271

XII INTERNATIONAL RANGELAND CONGRESS
AUSTRALIA 2025

Know your numbers: Soil carbon sequestration has potential to support carbon neutral red meat and wool production in semi-arid rangelands

Rigg, JL[1]; Newey, L[1]; Hackney, B[1]; Baldry, S[1]; McDonald, SE[2]; Orgill, SE[1]

[1] Select Carbon, 275 George Street, Brisbane, QLD 4000, Australia; [2] NSW Department of Primary Industries and Regional Development, Trangie, NSW 2823, Australia

Key words: Greenhouse gas emissions (GHGe); soil organic carbon (SOC); carbon neutrality; grazing management

Abstract
There is growing global pressure for agriculture, in particular red meat production, to reduce net greenhouse gas emissions (GHGe). A greenhouse gas (GHG) estimate is useful to benchmark and measure emissions and is useful to inform strategies to reduce or offset farm emissions. The average annual net farm emissions for two extensively grazed rangelands properties (Property A and B) in the semi-arid rangelands of southeastern Australia were calculated using the Primary Industries Climate Challenges Centre (PICCC) Greenhouse Gas Accounting Framework (GAF) tools over 5 years. Property A is 19,794 ha, has an average annual rainfall (AAR) of 390 mm and grazes cattle, sheep and goats for red meat production. Property B is 11,831 ha, has an AAR of 290 mm and grazes cattle and sheep for red meat and wool production. The average annual net farm emissions were 2,233 t CO_2-e/farm for Property A and 1,078 t CO_2-e/farm for Property B. As expected, in these low input systems, methane from livestock was the largest source of emissions for both enterprises.

Carbon neutrality within a farm business can be achieved when GHGe are balanced by carbon sequestered in soil and vegetation on farm. Soil is an important and large store of carbon in the landscape. Using Property A as an example, our calculations demonstrate that even a conservative increase in SOC through grazing management could increase SOC concentration by 0.05 % (e.g. from 0.53 to 0.58 % SOC; 0 to 100 cm) over a 25-year period (one of two permanence periods under the Carbon Credits (Carbon Farming Initiative) Act 2011). Calculated at property scale, this equalled 18,497 t CO_2-e per year sequestered in soil which could offset the average annual emissions produced.

Introduction
Greenhouse gases (GHG) are gases in the earth's atmosphere that trap heat. GHG reported under the Australian National GHG Inventory (National inventory report) include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other gases. There is currently very little documented evidence of emissions profiles of rangelands grazing enterprises in Australia. A farm carbon account is useful to benchmark and understand farm emissions, by accounting for sources and sinks of GHG within a farm business. The Australian red meat industry (in particular, MLA) has set the target to be carbon neutral by 2030 (CN2030). To achieve the goal of carbon neutral by 2030 producers must be able to reliably quantify and benchmark GHGe, as well as carbon stored and sequestered in

trees and soils. By benchmarking GHG emissions, producers can then determine strategies to reduce emissions and identify opportunities to sequester more carbon in soil or trees. This study aimed to benchmark GHGe over five years for two extensive grazing properties in the semi-arid rangelands of southeastern Australia and identify the potential to offset emissions via soil carbon sequestration.

Methods

A whole farm carbon account and an annual average GHGe estimate (total tonnes of CO_2-e per property) was calculated for two extensive semiarid rangelands properties in New South Wales Australia using the Primary Industries Climate Challenges Centre (PICCC) Greenhouse Gas Accounting Framework (GAF) tool (specifically the SB-GAF and Go-GAF tools, developed by the University of Melbourne). A five-year baseline (~2018-2022) was calculated, as would be typical for a soil carbon project under the following methodology: Carbon Credits (Carbon Farming Initiative - Estimation of Soil Organic Carbon Sequestration using Measurement and Models) Methodology Determination 2021 (referred to as 'the Method'). Emissions intensity (i.e, the amount of CO_2-e per kilogram of product) was also calculated for each property and each commodity. Property A is 19,794 ha, has an average annual rainfall (AAR) of 390 mm and grazes cattle, sheep and goats for red meat production. Property B is 11,831 ha, has an AAR of 290 mm and grazes cattle and sheep for red meat and wool production.

Results

Annual net farm emissions & annual emissions intensity

The average annual net farm emissions for Property A were 2,233 t CO_2-e/farm, ranging across the five years from 1,776 t CO_2-e (2019-20 FY) to 4,396 t CO_2-e/property (2022-23 FY) (Figure 1). The average annual net farm emissions for Property B were 1,078 t CO_2-e/property ranging from 528 t CO_2-e (2018-19 FY) to 1,335 t CO_2-e/farm (2021-22 FY) (Figure 2). Not surprisingly, methane from livestock was the largest source of emissions for both farms. Emissions intensity varied over the five-year period and varied by farm enterprise (Table 1).

Discussion

Globally, we are seeing a growing expectation that agriculture, amongst other industries, should work to reduce its net emissions. This is a whole of supply chain effort and red meat businesses have a part to play.

