Soil carbon depth functions under different land uses in Tasmania

Joshua Scandrett [A], Garth Oliver [B], Richard Doyle [C]

[A] School of Agricultural Science, University of Tasmania, Hobart, TAS, Australia, Email joshuas6@utas.edu.au
[B] Tasmanian Institute of Agricultural Research, University of Tasmania, Hobart TAS, Australia, Email garth.oliver@utas.edu.au
[C] School of Agricultural Science, University of Tasmania, Hobart, TAS, Australia, Email Richard.Doyle@utas.edu.au

Abstract

Agricultural soils play an important role in the global carbon cycle and can act as a significant carbon sink if managed appropriately. Thirty soil cores were sampled from five different land uses across a consistently mapped Brown Dermosol in the Midlands region of Tasmania. Each core was separated at three depths (0 – 10, 10 – 20, 20 – 30 cm) to generate 90 samples. Each of these samples was analysed for total organic carbon (TOC) to assess the effect of the different land uses on soil carbon dynamics with depth. As expected, TOC levels in the topsoil were depleted under intensive land management practices, however the carbon levels in the subsoils suggested that increases in land use intensity resulted in higher TOC levels below 10 cm. This emphasises the importance of sampling at depth when assessing soil carbon dynamics in relation to land use. After 12 years of intensive cultivation however, some fields showed little change in TOC levels, which is likely a function of the protective nature of the high clay and silt content (~70%) of the soil and the associated use of minimum tillage. If Australia enters into a CPRS and agriculture is included, recognition of the role of subsoils as a carbon sink will be necessary in ensuring carbon taxes are appropriately administered.

Key Words

SOC dynamics, land use intensity, sampling depth, CPRS

Introduction

As a result of Australia's ratification of the Kyoto protocol, and the intent by Australia to introduce a carbon pollution reduction scheme (CPRS), a need exists to properly define realistic carbon sequestration options with sound scientific evidence that could eventually underpin policy changes in the future. Having defensible knowledge as to the potential of Australian soils to sequester carbon will be crucial in ensuring that soils are included as a potential sink for atmospheric CO_2 in any future developing carbon pollution reduction scheme. For soils to be included in a potential CPRS, scientific evidence must consistently demonstrate the effect of different land uses on soil carbon levels, and these changes must be shown to be easily quantifiable. The majority of previous studies quantifying the effect of land use on soil carbon have mostly just measured changes in the topsoil (~15cm). The aim of this research was to assess changes in soil carbon at depth in response to increasing levels of land use intensity.

Materials and Methods

The data used in this research was collected from the property "Lowes Park" in the Midlands of Tasmania. The property has five centre pivot irrigators that overlap with an area of consistently mapped soil type (Leamy 1961). From these five overlapping fields, four were selected and used as sample sites. At each sample site, five soil cores were extracted with a truck mounted hydraulic push-tube apparatus, and from each core five sub-samples were taken at the following depths: 0 - 10, 10 - 20, 20 – 30 cm.

Five randomly sampled soil cores from six separate sampling sites provided in the extraction of 30 total soil cores. From these soil cores, 150 individual samples were generated, air-dried for a week and weighed for calculation of bulk density.

The 90 samples were sieved at 2 mm to remove any stones, or large organic material. Post sieving, each individual sample was sub-sampled and a portion of that sub-sample was milled for 20 seconds in a Retch MM200 ball mill to allow for complete disaggregation of all solid clay particles and soil aggregates. This allowed for complete combustion of material during the analysis process. Analysis total organic carbon (TOC) was performed on 20 - 30 mg of milled soil, on a Perkin-Elmer CNH dry combustion analyser.

For analysis of mineral associated carbon, a 20 g oven dry sample of each soil was dispersed in 100 ml of water containing 2.5 g of the dissolved chemical dispersant calgon (sodiumhexametaphosphate). The samples were put into 250 ml centrifuge tubes, and placed on their side on a horizontal shaker at 175 rpm for 16 hours. The suspended soil was then washed over a 53 µm sieve, taking care to account for the entire initial sample. The material was washed gently on the sieve with distilled water until the water running through the sieve appeared clear. Both fractions were recovered and the samples dried at 60°C until the water used in the separation process had evaporated. Each fraction was weighed, and the dried <53 µm fraction was milled, and analysed again for the carbon content. The calculation for the carbon content of the >53 µm fraction was calculated by difference from the TOC data set after accounting for the bulk density.

Relative land use intensity was calculated by assigning numerical values to particular land management practices, the sum of which was calculated for the period of cultivation and divided by the calculated intensity of the control site.

Results

From the 90 data points collected, the mean TOC values for each field can be compared. The experimental design aimed to have two key land uses. However when specific land use histories were collected a distinct difference between Field 1 and the remaining fields became apparent. Figure 1 below reveals the general trend in TOC content with depth, information about the variation in the results obtained, and specific differences and trends between individually sampled fields.

