What can grazing management realistically achieve for soil carbon in Australia?

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Abstract: *Grazing management is widely promoted as a means of increasing soil organic carbon (SOC) in Australian pastures, with producers frequently presented with claims of large potential gains. This paper synthesises findings from a systematic review of Australian grazing research (McDonald et al. 2023) and a decade-long replicated grazing experiment at Orange in NSW (Simmons et al. 2026) to provide an evidence-based assessment of what grazing management can realistically deliver for soil carbon in Australia. The review found no significant effect of stocking intensity or grazing method on SOC across 32 Australian studies. The replicated experiment found that rotational grazing systems accumulated modestly higher SOC than continuously grazed treatments (approximately 0.1 t C/ha/yr), but this difference represented only about 20% of total SOC change over 10 years and was dwarfed by gains from prior land-use change from cropping to pasture. Seasonal conditions, particularly drought, also drove large temporal fluctuations in SOC that were greater than any grazing management effect. These results indicate that claims of large, rapid SOC gains from improved grazing management are not supported by high-quality Australian evidence, and that changes observed in monitoring programs are likely to reflect land-use history and seasonal variation as much as management practice. Improved grazing management retains clear benefits for pasture productivity and ground cover, but expectations for soil carbon should be moderated.*

Key words: stocking rate, land-use change, pasture management, sequestration

Introduction

Soil carbon has attracted growing interest in the Australian grazing industry, driven by both its potential benefits for soil health and productivity and the financial opportunities offered by emerging carbon markets. Improving grazing management — through adjustments to stocking rate, rest periods and paddock rotation — is frequently promoted as a practical, low-cost method to increase soil organic carbon (SOC). Producers and advisors are regularly presented with examples of large SOC gains attributed to changed grazing practices (e.g. Mitchell *et al*. 2024), raising expectations that improved management can deliver substantial and rapid carbon benefits. However, the quality and consistency of the evidence underpinning these claims varies considerably. Many studies rely on comparisons between differently managed sites sampled at a single point in time, making it difficult to separate the effect of grazing management from pre-existing differences in soil properties, land history or seasonal conditions. Long-term, replicated experiments that are the most rigorous basis for conclusions about management effects are rare in the grazing literature. This paper brings together two complementary Australian studies: a systematic review and meta-analysis of grazing management effects on SOC (McDonald *et al*. 2023) and a 10-year replicated grazing experiment from Orange NSW (Simmons *et al*. 2026). Together, these provide an evidence-based picture of what grazing management can realistically deliver for soil carbon, and what other factors are likely to drive the SOC changes that farmers and land managers observe and measure.

What does Australian research tell us?

McDonald *et al.* (2023) conducted a systematic review and meta-analysis of 32 Australian studies examining the effects of stocking intensity and grazing method on SOC (Table 1). The analysis found no significant effect of either stocking

Table 1. Summary of meta-analysis results from McDonald *et al.* (2023) comparing the effect of stocking intensity and grazing method on SOC and key pasture variables in Australian studies.

Variable	Stocking intensity effect (%)	Grazing method effect (%)
Soil organic carbon	−1.3 (ns)	+4.4 (ns)
Herbage mass	−42*** (higher under low intensity)	+25* (higher under rest)
Plant growth rate	ns	ns
Ground cover	+8* (higher under low intensity)	+16* (higher under rest)

*ns = not significant; * $P < 0.05$; *** $P < 0.001$. Effect sizes are % change relative to higher stocking intensity or continuously grazed control.*

intensity or grazing method (continuous vs. rotational grazing) on SOC. This was despite positive effects of lower stocking intensity and rotational grazing on above-ground herbage mass and ground cover, both factors that are considered important drivers of SOC accumulation.

The lack of a detectable SOC response in Australian conditions likely reflects several factors. Australia's rainfall is among the most variable in the world, and year-to-year fluctuations in plant growth can swamp any gradual management-induced gains (Badgery *et al.* 2020). Australian soils also tend to be relatively infertile, and nitrogen availability in particular may limit the capacity of increased pasture biomass to drive SOC accumulation. Where soil microorganisms are nutrient-limited, they may break down organic matter to access nutrients, partially offsetting any gains from increased plant inputs (Kirkby *et al.* 2014).

Methodological limitations in available studies also constrained the ability to detect management-related SOC changes. Many Australian grazing studies are of relatively short duration, cover small spatial scales and rely on sampling at a single point in time. Without baseline measurements and repeated sampling, it is difficult to determine whether differences between treatments are due to management or pre-existing site variability.

Long-term replicated grazing experiment

Simmons *et al.* (2026) reported results from a 10-year replicated experiment established in 2012 at the Orange Agricultural Institute. The experiment was designed to separate the effects of stocking rate (8.8 or 13.6 dry sheep equivalents [DSE]/ha), rest period (0, 56 or 112 days between grazing events) and number of paddocks in rotation (1, 15 or 30 paddocks) on SOC stocks to 30 cm depth. A flexible grazing treatment adapted sheep number to pasture at each grazing to maintain a minimum of 600 kg green DM/ha post grazing. Soils were sampled at four time points: baseline (2011), 2015, 2018 and 2021. This design had multiple sampling dates, replication and defined treatments, which represents a high standard of evidence compared with most studies in the grazing literature.