Soil is an important and large store of carbon in the landscape. There are well known benefits of increasing soil organic carbon (SOC) for agricultural productivity and landscape function. In the rangelands, well-managed grazing animals are important tools in the landscape to build soil organic matter (the driver or the first step towards accumulating SOC) by stimulating plant growth, influencing plant composition, herbage mass and ground cover, nutrient redistribution, and breaking down vegetation and litter through trampling (McDonald et al., 2023, Orgill et al. 2017, Waters et al. 2015). Gray et al (2021) estimated a carbon sequestration rate of 0.17 t C/ha/yr in the 0 to 30 cm soil layer (over 20 years) in the Western Division of NSW if a relative increase of 10 % groundcover could be achieved. However, increasing and sustaining SOC through management in Australian rangelands can be a challenge (Henry et al. 2024). Therefore, management practices which focus on livestock productivity, pasture biomass and composition, and ground cover promotion will support producers to improve their overall emissions intensity, and protect and potentially build soil carbon in Australian rangeland landscapes.

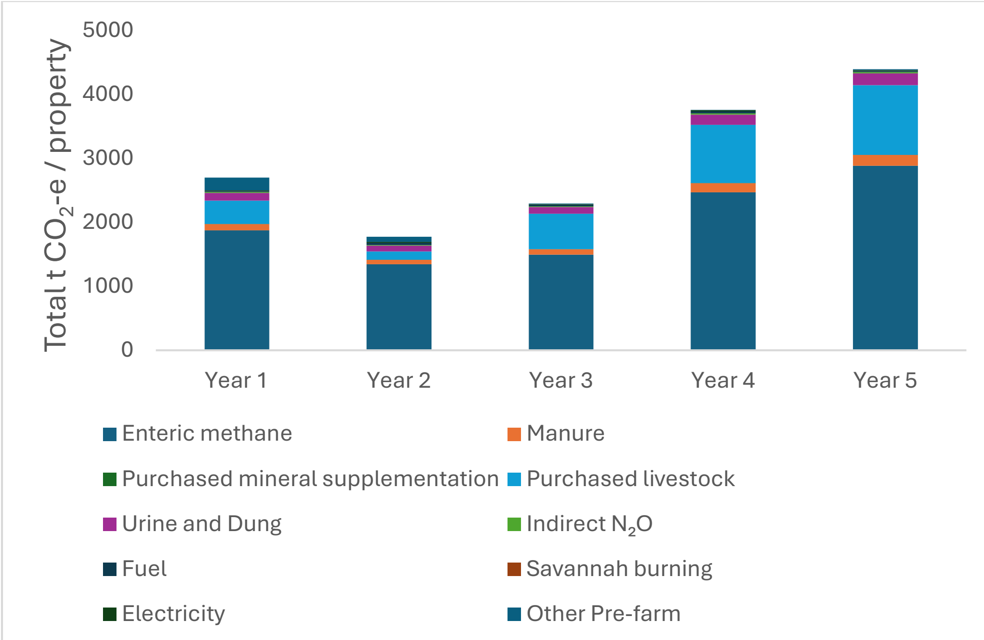

Figure 1. Annual net farm emissions (total t CO_2-e/ property) for Property A. Total emissions are the sum of all livestock enterprises on Property A including Sheep and Beef (SB-GAF) and Goat (Go-GAF). Year 1 was the start of June 2018 to end of May 2019, year 2 was the start of June 2019 to the end of May 2020, year 3 was the start of June 2020 to the end of May 2021, year 4 was the start of June 2021 to the end of May 2022 and year 5 was June 2022 to May 2023. Electricity, fuel and diesel were apportioned to each enterprise (therefore, not double counted). The category 'other Pre-farm' includes fertiliser, purchased feed, herbicides and pesticides lime and livestock away on agistment.

