A METHOD FOR MEASURING THE EFFECT OF DAIRY AND DRYSTOCK GRAZED PASTURES ON SOIL CARBON STOCKS

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Abstract

Soil is the largest terrestrial store of carbon (C) with some 2000 Pg to a depth of 1 m compared to 500 Pg in the atmosphere. Quantifying soil C stocks is a key requirement of the Intergovernmental Panel on Climate Change (IPCC). The IPCC recommends that C stocks be measured using the depth based approach where the C stock (tC ha^{-1}) is the product of sample depth (m), bulk density (t m^{-3}) and percent C. However, soil properties such as bulk density may vary spatially and temporally in response to land use change and management practices. For greater accuracy in determining the effects of land use change on soil C, a mass based coring approach coupled to equivalent soil mass calculations (ESM) of soil C stocks may be more accurate as it accounts for differences in bulk density.

Barnett et al. (2014) used a paired pit approach to sample 25 adjacent dairy and drystock pastures to a fixed depth of 0.6 m and showed that drystock grazed soils had about 8.6 $t.ha^{-1}$ more C in the top soil than adjacent dairy sites ($P<0.05$). However, there was no significant difference between land uses when C was accumulated to 0.6 m.

Our objective was to test a potentially more accurate method for estimating C stocks between dairy and drystock grazed pastures. We resampled the paired dairy and drystock sites to a depth of 0.6 m by taking 5 soil cores from each of two plots (5x5 m) within a paddock of each land use. Preliminary results have shown that dairy sites have on average 72 t ha^{-1} more soil ($P<0.05$) than drystock sites in the 0-0.25 m layer, outlining the importance of applying ESM calculations. Resampling of sites using the replicated coring approach was found to yield lower estimations of total C compared to the pit approach which was used for the initial sampling. Using a replicated coring approach takes into account the inherent spatial variability in C stocks, thus giving a more accurate estimation of the field mean and increasing the power to detect small differences in C stocks between land uses. Furthermore, C stocks can be estimated efficiently and cost effectively which is important for C monitoring and accounting purposes.

Introduction

The amount of carbon (C) stored in soil is equivalent to the amount stored in both the atmosphere and terrestrial vegetation (Conant et al., 2003). Soil plays a fundamental role in the global C cycle with the upper 1 m containing 1500–2000 Pg of organic C (Don et al., 2007; Schipper et al., 2007). Soil C is also an essential component of soil quality as it enhances soil structure, nutrient cycling and soil moisture holding capacity (Han et al., 2010).

The United Nations Framework Convention on Climate Change (UNFCCC) made it mandatory to report greenhouse gas removals and emissions for soil C pools at the national scale (Hewitt et al., 2012). As a consequence, the Soil Carbon Monitoring System (CMS) was developed as a national inventory for soil C stocks in New Zealand (Scott et al., 2002; Tate et al., 2005). The implementation of carbon-trading schemes has seen the scope narrow from national inventories to farm scale inventories where the direct measurement of soil C stocks is required (Singh et al., 2013). For example, the Waikato Regional Council is developing a carbon strategy which involves converting marginal land to forestry or natural bush, thus increasing C sequestration into soils and biomass at a regional scale. With such legislation, comes the need to accurately and efficiently quantify C stocks at the farm scale.

Our objectives were to 1) Compare C stocks between adjacent dairy and drystock pastures and relate the results to earlier work carried out by Barnett et al. (2014), and, 2) develop an efficient and cost effective sampling strategy that has sufficient power to detect small differences in C stocks between land uses and through time. Work on this project is ongoing and presented here are the preliminary findings.

Methods

Sampling soils was carried out on 23 adjacent dairy and drystock paddocks in the Waikato (figure 1). A previous study by Barnett et al. (2014) measured total C stocks on the same sites using a soil pit approach. The rationale behind resampling sites using a replicated coring approach was to get an estimate of the within paddock variability in C stocks and thus increase our ability to detect management effects on soil C stocks.

