies on SOC stocks could not be detected unless results were detrended for the dominant non-management drivers. Accounting for climate variability requires multi-decadal observations. Well-managed long-term studies in northern Australia, notably Wambiana Grazing Trial, Kidman Springs Fire Study and Brigalow Catchment Study, provide a critical resource for evaluating management strategies and for understanding the potential for SCS in regionally important land systems and climate zones.

For the complete report: Henry, B. (2023) Potential for soil carbon sequestration in Northern Australian grazing lands: 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

Potential for soil carbon sequestration through management strategies

Evidence from published data and reports indicate that the potential for SCS with adoption of many of the management strategies relevant to northern Australian grazing lands has high uncertainty. Preliminary analysis identified opportunities for increasing soil C with certain practices, but further trials are needed to better quantify SCS.

- Livestock management studies generally show that prolonged high grazing pressure in rangelands results in soils having lower SOC content than under moderate stocking rates. Results for northern Australia are consistent with global trials, but better understanding is needed of impacts on the SOC response of climate variability and land types typical of northern Australia. There was no evidence of significant impacts on SCS for different animal type (beef cattle vs sheep vs goats) other than as a result of total grazing pressure, and no significant difference across several studies comparing rotational grazing with traditional/ continuous stocking strategies.
- Destocking and exclosure experiments indicated a small increase in SCS, averaging in the order of 0.04 t C ha−1 yr−1. Destocking may be adopted as a strategy to increase soil condition (and SOC) in limited non-productive parts of grazing properties but is not a strategy that can earn ACCUs under the 2021 ERF soil C method (Australian Government 2021, refer to Clauses 10(3) and 11(2)), as it is not an eligible activity on areas used for production.
- Pasture improvement activities include sowing more productive grasses or incorporating nitrogen-fixing legume forages into grass pastures, as strategies to improve forage. They have potential to increase SOM inputs with an indicative rate of SCS from averaging across pasture improvement studies was 0.3 t C ha-1 yr-1. Research on the production and environmental benefits of planting Leucaena and Desmanthus in pastures in northern Australia is providing more consistent evidence for significant SCS potential especially where baseline pasture growth is limited by low soil nitrogen. For legume species such as Stylosanthes spp. that have been widely planted over many years, the 'additionality' standard under the ERF which requires a 'new or materially different' activity will need to be tested for project registrations. Modelling studies show that higher productivity would likely provide greater financial benefits for producers than participation in C markets at the 2022 ACCU price of around AUD30.
- Fire management studies indicated that small gains in SOC levels may occur with reduced frequency and intensity of burning but C sequestration in soil would be modest relative to that in woody biomass and that there may be a trade-off with pasture growth as tree cover increased. The production penalty would limit adoption for SCS gain.
- Land conversion strategies most relevant to northern Australia involve changes between tree cover and grasslands. The results reported from land use change studies were strongly dependent on factors such as the time since conversion and baseline condition, notably whether soil was initially degraded and depleted of SOC relative to natural levels. In summary:
    - Conversion from crop production to perennial grasslands from various regions consistently show an increase in SCS with an average rate of 0.4 t C ha-1 yr-1. This land use change has limited application in the north.
    - Published results for SCS following conversion from forest or woodland cover to perennial grassland ranged from -0.62 to +0.12 t C ha-1 yr-1. The average was a small decrease (-0.19 t C ha-1 yr-1) but is not meaningful due to conflicting results due to differences in design and methods between studies.
    - There was little evidence from global or Australian data that conversion of well managed pasture to forest cover results in significant SCS across the range of conversion strategies (afforestation, reforestation, vegetation thickening, regrowth retention), although regeneration of woody cover through retention of regrowth on degraded land may result in higher C stocks in both soil and biomass. Well-designed studies are needed to quantify the changes in C stocks and productivity and farm business impacts to understand full benefits and trade-offs for producers interested in conversion from grassland to tree cover. [1]

The Farm Business Resilience Program is jointly funded through the Australian Government's Future Drought Fund and the Queensland Government's Drought and Climate Adaptation Program