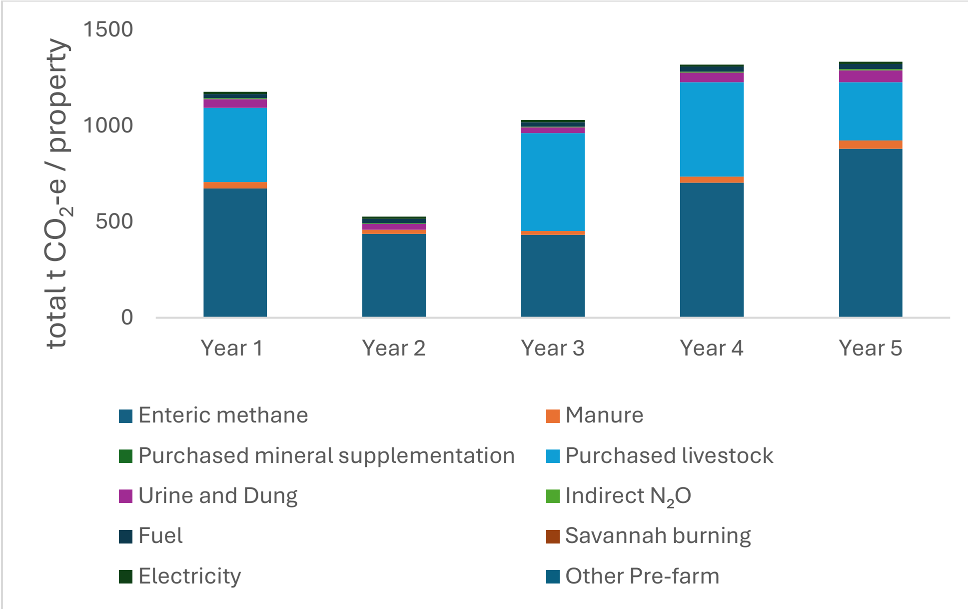

Figure 2. Annual net farm emissions (total t CO_2-e/ property) for Property B. Total emissions are the sum of all livestock enterprises on Property B including Sheep and Beef (SB-GAF). Year 1 was the 2017-18 financial year (FY), year 2 was the 2018-19 FY, year 3 was the 2019-20 FY, year 4 was the 2020-21 FY and year 5 was the 2021-2022 FY. Electricity, fuel and diesel were apportioned to each enterprise (therefore, not double counted). The category 'other Pre-farm' includes fertiliser, purchased feed, herbicides and pesticides, lime and livestock away on agistment.

Table 1. Emissions Intensity (kg CO_2-e / kg live weight (LW)) for Beef, Sheep and Goat enterprises for Property A and for Beef, Sheep and Wool enterprises on Property B over the 5-year period. The year 3 result for beef emissions intensity was artificially high (and therefore data not shown) for Property A. Beef emission intensity could not be calculated for years where there were no sales or purchases (year 2 to 4) for Property B.

Property	Enterprise	Emissions Intensity (kg CO_2-e / kg LW)				
		Year 1	Year 2	Year 3	Year 4	Year 5
A	Beef	10.6	9.0	-	29.2	15.8
	Sheep meat	49.2	15.6	16.0	15.4	13.3
	Goat	5.8	45.5	25.2	27.5	6.73
B	Beef	24.5	-	-	-	-
	Sheep meat	8.0	9.1	30.6	10.9	17.2
	Wool	25.9	28.9	95.1	34.7	53.4

Using the Property A case study as an example (average annual net emissions of 2,233 t CO_2-e), even a conservative increase in SOC sequestration could potentially offset the average annual emissions produced by the property. Assumptions and calculations to determine this are as follow:

- Grazing management increasing SOC concentration (SOC % equivalent to g/100 g) by 0.05 % (e.g. increase from 0.53 to 0.58 % SOC) over 100 cm over a 25-year period.
- Assuming a bulk density (BD) of 1.4 g/cm^3
- This equals an annual sequestration rate of 1.03 CO_2-e / ha/ year
- At the property scale, this is equivalent to 18,497 t CO_2-e per year sequestered in soil under 18,000 ha of grazed country.

This hypothetical soil carbon sequestration rate offsets even the highest annual GHGe for the 5-year baseline period. Whilst only carbon sequestration in *planted* trees is included when using the MLA GAF tools, carbon sequestration in regenerating vegetation and soil in rangeland systems may be an important consideration and, in some situations, may outweigh annual GHG emissions for a rangeland enterprise.

Acknowledgements
This work was as part of the Rangelands Living Skin Project (B.ADP.2019) funded by Meat and Livestock Australia (MLA) and NSW Department of Primary Industries (DPI). This work was completed in collaboration with Andrew and Megan Mosley and Angus and Kelly Whyte. The authors and project gratefully acknowledge their contribution.

References

Gray, JM, Wang, B, Waters, CM, Orgill, SE, Cowie, AL, & Ng, EL (2021) Digital mapping of soil carbon sequestration potential with enhanced vegetation cover over New South Wales, Australia. Soil Use and Management, 38, 229– 247. https://doi.org/10.1111/sum.12766

Henry, B, Allen, D, Badgery, W, Bray, S, Carter, J, Dalal, RC, Hall, W, Harrison, MT, McDonald, SE, and McMillan, H (2024) Soil carbon sequestration in rangelands: a critical review of the impacts of major management strategies, The Rangeland Journal 46 (3) RJ24005. https://doi.org/10.1071/rj24005

McDonald, SE, Badgery, W, Clarendon, S, Orgill, SE, Sinclair, K, Meyer, R, Butchart, DM, Eckard, R, Rowlings, D, Grace, P, Doran-Browne, N, Harden, S, Macdonald, A, Wellington, M, Pachas, ANA, Eisner, R, Amidy, M, Harrison, MT (2023) Grazing management for soil carbon in Australia: A review, Journal of Environmental Management, 347, 119146

Orgill, SE, Waters, CM, Melville, G, Toole, I, Alemseged, Y, Smith, W (2017). Sensitivity of soil organic carbon to grazing management in the semi-arid rangelands of south-eastern Australia. The Rangeland Journal, DOI 10.1071/RJ16020

Waters, CM, Melville, GJ, Orgill, SE and Alemseged, Y (2015). The relationship between soil organic carbon and soil surface characteristics in the semi-arid rangelands of southern Australia. The Rangeland Journal 37(3), 297-307.