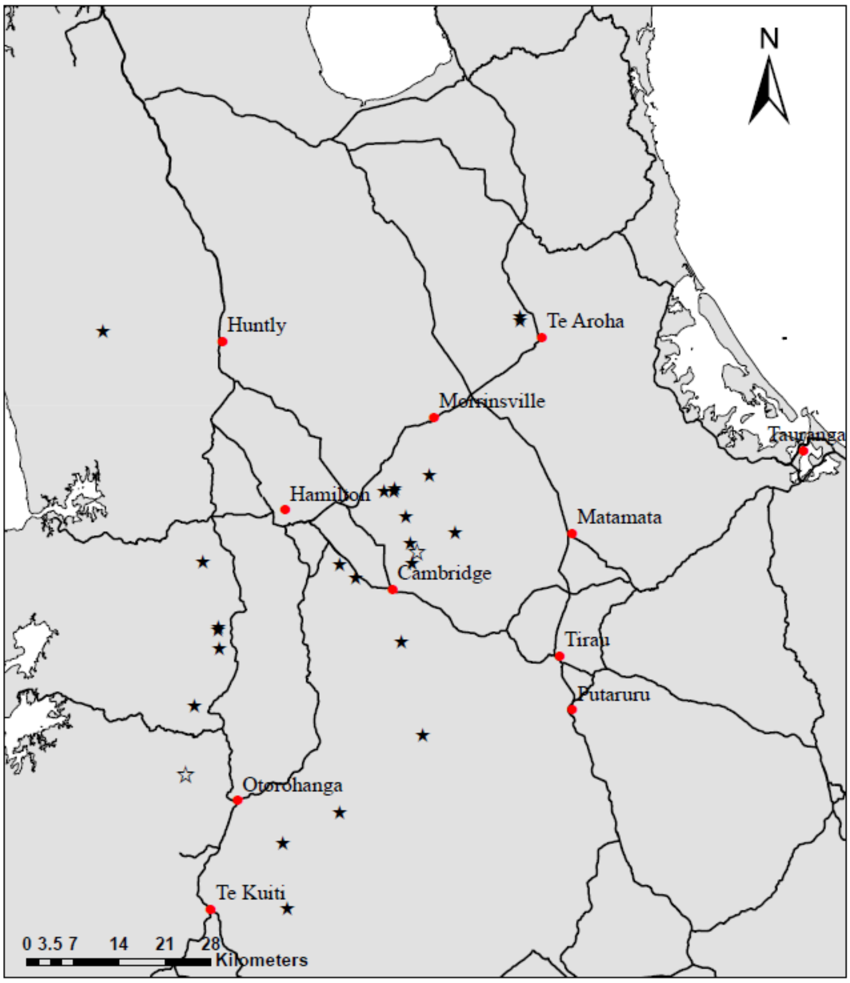

Figure 1. Location of paired dairy/drystock sites. Closed symbols indicate the sites that were resampled using the coring approach. Each star represents a pair of sites.

At each site, the initial pit position was located using GPS coordinates and measurements from fence boundaries which were obtained from previous sampling. A 5x5 m plot was set up 2 m from the initial pit location and 5 soil cores (65 cm deep) were taken randomly from the plot. The cores were bulked and cut into depth intervals of 0-10, 10-25, 25-40, 40-60 and 60-65 cm. The same procedure was carried out for a second plot which was positioned at a distance of 30 m from the first plot and in a random direction (figure 2). Soils were carefully matched between plot 1 and plot 2 and between adjacent sites to eliminate confounding variables.