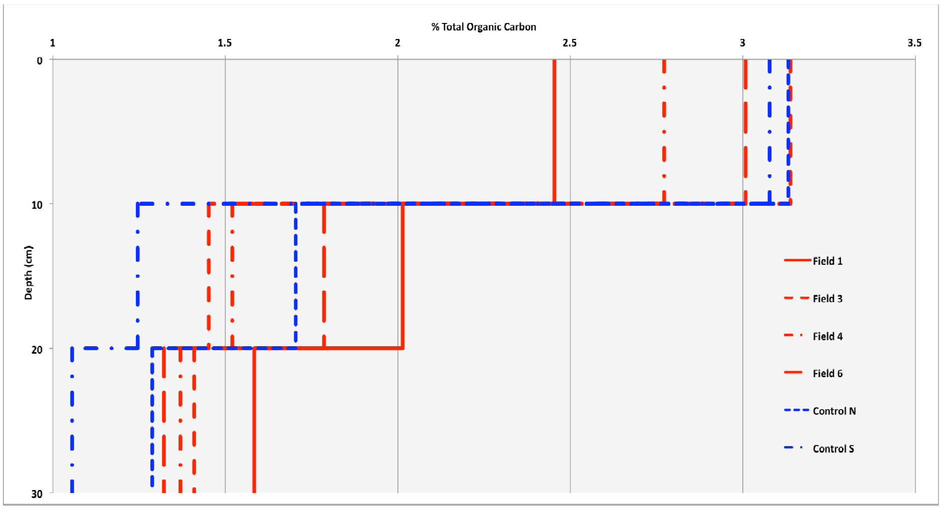

Figure 1. Graph showing TOC dynamics at depth for each sampled field. Each value is the mean TOC content of the 5 cores taken at that site. In the 0 – 10 cm section both control sites, Field 6 and Field 3 have relatively high carbon levels. The values of the 10 – 20 cm section are particularly variable, however Control South has low levels of carbon compared to all other sampled fields. Both values for the control sites are lower than all the sampled field sites for the 20 – 30 cm section suggesting the cropping is increasing carbon levels deeper in the soil profiles. Field 1 has significantly less carbon in the topsoil, relative to all other sampled sites, but has relatively high TOC levels in the soil deeper than 10 cm.

The calculation of relative land use intensity allows for the comparison of TOC content at depth for different fields whilst accounting for the different land use histories.

Discussion

Sampling sites of particular interest from Figure 1 are Control South and Field 1. Control South showed the greatest difference between the TOC value for the 0 – 10 cm soil section, and the TOC value of the 10 – 30 cm soil section. Conversely, Field 1 had an almost linear decline in TOC content with depth, a feature possibly attributable to a deep tillage event in 1998 (Figure 2). In the topsoil, Field 1 had 20% less TOC than Control South, a figure consistent with other land use studies into agricultural practices of high intensity performed in Tasmania (Sparrow 1999). The values for Control South and Field 1 are statistically different at every depth.

The two control sites had very similar amounts of carbon in the 0 – 10 cm soil section, however in the 10 – 20 cm section, Control North was not statistically different to any other field site except Control South. The difference between the controls decreased in the 20 – 30 cm soil section, however the value for Control North was more similar to the intermittent cropping sites. Sampling control sites was necessary to assess variability of carbon levels across the landscape. It should be noted that at the time of sampling, these pastoral soils had been subjected to an extended drought, which may have been responsible for a degree of soil degradation. This result is suggestive of the difficult nature of soil carbon measurement, and the difficulty in assessing whether differences in carbon measurements are a function of natural variation or of different land management practices.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Score	Intensity
Field 1	🟥	🟨	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩	🟨	32	**2.91**
Field 4	🟩	🟩	🟧	🟨	🟧	🟧	🟧	🟨	🟨	🟨	🟨	28	**2.55**
Field 6	🟩	🟩	🟩	🟧	🟧	🟨	🟩	🟩	🟨	🟧	🟨	23	**2.09**
Field 3	🟧	🟩	🟩	🟧	🟩	🟨	🟨	🟨	🟩	🟩	🟨	21	**1.91**
Control	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	11	**1.00**

Figure 2. Table of relative land use intensity. Green represents established pasture or lucerne (1). Yellow represents the cultivation of annual cereals using direct drilling (2). Orange represents the cultivation of annual cereals or poppies with conventional tillage (disc and harrow) (4). Red represents a deep tillage event following the production of potatoes (8). The sum of these assigned values gives a score, which is divided by the value for the control to give a value for relative land use intensity.

Relative land use intensity can then be plotted against the TOC values at all depths for the associated fields.

