The influence of managing grazing intensity on soil organic carbon and biodiversity

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Abstract

Total grazing pressure (TGP) management is advocated to increase ground cover but few rangeland studies have provided direct evidence of the relationship between management and natural resources. Using four paired paddock contrasts at two study sites in semi-arid western NSW, the effects of holistic grazing management (high intensity/short duration) with or without TGP fencing on soil organic carbon (SOC), ground cover, perennial grass utilisation and biodiversity (floristic and invertebrates) were examined. Grazing management did not significantly effect SOC in the surface 5 cm but we found a highly significant ($P<0.001$) relationship between perennial ground cover and SOC. Holistic grazing management resulted in higher perennial ground cover ($P<0.01$), higher plant species diversity ($P<0.001$) and a higher number of invertebrate Orders compared with continuously stocked paddocks. Significantly higher perennial ground cover ($P<0.001$), higher plant diversity and lower perennial grass utilization were found where TGP exclusion fencing was combined with holistic grazing management. We provide evidence for the co-benefits (ground cover and biodiversity) associated with managing both the total grazing pressure and incorporating strategic periods of pasture rest under holistic grazing management.

Introduction

Considerable opportunity to sequester carbon in Australian rangeland soils has been highlighted. Much of this opportunity is due to relatively low soil organic carbon concentrations and extensive areas covered by rangelands. Little data is available on the impact of grazing management to achieve changes in SOC in these areas exists. Due to the inherent link between ground cover, SOC and soil conservation, there may be significant co-benefits of adopting improved pastoral management techniques. Anecdotal evidence suggests the current best practice approach to improve ground cover in the rangelands includes the control over total grazing pressure (TGP), using exclusion fence. The impact of this practice on carbon sequestration in soil or the prevention of lost soil carbon through erosion is a focus of this ongoing study.

Methods

Site descriptions are given in Table 1. Holistic grazing management was compared with continuous stocking (Site 1) and with high or low external grazing pressure with no domestic stock (reference sites) at Site 2. Soil organic carbon (SOC) was determined by dry combustion (LECO combustion furnace) on the < 2 mm soil fraction for the soil surface (0-5 cm), sampled at a minimum of 200 m intervals within each paddock. At each sampling location, soil was sampled in the centre of a 0.25 m^2 quadrat. At each location, the number of plant species, percentage perennial and bare ground and utilization of dominant perennial grass within two (0.25 m^2) quadrats (beneath the soil core and a random quadrat) was estimated. Invertebrates were recorded using randomly located pitfall traps along two 50m transects within each paddock at both sites spring 2014. Ten pitfall traps were placed at 5m intervals along each transect. The contents of cups were removed at and identified to Order for each paddock.

Mixed linear models were then used to examine relationships between soil variables and ground cover, floristic diversity and perennial grass utilisation specifying site as a random effect. All analyses were undertaken using R Version 2.13 (R Development Core Team, 2011). The total numbers of invertebrate Orders in each paddock are reported here.

Results

Significant differences in ground cover were found at Site 1 ($P<0.01$) with 9 % higher perennial ground cover and 20% less bare ground associated with holistic grazing (high intensity/short duration) compared to continuous stocking (Table 2). The number of plant species was also significantly higher ($P<0.001$) with holistic grazing compared with continuous stocking. Higher total number of invertebrate Orders was found in the holistic grazed paddock. No significant difference in grass utilisation or SOC was found between paddocks at Site 1, however, SOC was significantly ($P<0.001$) influenced by perennial ground cover. For example, SOC (g/100g) predicted means (se) for 30 % and 5 % perennial ground cover were 0.61 (0.039) and 0.46 (0.044) respectively.

At Site 2, significantly ($P<0.001$) lower levels of perennial ground cover were associated with no stock - higher TGP and higher perennial ground cover with lower external grazing pressure (Table 2). Holistic grazing management (+ TGP fence) had a significantly ($P<0.001$) greater number of plant species but no stock + low TGP had a higher number of invertebrate Orders. Significantly ($P<0.001$) higher levels of grass utilisation were associated with high TGP. High TGP (no domestic stock) also had significantly ($P<0.001$) higher levels of SOC than other paddock contrasts.

