

Soil carbon storage in the root zone of a perennial grass pasture

Phil Ward¹, Rob Wochezlander², David Ferris³, Clinton Revell³ and Richard Harper²

¹ CSIRO Agriculture Flagship, Private Bag 5, Wembley WA 6913, phil.ward@csiro.au

² Murdoch University, Veterinary and Life Sciences, 90 South St, Murdoch WA 6150

³ Department of Agriculture and Food WA, 3 Baron-Hay Court, South Perth WA 6151

Abstract

Carbon sequestration in soils is an issue of international significance, as soils represent a large carbon pool and can be a major sink for atmospheric carbon dioxide. In southern Australia, soil carbon under agricultural land uses has received attention, particularly in relation to the potential for perennial plants to sequester carbon. Although considerable attention has been applied to carbon sequestration associated with reforestation, there has been less work associated with perennial pastures. It can be argued that farmers are more likely to change pasture than undertake reforestation, thus if carbon mitigation via the land sector is to occur over large areas, the dynamics of carbon under perennial pastures needs assessment. Standard soil testing for carbon stocks extends to a depth of 0.3 m whereas perennial pastures have the potential to grow roots much deeper than this, and potentially can have impacts on soil carbon storage to the full depth of the root zone. In this research we measured soil carbon to a depth of 4.0 m under a replicated trial on a deep sandy soil including plots of Gatton panic (*Megathyrsus maximus*) and plots of a barley/lupin rotation, five years after commencement of the trial. Soil water measurements suggested a maximum rooting depth for the pasture of 3.5 m, and 1.5 m for the annual crops. Despite differences in root depth, there were no significant differences in soil carbon between the two land uses. However, total soil carbon storage was considerably higher (44 t C/ha) when measured to a depth of 4 m compared with the standard 0.3 m depth (23 t C/ha).

Key words

Sub-tropical pasture, Evercrop

Introduction

Increasing atmospheric carbon dioxide concentrations have generated interest in the global carbon cycle, particularly with regard to major storage pools for carbon. Soil carbon is one such major pool, and can sometimes be manipulated by agricultural management (Lal, 2004; Sanderman et al., 2011; Hoyle et al., 2013). In particular, the inclusion of perennial vegetation into farming systems has been identified as a potential pathway for increasing soil carbon (Sanderman et al., 2011).

In Western Australia, adoption of perennial sub-tropical grass pastures is increasing, largely in an effort to reduce wind erosion on soils of marginal cropping potential. The perennial pastures provide year-round ground cover, and growth in response to summer rainfall, which help to reduce the erosion risk. Wind erosion in itself can be a significant source of carbon loss from soil (Harper et al., 2010). Previous research has demonstrated that perennial pastures generally produce deeper root systems than annual plants, (e.g. Ward et al., 2001), and therefore, perennial pastures may be associated with increased soil carbon sequestration (Sanderman et al., 2011). However, in order to determine impacts of perennial pastures on soil carbon, sampling to a depth greater than the Kyoto standard of 0.3 m might be necessary (Harper and Tibbett, 2013).

Sanderman et al. (2013) measured soil carbon under several tropical grasses (including Rhodes grass, Gatton panic and Kikuyu) and showed that Kikuyu was occasionally associated with increased soil carbon (relative to adjacent fields of annual crops and pastures), but Rhodes grass and Gatton panic had no impact on total soil carbon. Similarly, Lawes and Robertson (2012) used paired fields and again showed that Rhodes grass and Gatton panic did not increase soil carbon. However, Sanderman et al. (2013) only measured to a soil depth of 0.3 m (following the Kyoto protocol), and Lawes and Robertson (2012) only measured to 0.9 m. As noted by Ward et al. (2014), Gatton panic and Rhodes grass roots can reach depths of more than 3 m, and so these previous reports did not sample the full rooting depth. In this research we assess carbon in soils to a depth of 4.0 m, encompassing the entire root system of the perennial grass pasture. Measurements are compared with soil carbon to the same depth under a conventional cropping rotation, in a replicated field trial.

Materials and Methods

Site details

A site was chosen on a deep sandy soil at 30° 46' 58"S, 115° 51' 43"E, near Moora, 150 km north of Perth, WA. The surface soil (0.0-0.1 m) had a pH of 5.4. Average rainfall at the site (SILO gridded data set; <https://www.longpaddock.qld.gov.au/silo/>) is 498 mm, of which 406 mm falls in the May to October period.