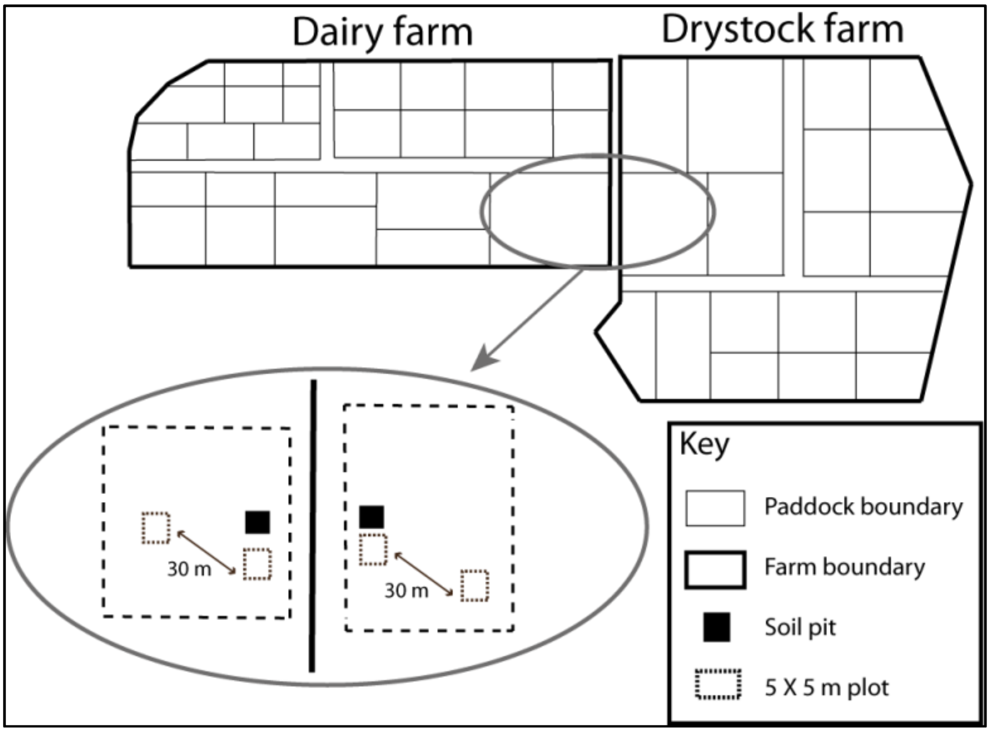

Figure 2. An example of the sampling strategy used to resample paired dairy/drystock sites.

Soil samples were air dried, passed through a 6 mm sieve to remove roots and subsequently weighed. A moisture factor was applied to each sample to correct the mass to an oven dry mass of soil. The mass of soil per unit area (t ha^{-1}) was determined using the following equation:

$$M_{soil} = \frac{M_{sample(OD)}}{\pi\left(\frac{D}{2}\right)^2 \times n} \times 10000 \qquad (1)$$

Where: M_{soil} is the mass of the soil per unit area in t ha^{-1}, $M_{sample(OD)}$ is the oven dry mass of soil (t) , $\pi(D/2)^2$ is the cross-sectional area of the corer (m^2), *n* is the number of cores taken and 10 000 is a correction factor to convert m^2 to ha.

Soil samples were passed through a 2 mm sieve and a subsample was obtained to determine C concentrations using an Elementar (Isoprime 100) combustion analyser. The total C stock (t ha^{-1}) for each depth increment was calculated:

$$\text{C stock (t ha}^{-1}) = M_{soil} \times \%C_{OD} \quad (2)$$

Where M_{soil} is the mass of the soil per unit area in t ha^{-1} and $\%C_{OD}$ is the oven dry concentration of C (%C). Total C stocks were adjusted to an equivalent soil mass for each paired site to take differences in bulk density into account (Wendt and Hauser, 2013).

Results and Discussion

Difference in soil mass between dairy and drystock sites

To a fixed depth of 25 cm, dairy sites had about 72 t ha^{-1} more soil than the drystock sites ($P<0.02$) (table 1). To a depth of 60 cm , dairy sites had an average of 124 t ha^{-1} more soil than drystock sites but the difference was not significant ($P>0.05$). Dairy farms are more intensively managed and have higher stocking rates compared to dairy farms. Barnett et al. (2014) estimated stocking rates for the farms used in this study and found drystock sites to have an average stocking rate of 14 units ha^{-1} compared to 24 units ha^{-1} for the dairy sites. Higher stocking rates increase soil compaction, thus increasing the soil mass to a fixed depth. The difference in soil mass between adjacent land uses outlines the importance of comparing C stocks to an equivalent mass of soil rather than to a fixed depth.

Table 1. Soil mass to a fixed depth for 22 adjacent dairy and drystock paddocks

Soil depth (m)	**Dairy (t ha^{-1})**	**Drystock (t ha^{-1})**	**Difference (t ha^{-1})**	**SED[A]**	**P value**
0-0.25	2016 (94)	1943 (90)	72	29	**0.02**
0-0.4	3293 (169)	3204 (175)	89	45	0.05
0-0.6	5084 (270)	4960 (285)	124	78	0.12

Standard error of the mean in parenthesis

[A] SED, standard error of the difference between the means

Within site variability in C stocks

The C stock of plot 1 was linearly correlated with plot 2 which was located at least 30 m away: plot2 = 0.95 ± 0.068 plot1 + 3.49 ± 12.19 (mean ± standard error, adjusted R^2=0.86, figure 3). Furthermore, the 95% confidence bound for the regression line covers the 1:1 line, suggesting C stocks were similar between plots 1 and 2. The majority of sites used in this study were on flat to gently rolling land with Allophanic soils being dominant. Giltrap and Hewitt (2004) studied the spatial variability of C stocks in Allophanic soils under flat land and found the variation in soil C to be low over small distances (i.e. within 30 m) and relatively high over distances of 100 m.

