Grazing management is linked to increased soil carbon in southern NSW

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Key findings

- Grazing treatment had no influence on pasture sward composition when averaged over seasons.
- Grazing, rather than the type of grazing management, increased soil carbon under native pastures.
- Soil under cell-grazed pastures had a significantly greater carbon stock to 0.30 m compared with ungrazed pastures (32.9 t C/ha vs 25.6 t C/ha), however, there was no difference between cell and tactically grazed (29.5 t C/ha) pastures.

Introduction

Grazing management is a known influence of organic carbon (OC) accumulation in agricultural soil, but there is conflicting evidence on the extent. This study compared OC and nitrogen (N) stocks at the conclusion of a five-year grazing trial on a fertilised native pasture in south-eastern Australia. The study included three grazing treatments: ungrazed, tactically grazed (set stocking with biannual rest periods) and cell grazed (intense stocking with frequent long rest periods).

Site details

Site

The replicated trial was conducted on a commercial sheep property near Berridale in south-eastern NSW. The trial was part of the Monaro Research, Development and Demonstration of Sustainable Grassland Management Project 2005–2010 (MRDSGM; SECMB C1/8) (Pope et al. 2011). Berridale has an average annual rainfall of 582 mm (1947–2015), which is summer dominant, and average annual maximum and minimum temperatures of 18 °C and 4 °C (Bureau of Meteorology). There was below average annual rainfall for the five years before the trial started, and for all years of the trial with the exception of 2007 (Figure 1).

The site was native grassland dominated by native perennial grass species, including wallaby grasses (*Rytidosperma* spp.), speargrasses (*Austrostipa* spp.) and snowgrass (*Poa sieberiana*). Naturalised annual grasses, legumes and weeds were also present. The site had been grazed by sheep since the early 1900s and had never been cultivated. Before the trial was established, the site had no fertiliser applied and no introduced pasture species sown. The stocking rate before the experiment was three dry sheep equivalent (DSE) per hectare.

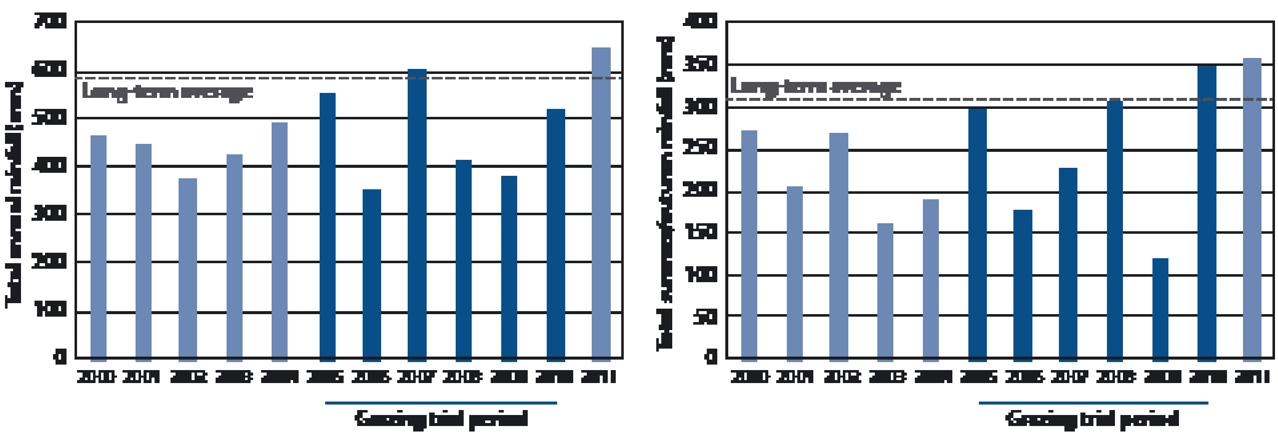

Figure 1. Annual rainfall and summer plus autumn; December to May rainfall (mm) for the Berridale grazing trial site for 2000–2011. Data was taken from the Berridale Bureau of Meteorology station (071022) and incomplete years (2000–2006) substituted by the nearest station: Cooma airport (070217). Long-term average is from the Berridale Bureau of Meteorology station (071022) and calculated from 1947 to 2015.

Soil type

The soil is classified as a brown chromosol (Australian Soil Classification) derived from biotite granodiorite. The A1 horizon (0–0.08 m) is a sandy loam, with a pH_{Ca} of 5.0 and cation exchange capacity (CEC) of 5.8 cmol+/kg. The A2 horizon (0.08–0.32 m) is a light sandy clay loam, with a pH_{Ca} of 5.3 and CEC of 3.6 cmol+/kg. The B2 horizon (0.32–0.45 m) is a medium clay, with a pH_{Ca} of 5.5 and CEC of 11.1 cmol+/kg.