Plots were established in a randomised block design with 3 replicates. Treatments included crop plots, perennial tropical grass pasture plots, and combined crop and pasture plots in a system known as pasture-cropping (Lawes et al., 2014). Specifically, plots included: Gatton panic (*Megathyrsus maximus*) pasture, low N (PL); Gatton panic pasture cropped, low N (PCL); Gatton panic pasture cropped, high N (PCH); Crop only, low N (CL); and crop only, high N (CH). Low N treatments received 50 kg N/ha, and high N treatments received 80 kg N/ha. Gatton panic pastures were sown in August 2008, and were maintained until the end of the trial in May 2014. Crops were barley (*Hordeum vulgare*) (2009, 2011, 2013) and lupins (*Lupinus angustifolius*) (2010, 2012). Further details are given in Lawes et al. (2014).

Soil sampling

Soil sampling was conducted in April 2014, in two of the replicate blocks. Depths sampled were 0.00-0.10, 0.10-0.20, 0.20-0.30 by taking vertical soil cores, and 0.45, 0.80, 1.25, 1.75, 2.25, 2.75, 3.25 and 3.75 m by taking horizontal soil cores. Each depth sampled below 0.3 m was assumed to provide data for the depth range from the mid-point between samples, and the 3.75 m sample was assumed to provide data for the depth range 3.5 to 4.0 m. For each depth, four volumetric soil cores of 0.1 m length and 0.03 m radius were extracted. Soils were air-dried, sieved <2mm, and analysed for soil carbon by LECO combustion. A sub-sample was further dried at 105°C so that carbon contents could be calculated on an oven-dry basis. Soil dry bulk density was used to convert carbon percentage to an estimate of carbon mass per hectare. Material retained on the 2 mm sieve was separated into gravel and root fractions, and each was weighed separately. Carbon content of roots was assumed to be 50% of total root dry matter.

Results

Soil carbon storage

In the surface 0.3 m, there were no significant differences ($p = 0.65$) between the treatments in terms of soil carbon storage (Figure 1a). Average carbon storage was 23 t C/ha. Soil carbon storage summed within the full root profile of 4.0 m averaged 44 t C/ha (Figure 1b), and once again, there were no significant differences ($p = 0.75$) between treatments.

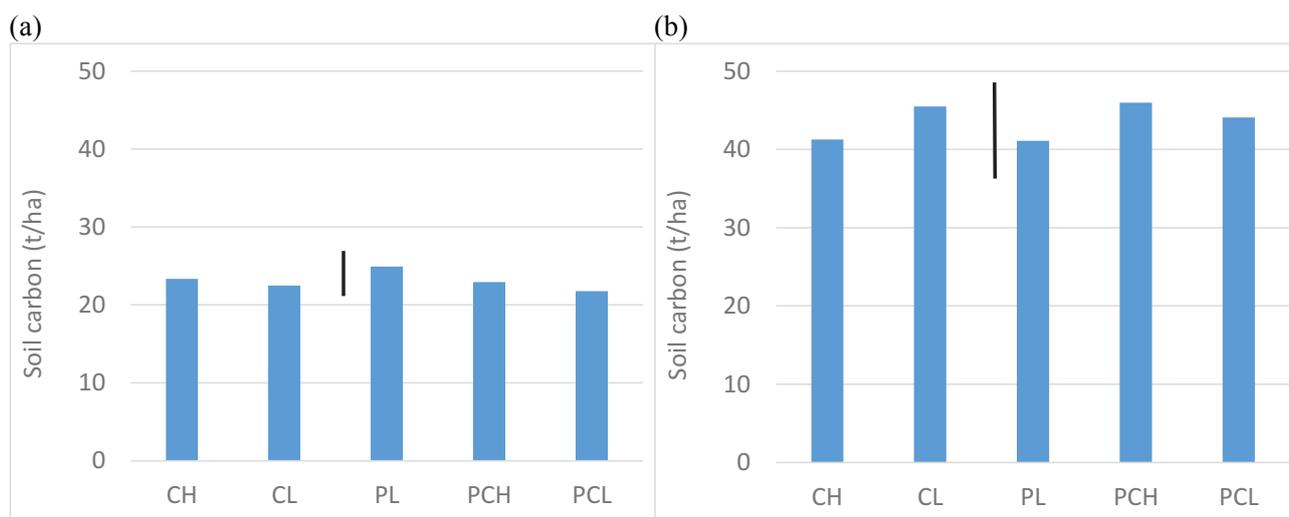


Figure 1. Soil carbon (t/ha) in the top 0.3 m (a) or 4.0 m (b) of soil. Vertical bars represent LSD values. CH and CL indicate crop only, with high or low nitrogen respectively; PCH and PCL indicate pasture cropped treatments with high and low nitrogen respectively; and PL indicates pasture only.