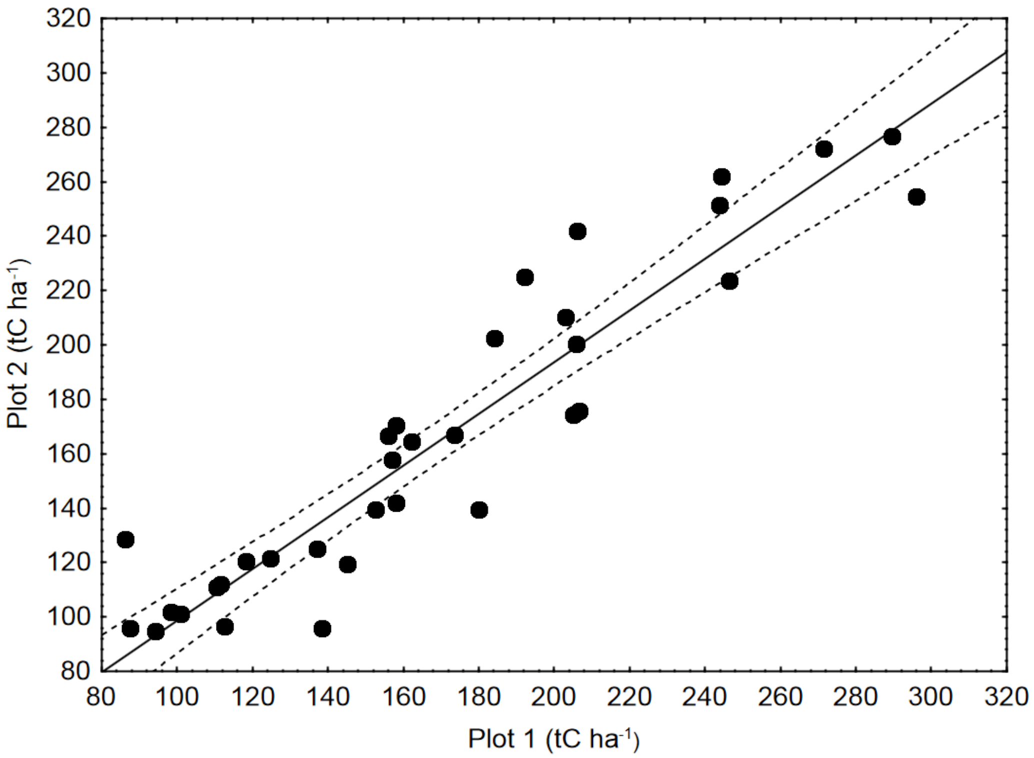

Figure 3. Correlation of C stocks between plots 1 and 2, located 30 m apart. C stocks are compared to an equivalent soil mass for each paddock. Straight line is a linear regression line and the dotted lines represent the 95% confidence bound for the regression fit (regression line equation: Y = 0.95 ± 0.068X + 3.49 ± 12.19 (mean ± standard error), adjusted R^2 = 0.86).

Pit approach vs. coring approach

The C stocks estimated using a single pit correlated strongly with the average C stock from plot 1 and plot 2 (figure 4). However, the regression line lies well below the 1:1 line which indicates that the pit approach estimated greater C stocks. We hypothesise that the difference in C stocks between the two methods may be a consequence of taking representative bulk density cores in each horizon when using the pit approach. Bulk density cores are usually placed beneath the rooting zone which may result in an overestimation of the soil mass in the top soil. This occurs because the rooting zone has a lower bulk density than the underlying mineral soil. Therefore, C stocks may also be overestimated in the topsoil when using the pit method.