Discussion

While there was no difference in SOC due to grazing management, there was a significant relationship between SOC and perennial ground cover at both sites. The effect of management on ground cover suggests SOC may also be influenced, perhaps over a longer time frame than reflected in the management history (i.e. >10 years). The higher concentration of SOC found at Site 2 under high TGP (no domestic stock) is likely due to the higher density of trees in this paddock (Belay and Kebede 2010). At Site 2, no stock + low TGP was considered a 'pristine' reference site but had lower concentrations of SOC and lower numbers of plant species compared with holistic grazing + TGP fence. This may indicate opportunities for grazing management to influence the concentration of SOC through increased above and below ground biomass (and associated root exudate, Stockmann *et al*. 2013) resulting from higher pasture utilization.

The number of invertebrate Orders suggests, the habitat value of increased ground cover may be greater when grazing is absent. Determining the differences in plant functional types (perennial/annual and native/exotic) as well as invertebrate species for each location will be undertaken as part of this ongoing study. High levels of TGP (goats and kangaroos) at Site 2 resulted in almost double the amount of bare ground, lower floristic diversity and greater levels of grass utilisation. The magnitude of these effects may be considerably higher if domestic stock were also included. In the absence of high levels of TGP, Site 1 provides an insight to the effect of holistic management which appears to provide multiple benefits in terms of ground cover and biodiversity.

References

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Table 1 . Descriptions of the two study sites. At each site, paddocks were compared within the same Land System.

Site	Management	Bioregion	Land System	Soil Type (ASC)	No. soil samples	No. 0.25m^2 quadrats	Total paddock area (ha)	Domestic grazing pressure[1.]	Non-domestic grazing pressure[2.]	
									goats	kangaroos
1	Holistic (>10 years)	Darling Riverine Floodplain	Wongol	Vertosol	49	98	575	High	Low	Low
	Continuously stocked (>20 years)	Darling Riverine Floodplain	Wongol	Vertosol	43	96	1831	Low	Low	Low
2	Holistic + TGP fence (>10 years)	Cobar Peneplain	Penshurst	Kandosol	20	40	232	High	None	Low
	No stock + high TGP (>20 years)	Cobar Peneplain	Penshurst	Kandosol	20	40	1472	None	High	High
	No stock + low TPG (>20 years)	Cobar Peneplain	Penshurst	Kandosol	20	40	218	None	Low	Low

1. Derived from landholder records averaged over period 2010 to 2013; [2.] Animal counts represent average density (km^2) sourced from 2010, 2011, 2012 and 2013 annual aerial survey as part of the NSW Kangaroo Management Program.

Table 2. Predicted means (se) for six variables (percentage ground cover; soil organic carbon (SOC, 0-5 cm); number of plants; plant utilization for key perennial grass and invertebrate Orders. Means are given for different grazing management strategies on a Vertosol (site 1) and Kandosol (Site 2).

Site	Paddock	Management	Percentage ground cover		SOC (g/100g)	No. Plants (0.25m^2)	Utilization of key perennial grass (%)	No. Invertebrate Orders (50m transect)
			Perennial	Bare				
1	2	Holistic (>10 years)	25.6 (2.32)	36.1 (3.82)	0.54 (0.039)	2.36 (0.174)	36.2 (5.83)	18
	1	Continuously stocked (>20 years)	16.6 (2.44)	56.1 (4.03)	0.51 (0.038)	1.46 (0.150)	45.6(5.31)	15
2	1	Holistic + TGP fence (>10 years)	15.0 (2.81)	17.0 (2.84)	1.13 (0.075)	7.07 (0.330)	33.4 (4.16)	18
	1	No stock + high TGP (>20 years)	2.5 (2.81)	30.3 (2.84)	1.41 (0.082)	6.17 (0.330)	77.3 (6.43)	18
	1	No stock + low TPG (>20 years)	19.0 (2.68)	12.5 (2.93)	1.05 (0.076)	5.25 (0.314)	3.1 (3.89)	20