Root distribution and total carbon stock

Root biomass was significantly ($p=0.023$) greater in the plots containing perennial pasture than in the CH and CL plots (Figure 2a), and virtually all of this difference was due to root material in the top 0.3 m of soil (Figure 2b). However, adding root carbon to the total soil carbon amounts, to give a total carbon sequestration, resulted in no significant differences ($p = 0.208$) between treatments. Total carbon sequestration (soil plus root) to a depth of 4.0 m averaged 51 t C/ha.

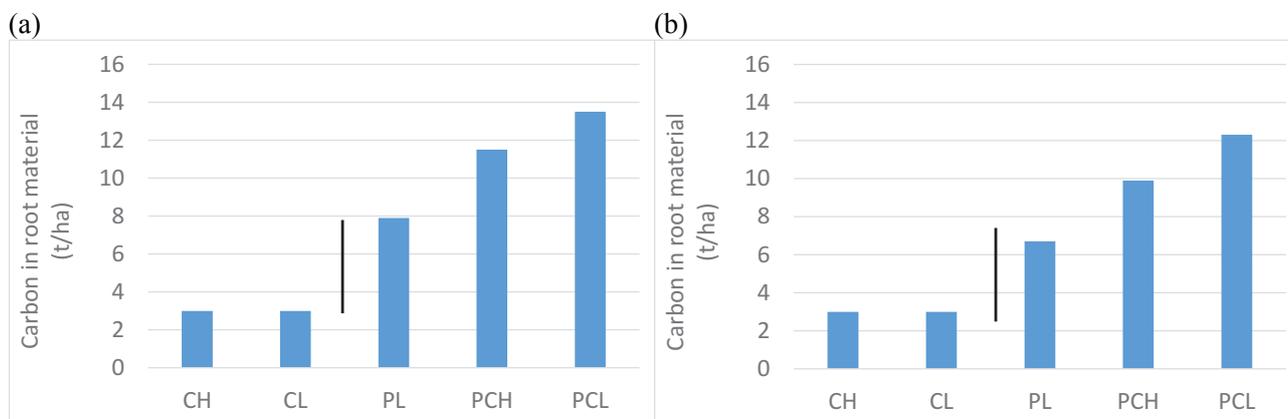


Figure 2. Carbon storage in root material in the top 4.0 m (a) or 0.3 m (b) of soil. Vertical bars represent LSD values. CH and CL indicate crop only, with high or low nitrogen respectively; PCH and PCL indicate pasture cropped treatments with high and low nitrogen respectively; and PL indicates pasture only.

Discussion

Perennial pastures have become more popular over the last few years in the sandplain areas north of Perth. The major driver of this expansion has been the desire to stabilize sandy soils prone to wind erosion, and the perennial growth of the sub-tropical grasses has largely achieved this aim through increased ground cover (Ward et al., 2014). There has also been considerable debate in the farming and scientific communities about the carbon balance of these systems, given the reduced soil disturbance, and increased root growth associated with the perennial pastures. Our results demonstrate that Gatton panic, after five years of pasture growth, did not lead to a measureable increase in soil carbon when compared with an annual cropping rotation, even when measurements extended to the complete depth of the root system. Differences between the treatments may have been observed if pastures had been left for a longer time period (more than 5 years) before sampling. Our results support similar results reported by Sanderman et al. (2013) and Lawes and Robertson (2012), measured over the top 0.3 m or 0.9 m of soil respectively. Interestingly, this is also consistent with results for a study of soil carbon changes following 26 years of reforestation with eucalypts in the same region (Harper et al., 2012), which suggests that soil carbon sequestration may be constrained by the sandy texture of the soils in the region. In our results, sampling to a greater soil depth encompassing the entire root system of the perennial grass pasture did not lead to a different outcome. Therefore, there appears to be little incentive in further deep soil sampling when comparing different land uses of perennial grass pastures and cropping rotations.