Fertiliser

The grazing treatments selected for this study were located within a high fertiliser treatment, with subterranean clover (*Trifolium subterraneum*) broadcast before grazing started. The high fertiliser treatment aimed to rapidly achieve the Colwell P target (>30 mg/kg) with 250 kg/ha of single superphosphate applied annually in autumn, after which the maintenance phosphorus (P) was applied based on the stocking rate. In 2006, gypsum (125 kg/ha) was applied to address sulphur (S) deficiencies.

Grazing trial design

Grazing treatments, ungrazed, tactically grazed and cell grazed, were replicated across three fields that had similar soil–landscape attributes and were located within 500 m of one another. The grazing treatment plots (three small fenced areas in each field; 10 m × 10 m) were established in October 2005 and grazed by Merino wethers. The ungrazed plots were excluded from grazing for the duration of the trial. The tactically grazed plots were rested for 4–6 weeks over late spring/summer and late summer/autumn to allow seed set and recruitment. The cell grazed plots were grazed four to five times a year by mob stocking, with long and variable rest periods between grazing. Every 80 to 120 days, the cell grazed plots were grazed for one day at a stocking density that was estimated at approximately 300–400 DSE/ha during grazing and an average annual stocking rate that represented the background stocking rate of the field. For more information see Pope et al. (2011).

Results

Pasture composition

When the functional groups of annuals, perennials and legumes were considered, grazing treatments did not affect sward composition when averaged over seasons (Figure 2). However, there was a significant (P<0.05) interaction between season and grazing treatment on the annual grass composition. This was due to tactically grazed pastures having a greater proportion of annual grasses than the cell and ungrazed treatments in 2006 (Figure 2). This response is likely due to their first closure in autumn 2006 as part of the treatment plan. From 2005 to 2009 there was no grazing treatment effect on pasture composition. There was a significant (P<0.05) effect of season on pasture composition in 2010, coinciding with above-average summer and autumn rainfall (Figure 1), and resulting in increased legumes and consequent decline in perennial grasses (Figure 2). The perennial grass, annual grass and legume species were primarily one of four species; *Rytidosperma* spp (wallaby grass) and *Austrostipa* spp (spear grass) for the perennial grass species, *Vulpia* spp (silver grass) for the annual grass species (although annual grasses represented less than 5% of the total pasture composition) and *Trifolium arvense* (hare's foot clover) for the legume species.

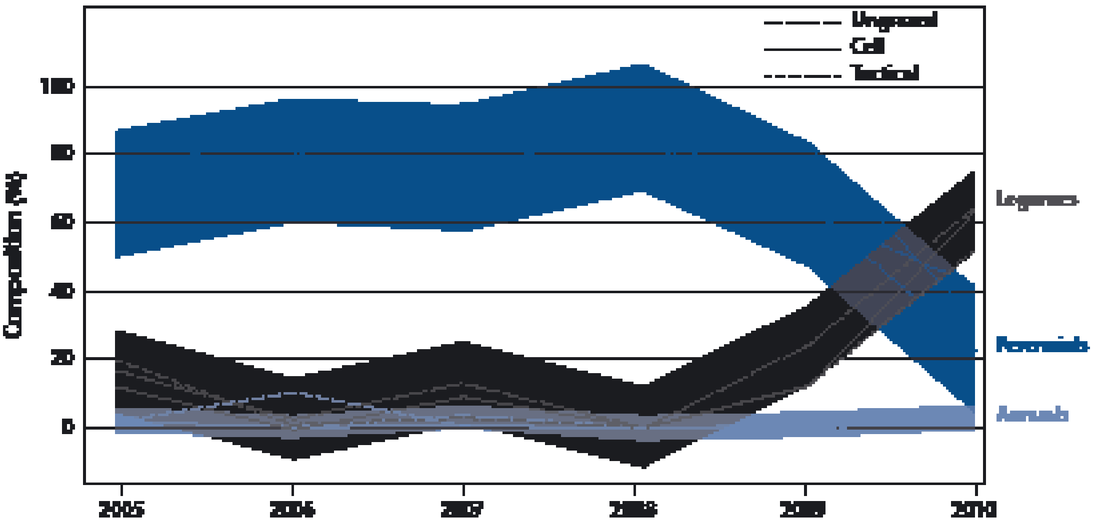

Figure 2. Percentage of perennial grasses, annual grasses and legumes for the ungrazed, cell grazed and tactically grazed treatments. Samples collected in spring 2005–2010. An approximate 95% confidence region for the ungrazed treatment is indicated by shading.

