

Soil carbon under perennial pastures; benchmarking the influence of pasture age and management

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Abstract. This paper reports baseline soil carbon stocks from a field survey of 19 sites; 8 pairs/triplet in the Monaro region of New South Wales. Site comparisons were selected by the Monaro Farming Systems group to demonstrate the influence of land management on soil carbon, and included: nutrient management, liming, pasture age and cropping history. Soil carbon stocks varied with parent material and with land management. The fertilised (phosphorus) native perennial pasture had a greater stock of soil carbon compared with the unfertilised site; 46.8 vs 40.4 Mg.C.ha to 0.50 m. However, the introduced perennial pasture which had been limed had a lower stock of soil carbon compared with the unlimed site; 62.8 vs 66.7 Mg.C.ha to 0.50 m. There was a greater stock of soil carbon under two of the three younger (<10 yr old) perennial pastures compared with older (>35 yr old) pastures. Cropped sites did not have lower soil carbon stocks at all sites; however, this survey was conducted after three years of above average annual rainfall and most sites had been cropped for less than three years. At all sites more than 20% of the total carbon stock to 0.50 m was in the 0.30 to 0.50 m soil layer highlighting the importance of considering this soil layer when investigating the implications of land management on soil carbon. Our baseline data indicates that nutrient management may increase soil carbon under perennial pastures and highlights the importance of perennial pastures for soil carbon sequestration regardless of age.

1. Introduction

Well-managed, perennial pastures may increase soil carbon (C) agricultural soils compared with cropping systems [1]. This is due to the extensive fibrous root systems of perennial pastures that may contribute more organic matter (OM) through root biomass and create drier soil conditions, and the minimal soil disturbance compared with most agricultural crops and cropping practices. In this study we used a paired-site approach to benchmark and compare; a) the age and management of perennial pastures on soil C stocks and b) the impact of changing land use from perennial pasture to annual cropping on soil C stocks. This paper presents baseline soil C (Mg.C.ha to 0.30 and 0.50 m) data for the Monaro region, New South Wales (NSW).

2. Methods

Site location and sampling

Nineteen sites were sampled in the Monaro region, southern NSW. The Monaro region is located 800 m above sea level with an average annual rainfall of 645 mm and is classified as Cfa - Köppen-Geiger



climate classification [2]. Paired or triplet study sites were selected where the desired comparison was within 500 m. To be included in the paired comparison, sites were required to be on the same parent material (granite, sedimentary or basalt) and have similar soil and landscape attributes. Site comparisons were selected by the Monaro Farming Systems land-holder group to demonstrate the influence of management practices on soil C (Table 1). Sites with native perennial pastures (NPP) had never been cultivated and were typically wallaby grasses (*Rytidosperma spp.*), speargrasses (*Austrostipa spp.*) and snowgrass (*Poa sieberiana*). Introduced perennial pastures (IPP) were typically phalaris (*Phalaris aquatica L.*) and cocksfoot (*Dactylis glomerata L.*). Both NPP and IPP included exotic annual species such as subterranean clover (*Trifolium subterraneum*). Sites were sampled on a 25 x 25 m sampling grid according to SCRP protocols [3] using a hydraulic soil corer in late spring 2012. Ten cores were collected at each site to 0.50 m using a 40 mm diameter core and combined to form one composite sample for each soil layer (0.10 m increments) for each site. Four cores were collected to 0.50 m using a 75 mm diameter core for bulk density (BD).

Table 1. Comparison details and site history for each parent material class. Vegetation types include: native perennial pastures (NPP), introduced perennial pastures (IPP), crop and pine plantation. Soil treatments include: liming and phosphorus (P) application.

Parent material	Comparison	Treatment
Granite	IPP: Limed vs unlimed NPP vs <5 yr old IPP vs Crop	2.5t/ha lime broadcast in 2002. IPP sown 1970. Crop (wheat): cropped since 2011 (previously IPP). New IPP sown 2011 (previously cropped since 2009 from IPP).
	IPP: High P vs Low P	High P site: P management plan since 2005. Low P; nil P. High P and low P application on native pasture
Sedimentary	IPP: Aspect North vs South	IPP sown 1989 and pasture improved in 2010
	IPP: <10 yr old vs >35 yr old >35 yr old IPP vs Crop vs Pine plantation	Old IPP sown in 1974. New IPP sown in 2003. IPP sown in 1960. Crop (oats): cropped since 1998. Pine plantation established 2002.
	NPP vs <5 yr old IPP vs Crop	Crop (wheat): cropped since 2009 (previously NPP). New IPP sown 2010 (previously cropped since 2004 from IPP).
Basalt	NPP vs Crop	Crop (barley): first year crop (previously NPP).

Analytical methods

Total Carbon (TC g/100g) was determined on all samples using a LECO (CNS 2000) combustion furnace [4]; Method 6B3). Bulk density (BD) was determined for each core and each depth interval as described by Dane and Topp [5]. Results were calculated as BD in g/cm³ on an oven-dry basis. Results for this paper are reported as C stock in Mg.C.ha calculated by fixed depth C stock (FDCS); FDCS (Mg C ha) = TC (g/100g) x BD (g/cm³) x depth (cm) x gravel correction factor.