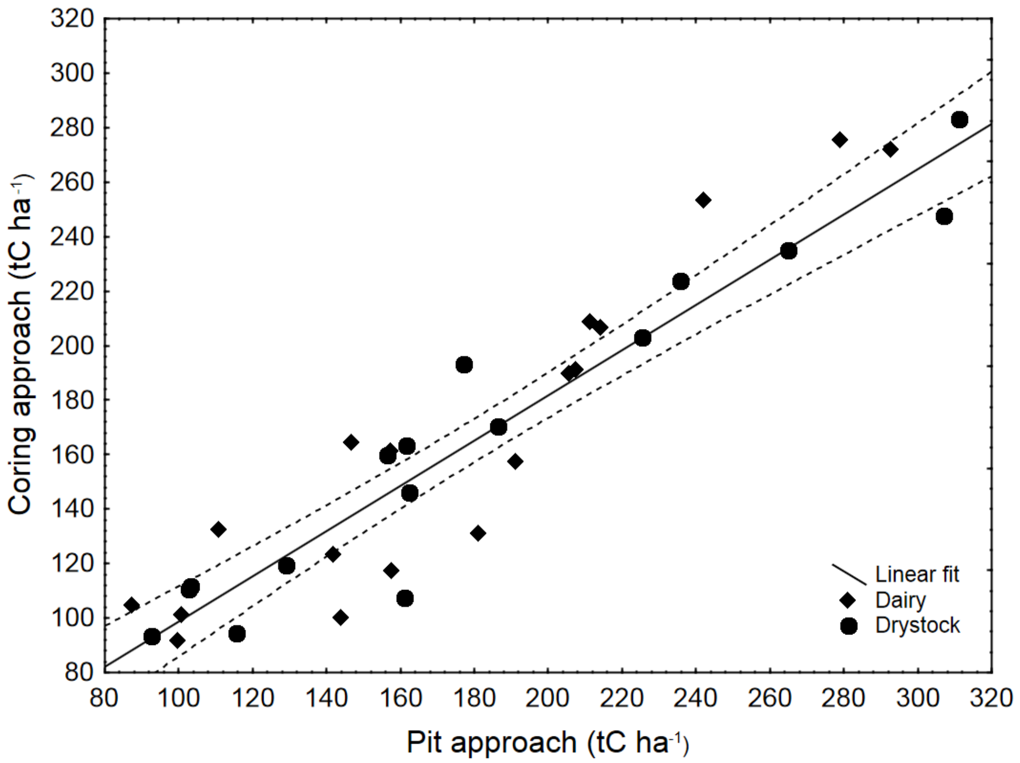

Figure 4. C stocks estimated using the pit approach and the coring approach. C stocks are compared on an equivalent soil mass bases to ~60cm. Solid line is a linear regression line: Y = 0.86 ± 0.063X + 11.62 ± 11.23, adjusted R^2 = 0.89. Dashed lines represent the 95% confidence bounds for the regression line.

Table 2 shows that the difference in the mass estimated using the pit approach and the coring approach is greatest towards the top of the profile. The pit approach estimated the average mass of soil to be 139 t ha^{-1} greater in the 0-0.25 m depth interval compared to the coring approach ($P<0.01$). For all other depth increments, the estimated masses of soil were not significantly different. The significant difference in soil mass in the 0-0.25 m depth increment can be attributed to the fact that bulk density cores were placed beneath the rooting zone for the pit method and the soil mass was overestimated.

Table 2. Mass of soil (t ha^{-1}) for a series of depth intervals, estimated using the pit approach and the coring approach. Percent values represent the difference in estimated C stocks as a percentage of the C stock measured using the pit approach.

	0-0.25 m	**0.25-0.4 m**	**0.4-0.6 m**	**Whole profile**
Pit approach (t.ha^{-1}) Barnett et al. (2014)	2119	1297	1733	5150
Coring approach (t.ha^{-1})	1979	1269	1773	5022
Difference (t.ha^{-1})	139* (6.6%)	28 (2%)	-40 (-2.2 %)	128

* Significant difference at the 5% level

Conclusions

The soil mass from 0-0.25 m was significantly greater for dairy systems than for drystock systems, indicating that comparing C stocks by an equivalent soil mass is essential. The variability in C stocks over a distance of 30 m was minimal as most sites were on flat to gently rolling land and contained Allophanic soils. Some data points plotted well away from 1:1 line, suggesting that a replicated approach is important for determining an accurate estimation of the mean C stock for these sites. There was a discrepancy in C stocks estimated using the pit approach and the coring approach and was likely due to the positioning of bulk density cores beneath the rooting zone when applying the pit method.

Acknowledgements

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