The site had been converted from cropping to permanent pasture three years before the experiment began. This land-use change turned out to be the dominant influence on SOC throughout the experiment.

What drove SOC change?

All treatments increased SOC substantially over the 10-year period, at a mean rate of 0.77 t C/ha/yr at 0–30 cm depth. However, the rate of gain was far from steady. Accumulation was fastest in the first sampling period (2011–2015: 1.22 t C/ha/yr), reflecting the ongoing effect of the shift from cropping to pasture.

During the 2017–2019 drought, accumulation slowed dramatically (2015–2018: 0.13 t C/ha/yr), before recovering in the following period (2018–2021: 0.80 t C/ha/yr). These fluctuations across all treatments demonstrate clearly that seasonal conditions and land-use history and not grazing management were the primary drivers of SOC change at this site.

The most important biophysical driver of SOC accumulation identified in the analysis was the amount of bare ground. More bare ground was consistently associated with lower SOC gains. Maintaining ground cover, a key objective of sound grazing management, appears to be a pathway through which grazing management influences soil carbon.

How much did grazing management contribute?

Despite the dominance of land-use change and seasonal effects, grazing management did have a statistically significant influence on SOC. Rotational grazing systems with 15 or 30 paddocks and rest periods of 56 or 112 days had greater SOC stocks than continuously grazed treatments (Table 2). Stocking rate did not significantly affect SOC stocks.

Table 2. Effect of grazing system on mean SOC stock (t/C/ha) at 0–30 cm depth across all years at Orange Agricultural Institute (adapted from Simmons *et al.* 2026). Values sharing the same letter are not significantly different (*P* > 0.05).

Grazing system	SOC stock 0–30 cm (t/C/ha)
Paddock number	
Flexible	44.3[b]
1 paddock (continuous)	43.9[b]
15 paddocks	45.4[a]
30 paddocks	45.5[a]
Rest period (days)	
Flexible	44.3[b]
0 days (continuous)	44.0[b]
56 days	45.4[a]
112 days	45.7[a]
Stocking rate	
Flexible (9.6 DSE/ha)	44.3
Low (8.8 DSE/ha)	44.7
High (13.6 DSE/ha)	45.6

DSE = dry sheep equivalents. Superscript letters indicate significant differences between treatments within each grouping variable (Tukey's HSD, P < 0.05); no letters indicate no significant differences.

Across the 10-year experiment, the difference in SOC between rotational and continuous grazing equated to approximately 0.1 t C/ha/yr, representing about 20% of the total SOC change observed. Importantly, doubling the number of paddocks (from 15 to 30) or the rest period (from 56 to 112 days) did not provide additional SOC benefit; the main advantage came from including any form of rotational rest, rather than the intensity of that rotation.

What does this mean for farmers and advisors?

These results offer some important practical messages for producers and advisors thinking about grazing management and soil carbon.

Rotational grazing can help, but gains are modest. Switching from continuous to rotational grazing in improved pasture systems can deliver a genuine, if small, improvement in SOC. At this temperate high-rainfall site, the benefit equated to roughly 0.1 t C/ha/yr. Over a decade, that adds up to a meaningful difference in soil carbon, but it is far smaller than what is sometimes estimated from short-term monitoring.

Land-use history matters more than grazing management. If a property has recently transitioned from cropping to pasture or from degraded to improved pasture, SOC is likely to increase substantially regardless of the specific grazing approach taken. Attributing these gains solely to a change in grazing practice overestimates the contribution of this type of management.

Seasonal conditions can cause large swings in measured SOC. The drought of 2017–2019 suppressed SOC accumulation across all treatments at the Orange site. Any monitoring program that happens to sample before and after a drought period will record very different SOC changes from one that samples during wetter years. This means that single measurements or short monitoring windows can be highly misleading.

More paddocks or longer rest periods do not always give more carbon. Moving from 15 to 30 paddocks, or extending rest from 56 to 112 days, did not increase SOC beyond what was achieved by basic rotational systems. Simple rotational management that prevents severe overgrazing and maintains ground cover appears to capture most of the available benefit.

Ground cover is a key link between grazing and soil carbon. The most consistent driver of SOC gains across all treatments was maintaining good ground cover. Management that protects ground cover — whether through rotation, reduced stocking rates, or strategic spelling — is most likely to support soil carbon, alongside the better-established benefits for productivity and landscape resilience.

Conclusions

The Australian evidence, including both a comprehensive review of 32 studies and a high-quality 10-year replicated experiment, indicates that grazing management alone has a modest and context-dependent influence on SOC. Where differences are detected, they are relatively small and are substantially outweighed by the influence of land-use history and seasonal conditions. Improved grazing management that maintains ground cover and allows some pasture recovery can provide a real if incremental benefit to soil carbon in improved pasture systems. However, expectations of the gains achievable through grazing management are likely to be in the range of ~0.1 t C/ha/yr under favourable conditions, which is meaningful for soil health and productivity but modest in the context of carbon accounting or offsetting livestock emissions. When assessing or monitoring soil carbon on farm, it is important to consider what else may have changed. A recent shift from cropping to pasture, a run of good seasons, or improved fertiliser management will all drive SOC increases that can easily be mistaken for the effect of grazing management. Robust monitoring requires baseline measurements, repeated sampling over time, and accounting for these broader influences.

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