Soil carbon, when measured for sequestration calculations, is usually measured in the top 0.3 m of soil. Sanderman et al. (2013) and Roper et al. (2013) found that Kikuyu pasture could result in greater carbon sequestration relative to annual crops or pastures, but that other grasses were less effective. Differences in both experiments were observed mainly in the top 0.1 m of soil, which could be due to decreased wind erosion, as suggested by Harper et al. (2010). In our results, differences in root distribution between the annual and perennial plants were observed, but were largely confined to the top 0.3 m of soil, as also observed by Sanderman et al. (2013). Therefore, even when considering root growth in perennial grass pastures, the top 0.3 m of soil seems to include all the relevant information.

Total carbon stock was substantially higher when measured throughout the top 4.0 m of soil, compared with the top 0.3 m of soil. Harper and Tibbett (2013) also showed that deep soil carbon (up to 38 m deep) can add substantially to the total carbon stock, and should be included in estimates of carbon sequestration. However, our results showed that there was no difference between land uses in terms of the deep soil carbon. While

this carbon is important to include in overall calculations of carbon stock, it does not seem to be a useful indicator of changes in carbon in response to altered land use.

Conclusions

Gatton panic was not associated with increased soil carbon relative to a conventional annual crop rotation, even when measured to the entire depth of the root system. Differences between annual and perennial vegetation were observed in root growth, and these differences were largely confined to the top 0.3 m of soil. Therefore, sampling to the top 0.3 m of soil seems adequate to calculate relative carbon stock in perennial grass pastures.

Acknowledgements

Thanks to Shayne Micin and Ramona Jongepier (CSIRO) and Christiaan Valentine (DAFWA) for excellent technical assistance, and to Chris Vanzetti for access to his farm to perform the research. This research was partly funded by the Department of Agriculture, Fisheries and Forestry.

References

- Harper RJ, Gilkes RJ, Hill MJ, Carter DJ. 2010. Wind erosion and soil carbon dynamics in south-western Australia. *Aeolian Research*, 1, 129-141.
- Harper RJ, Okom AEA, Stilwell AT, Tibbett M, Dean C, George SJ, Sochacki SJ, Mitchell CD, Mann SS, Dods K. 2012. Reforesting degraded agricultural landscapes with Eucalypts: Effects on carbon storage and soil fertility after 26 years. *Agriculture, Ecosystems & Environment*, 163, 3-13.
- Harper RJ, Tibbett M. 2013. The hidden organic carbon in deep mineral soils. *Plant and Soil*, 368, 641-648.
- Hoyle FC, D'Antuono M, Overheu T, Murphy DV. 2013. Capacity for increasing soil organic carbon stocks in dryland agricultural systems. *Soil Research*, 51, 657-667.
- Lal R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma*, 123, 1-22.
- Lawes RA, Robertson MJ. 2012. Effect of subtropical perennial grass pastures on nutrients and carbon in coarse-textured soils in a Mediterranean climate. *Soil Research*, 50, 551-561.
- Lawes RA, Ward PR, Ferris D. 2014. Pasture cropping with C4 grasses in a barley–lupin rotation can increase production. *Crop and Pasture Science*, 65, 1002-1015.
- Roper MM, Fillery IRP, Jongepier R, Sanford P, Macdonald LM, Sanderman J, Baldock JA. 2013. Allocation into soil organic matter fractions of ¹⁴C captured via photosynthesis by two perennial grass pastures. *Soil Research*, 51, 748-759.
- Sanderman J, Baldock J, Hawke B, Macdonald L, Massis-Puccini A, Szarvas S. 2011. National Soil Carbon Research Programme: Field and laboratory methodologies. CSIRO Sustainable Agriculture Flagship, CSIRO Land and Water, S. Aust. Available at: www.clw.csiro.au/publications/science/2011/SAF-SCaRP-methods.pdf
- Sanderman J, Fillery IRP, Jongepier R, Massalsky A, Roper MM, Macdonald LM, Maddern T, Murphy DV, Wilson BR, Baldock JA. 2013. Carbon sequestration under subtropical perennial pastures I: Overall trends. *Soil Research*, 51, 760-770.
- Ward PR, Dunin FX, Micin SF. 2001. Water balance of annual and perennial pastures on a duplex soil in a Mediterranean environment. *Australian Journal of Agricultural Research*, 52, 203-209.
- Ward PR, Lawes RA, Ferris D. 2014. Soil-water dynamics in a pasture-cropping system. *Crop and Pasture Science*, 65, 1016-1021.