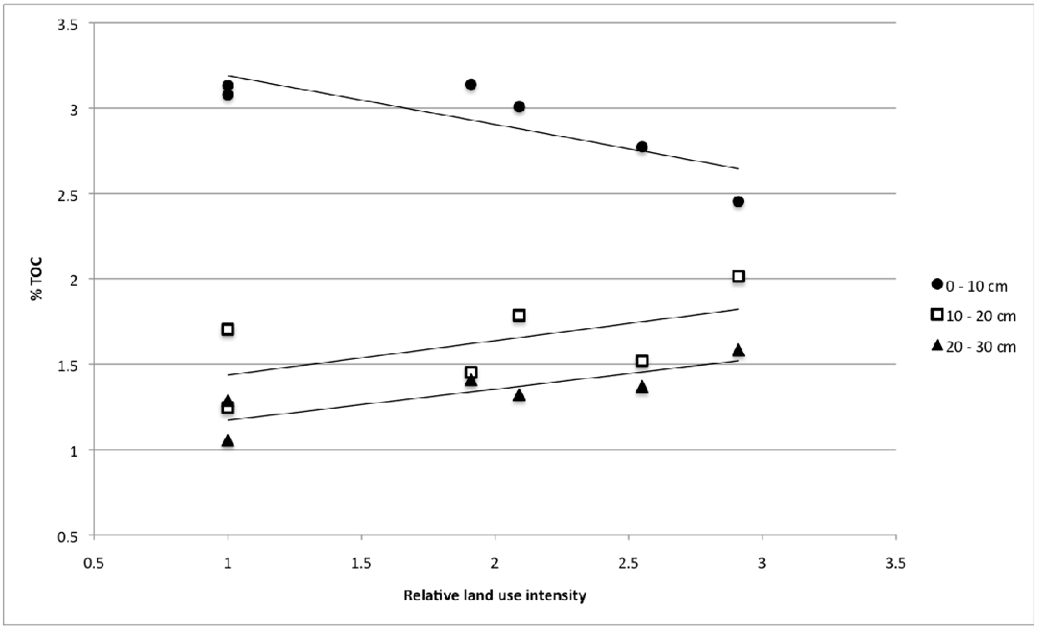

Figure 3. Graph showing relationship between TOC percentage and relative land use intensity for the three sampled depths. Note the inverse relationship in the 10 – 30 cm soil section under increasing land use intensity. This suggests either carbon burial, increased root growth and subsequent carbon deposition, or the accumulation of soluble organic carbon in the more intesive land management practices. Topsoils show the expected decline in soil carbon with increased intensity of use.

In general, the establishment of perennial systems such as lucerne or improved pasture results in increases in soil carbon content (Contant 2001). Since lucerne is a deep-rooted perennial, the high level of carbon in the 10 – 30 cm section could be a function of the long term deposition of carbon to those depths, or mixing by deep tillage.

These interactions discussed above are summarised in Figure 3. Figure 3 shows the trend of TOC content for increasing land use intensity for each depth, regardless of field. As expected and suggested in the relevant literature, the carbon content of the topsoil decreases with increasing land use intensity (Lal 1997). However what is of most importance in this graph is the dynamics of the carbon associated with the soil deeper than 10 cm. This graph shows that an increase in land use intensity, and thus presumably productivity, results in an increase in carbon associated with that soil. This indicates the crucial importance of sampling at depth when assessing carbon stocks or the dynamics of soil carbon associated with changes in land use.

The lack of significant change in TOC content for various land management practices suggests the resilience of these soils to carbon loss. Despite heavy usage over a 10 – 12 year period, TOC levels in soils have changed very little. This is complementary to other studies assessing the effects of agricultural management on Dermosols in Tasmania, which suggest that despite their intense use, these soils are still in good health (Cotching 2002). The resilience of these soils to carbon loss is likely a function of the high clay and silt content of the sampled soils (~70% clay and silt content). Published evidence indicates that one of the principle factors in physical protection of organic matter in soils is its ability to associate with clay and silt particles (Hassink 1997). Therefore, soils with a higher clay and silt content will show a greater resistance to the degradation of organic matter.

Conclusion

The major finding of this research was that the process of intermittent cropping, and the associated increases in the productivity of the soil, resulted in the accumulation of carbon at depths below 10 cm. Although in this research the TOC deficit incurred in the topsoil was not exceeded by the gains made in the mean subsoil levels, this work is suggestive of the potential of subsoils as a strong carbon sink. More research into carbon dynamics at depths below 10 cm could confirm the use of subsoils as a significant carbon sink. If a CPRS is established and agriculture included, this will be a vital avenue of soils research. The challenge for soils scientists is to reliably predict the quantity of carbon that could be sequestered by the implementation of certain agricultural practices. For soils to be included in a CPRS, the action of sequestration and the dynamics of carbon in soils must be defensible and backed up with significant data of relative consistency. This appears to be the major challenge facing the potential of soils to become part of a CPRS.

References

Contant T, Paustian K, Elliot E (2001) Grassland management and conversion into grassland: effects on soil carbon. *Ecological Applications* **11,** 343-355.

Cotching W, Cooper J, Sparrow L, Mccorkell B, Rowley W (2002) Effects of Agricultural management on Dermosols in northern Tasmania. *Australian Journal of Soil Research* **40,** 65-79.

Hassink J (1997) The capacity of soils to preserve organic C and N by their association with clay and silt particles. *Plant and Soil* **191,** 77-87.

Lal R, Kimble J (1997) Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecosystems,* **49,** 243-253.

Leamy ML (1961) Reconnaissance soil map - Interlaken. IN Soils, C.D.O. (Ed. *Division Report.* Adelaide.)

Sparrow L, Cotching W, Cooper J, Rowley W (1999) Attributes of Tasmanian Ferrosols under different agricultural management. *Australian Journal of Soil Research* **37,** 603-22.