3. Results and Discussion

Parent material significantly influenced the stock of soil C; with basalt- and sedimentary-derived soil having a significantly greater stock of C ($P < 0.05$) in the 0 to 0.50 m compared with granite-derived soil; 77.5 (7.1 sd) vs 72.1 (17.2 sd) vs 54.9 (9.3 sd) Mg.C.ha respectively. The 0.30 to 0.50 m soil layer contained a considerable proportion of soil C with on average 31 %, 21 % and 24 % measured in the 0.30 to 0.50 m layer for basalt-, sedimentary- and granite-derived soil respectively. This highlights the importance of considering this soil layer when investigating the implications of land management on soil C stocks.

The high P treatment under NPP on granite-derived soil had a greater stock of soil C compared with the low P treatment; 46.8 vs 40.4 Mg.C.ha to 0.50 m (Table 2). Granite-derived soil in the

Monaro region are inherently low in P. Addressing the P requirements of pastures can increase above and below ground biomass and therefore OM supply to the soil [6] and can increase the stability of soil C [7].

The limed treatment under IPP on granite-derived soil had a lower stock of soil C compared with the unlimed site; 62.8 vs 66.7 Mg.C.ha to 0.50 m (Table 2). This is consistent with Chan et al. [6] and may indicate increased microbial decomposition of native soil C when acidic soil constraints are removed by liming.

Interestingly, there was a greater stock of soil C under two of the three younger (<10 and <5 yr old) perennial pastures compared with older pastures (>35 yr old IPP or NPP). The <5 yr old pasture on sedimentary-derived soil which had more soil C (+29.5 Mg.C.ha to 0.50 m) compared with the older pasture was sown in 2010 and had been cropped for the previous 6 years. Therefore this greater stock of soil C may be explained by continued fertiliser (N,P,S) application during both the cropping and pasture phase and the three years of above average rainfall since pasture establishment in 2010.

Two of the cropping sites; one on sedimentary-derived soil and one on basalt-derived soil, had a lower soil C stock compared with their perennial pasture pair; 54.6 vs 60.2 and 72.4 vs 82.5 Mg.C.ha to 0.50 m respectively (Table 2). However, there was no difference between the cropped and pasture site on granite-derived soil and there was a greater stock of soil C under the cropped site compared with the NPP on the remaining sedimentary-derived soil; 60.6 vs 68.0 Mg.C.ha to 0.50 m (Table 2).

Table 2. Carbon stocks (Mg/C/ha) for the 0 to 0.30 and 0 to 0.50 m soil layers. Underlined treatments were used to calculate differences in carbon stock (Mg/C/ha) for a given pair/triplet.

Parent material class and comparison	Treatment	C stock (Mg.C/ha)		Comparison (Mg.C/ha)	
		0 - 0.30 m	0 - 0.50 m	0 - 0.30 m	0 - 0.50 m
<i>Granite derived soil</i>					
NPP: <u>Low P</u> vs High P	NPP Low P	32.92	40.44		
	NPP High P	36.29	46.08	(+) 3.4	(+) 5.6
IPP: <u>Unlimed</u> vs Limed	Unlimed	52.8	66.7		
	Limed	46.9	62.8	(-) 5.9	(-) 3.9
<u>NPP</u> vs <5 yr old IPP vs Crop (wheat)	NPP	41.4	58.5		
	IPP <5 yr old	39.5	51.5	(-) 1.9	(-) 7.0
	Crop	41.4	58.1	0.0	(-) 0.4
<i>Sedimentary derived soil</i>					
IPP: <u>Northern</u> vs Southern Aspect	Northern Aspect	47.3	56.4		
	Southern Aspect	45.7	55.6	(-) 1.6	(-) 0.8
IPP: <u><10 yr old</u> vs >35 yr old	IPP <10 yr old	75.2	92.7		
	IPP >35 yr old	73.6	96.6	(+) 1.5	(-) 3.9
	IPP >35 yr old	45.2	60.2		
<u>IPP >35 yr old</u> vs Crop (oats) vs Pines (10 yr old)	Crop	42.7	54.6	(-) 2.5	(-) 5.6
	Pines (10 yr old)	67.2	85.7	(+) 22.0	(+) 25.4
	NPP	46.5	60.6		
<u>NPP</u> vs <5 yr old IPP vs Crop (wheat)	IPP <5 yr old	70.3	90.1	(+) 23.8	(+) 29.5
	Crop	52.1	68.0	(+) 5.7	(+) 7.4
<i>Basalt derived soil</i>					
<u>NPP</u> vs Crop (barley)	NPP	61.3	82.5		
	Crop	46.8	72.4	(-) 14.5	(-) 10.1

4. Conclusion

Soil C stocks in the Monaro region varied with parent material and with land use and management. Our baseline information from 19 sites; 8 pairs/triplets, in the Monaro region of southern NSW indicates that nutrient management may increase soil C stocks under perennial pastures. This field survey also highlights the importance of perennial pastures, regardless of pasture age, for the accumulation of C in soil. In this field survey cropping did not decrease soil C stocks at all sites and cropping may therefore offer an opportunity for landholders to diversify their enterprise without compromising soil C in the long-term. However, three of the four cropped sites had only been cropped for less than three years, and these three years coincided with three years of above average annual rainfall in the Monaro region. Furthermore, the vulnerability of C to decomposition (that is, C fractions) was not investigated in this study and it suspected that under different previous rainfall circumstances these results may have been different.

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