Soil carbon

There was a significantly ($P<0.05$) higher stock of OC in the 0–0.30 m soil layer (calculated on an equivalent soil mass – ESM) under the cell-grazed treatment compared with the ungrazed treatment; 32.9 t C/ha vs 25.6 t C/ha respectively (Table 1). However, there was no difference in OC stocks between the cell and tactically-grazed treatments (32.9 t C/ha vs 29.5 t C/ha respectively) suggesting that it was the presence of grazing, rather than that type of grazing management that influenced OC stocks. When OC stocks for individual soil layers were compared (on a soil-depth basis), the effect of grazing treatment was statistically important ($P<0.05$) and reasonably consistent across all soil layers (Table 1).

We propose that a combination of factors contributed to a greater OC stock in soil OC under grazed pastures including:

- differences in plant shoot/root allocation
- root growth and root turnover with defoliation under grazing
- lower plant productivity where grazing is excluded due to shading and nutrient tie-up.

Summary

This study demonstrated that removing grazing is unlikely to increase soil C stocks under native pastures in southern Australia, and that actively grazing pastures can significantly increase soil C stocks. Whilst there was no significant difference in soil C between cell or tactical grazing treatments, cell-grazing native pastures significantly increased soil C in the 0–0.30 m soil layer compared with the ungrazed treatment on a shallow granite-derived soil. Unlike other grazing studies where grazing management is suggested to increase C stocks in the surface soil as a response to trampling and manure, statistically important increases were only detected when the 0–0.30 m soil layer was compared across treatments.

There was no difference detected in labile C or N stocks due to grazing treatment, which may indicate that the differences in soil C stocks were not from short-term accumulation of particulate OM, such as seasonal pasture growth, but might be from longer-term (5 years) management.

Despite lower than average rainfall during the trial, soil C under native pastures on shallow granite-derived soil responded to grazing management. It is unknown whether cell grazing would affect soil C stocks under introduced pastures under similar conditions, or in the more fertile and productive basalt- and deep granite-derived soils of the Monaro region, which already have higher C stocks.

Table 1. Mean total OC, total N and labile C stock (t/ha) for the 0–0.30 m layer (in 2011) calculated on an equivalent soil mass (ESM), and in soil layers to 0.40 m calculated based on soil depth. Least significant difference (l.s.d.) and standard error of means (sem) presented.

Carbon and nitrogen stocks (t/ha)	Soil depth (m)	Grazing treatment			l.s.d.	sem
		Ungrazed	Tactical	Cell		
OC stock	0–0.30 (ESM)	25.6	29.5	32.9	7.1	1.8
Total N stock	0–0.30 (ESM)	2.5	2.7	2.7	0.7	0.2
Labile C stock	0–0.30 (ESM)	7.3	8.1	9.1	2.9	0.7
OC stock – soil layers	0–0.05	8.4	9.5	10.6	3.4	0.9
	0.05–0.10	5.8	6.1	7.4		
	0.10–0.20	7.2	8.6	8.6		
	0.20–0.30	4.2	5	6.3		
	0.30–0.40	4.7	4.5	5.5		
Total N stock – soil layers	0–0.05	0.7	0.8	0.8	0.3	0.1
	0.05–0.10	0.6	0.5	0.5		
	0.10–0.20	0.7	0.7	0.7		
	0.20–0.30	0.6	0.6	0.6		
	0.30–0.40	0.7	0.6	0.6		
Labile C stock – soil layers	0–0.05	2.9	3.1	3.4	1.3	0.3
	0.05–0.10	1.7	1.7	2.4		
	0.10–0.20	1.8	2.1	2		
	0.20–0.30	0.9	1.2	1.4		
	0.30–0.40	1.2	0.9	1.2		

Furthermore, these results are from the conclusion of a replicated grazing trial conducted with small plot treatments, which brings the benefits of controlling environmental factors that influence soil C, such as climate, topography, aspect, soil type, controlling grazing pressure and reducing the spatial variability of soil C. However, grazing management occurs at the farm scale, and particularly for the cell-grazing treatment, measuring changes in soil C is likely to be more complex with field size, number of cells, distance to water, and variations in soil properties and pasture composition likely to influence the grazing treatment effects and soil C interactions.

This study provides evidence that there is the potential for agricultural soils to have higher soil C stocks as a result of grazing management compared with no grazing in the short term.

References

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Acknowledgements

The authors would like to acknowledge the Monaro Research, Development and Demonstration of Sustainable Grassland Management Project 2005–10 for trial and pasture data. This paper was part of a PhD thesis through Charles Sturt University and is published in the journal: *Land Degradation & Development*. DOI: 10.1002/ldr.2560.