Assessment of soil carbon stores at the farm scale in Tasmania, Australia

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Abstract

The measured farm soil carbon stores in the upper 30 cm of soil were 371 to 699 T/ha CO_2 equivalents across the three farms assessed. The highest value occurred on predominantly Dermosols and Ferrosols, which have high clay contents, are under perennial irrigated pasture for dairying, and have a mean annual rainfall of 1242 mm. The lower soil carbon stores occurred on Kurosols, Sodosols and Tenosols which have sandy loam surface textures, are used for cropping and have mean annual rainfalls of 560 – 760 mm. This study demonstrates that farmers are custodians of a large 'bank' of soil carbon which is susceptible to degradation and conversion into CO_2 if management is not sustainable. The calculated farm carbon storage in the upper 30 cm of soils varied depending on the scale of investigation. Broad scale assessment using information from the Australian Soil Resource Information System ranged from being 25 - 82% less than that determined from farm scale information.

Key Words

Carbon stores, assessment scale

Introduction

Recent concern over the contribution made by agriculture to greenhouse gas production has lead to interest in soil carbon as a potential store for atmospheric carbon (Izaurralde *et al.,* 2001; Scholes and Noble, 2001). There is also increasing pressure and demand for estimates of current soil organic carbon stocks as well for information on how different farming enterprises can be managed in order to minimise their carbon footprint. It is important, however, that accurate and reliable data are used as the basis for these estimates in order to minimise errors. Some farmers are interested in the 'big picture' of carbon stores and fluxes on their farm rather than just their emissions and sequestrations which are the focus of current carbon accounting using existing carbon calculators such as FullCAM (Richards *et al.,* 2005). The farmers involved in this study wanted to see information which is already routinely compiled as part of a well delivered property management plan e.g. farm map, soil types, land use areas (cropping, pastures) used to demonstrate the valuable role that farmers play as carbon stewards.

The objectives of this research were to measure current on-farm soil carbon stores by physical measurement, and compare different scales of assessment of farm carbon stores

Methods

Three pilot farms were used that were representative of enterprise types in Tasmania. Seventeen sites were selected on each of the three farms. These sites were representative of the soils and topography previously mapped on the properties. Not all mapped polygons were sampled and some large polygons or soils with multiple polygons had multiple samples taken. Measurement of soil carbon was undertaken according to the protocols of McKenzie and Dixon (2006). Sampling was carried out in September. Samples were collected in areas sufficiently far from fence lines, gateways and headlands to avoid these edge effects. Five soil cores were taken along a 60 m transect using a 50 mm diameter push auger. Cores were combined to form a single composite specimen for each of 3 depths, 0-50 mm, 50-100 mm and 100–300 mm. These samples were dried at 40^{o}C for at least 48 hours, ground to pass a 2 mm sieve, and stored in air-tight containers. The samples were then analysed for total carbon by dry furnace combustion (Rayment & Higginson, 1992). Bulk density was measured at the sampling site in order to calculate the mass of soil organic carbon (area and depth). Stainless steel cylinders, 60 mm long and 60 mm in diameter, were hammered into the soil at the starting point of the composite sampling transect. Cores were collected from 0-60 mm, 50-110 mm and 150-210 mm depth. Cores with soil intact were excavated and trimmed before the contents were emptied into plastic bags, dried at 105^{o}C, and then weighed. The mass of carbon stored at each sampling depth, to a total depth of 30 cm, was calculated and converted to carbon dioxide equivalents (CO_2e) by multiplying by 44/12. This carbon dioxide mass value was then multiplied by the area of mapped polygons of each soil type occurring on the farm and the totals summed for the entire farm property.

Assessment of farm carbon stores was compared using the farm scale maps and regional scale information on the Australian soil resource information system (ASRIS) which is accessible via the world wide web. Farm scale soil map information used for Farm A was 1: 10 000 scale land capability mapping at subclass and unit level, for Farm B soil map information was a combination of 1: 10 000 scale and 1: 100 000 scale soil type or complex mapping, and for Farm C 1: 25 000 scale land capability at subclass and unit level was used. The mass of carbon was calculated on a per hectare basis using the data collected from the 17 sites on each farm. These values were then multiplied by the by the mapped areas of the soils or land capability units they represent to give a total farm carbon store in CO_2e.

Soil attribution for ASRIS in Tasmania has been completed for the North West and North East regions providing soil information for two thirds of the agricultural land of Tasmania at ASRIS Land District level which is equivalent to a scale of 1: 250,000. Information accessed from ASRIS for the 1-2 polygons mapped on each farm included the soil carbon content (%) and bulk density for each layer to a depth of 300 mm. The information provided on ASRIS is an integrated value of soil properties for each polygon, based on up to 6 soil components for each polygon attributed in the database. The mass of carbon was calculated from the ASRIS data on per hectare basis which was then multiplied by the area of farm represented by the corresponding polygon to give a total farm carbon store.

Results and discussion

The soil carbon stored on each of the pilot farms in the upper 30 cm of soil (Table 1) was calculated as: Farm A 170,454 T CO_2e; Farm B 302,300 T CO_2e; Farm C 213,445 T CO_2e (Farm A 46,487 T C; Farm B 82,445 T C; Farm C 58,212 T C). The farm total soil carbon stores are large and indicate that farmers are custodians of a large amount of soil carbon. Farm B was the largest property (753 ha) and had the greatest soil carbon store. Farm C was the smallest property (305 ha) but it had a greater soil carbon store than Farm A (460 ha), which is likely to be due to a combination of soil type, land use and climate. The soil carbon stores amount to 371, 401 and 699 T/ha CO_2e (101, 109, 191 T C/ha) for Farms A, B and C respectively. The highest per hectare value on Farm C occurred on predominantly Ferrosols and Dermosols, which have high clay contents, are under perennial irrigated pasture for dairying, and have a mean annual rainfall of 1242 mm. Farms A and B are both dominated by Kurosols, Sodosols and Tenosols which have sandy loam surface textures, are used for cropping and have mean annual rainfalls of 766 mm (Farm A) and 562 mm (Farm B). Under Tasmanian conditions, clay textured soils (Dermosols, Ferrosols, Vertosols) have been found to have greater soil carbon contents than sandy textured soils (Kurosols, Sodosols, Tenosols) and perennial plant systems such as permanent pasture result in greater soil carbon contents than cropping systems due to greater inputs over the long term (Cotching, 2009).

The farm carbon storage in the upper 30 cm of soils determined from broad scale data obtained from the ASRIS web site is compared with that determined at the farm scale in this study (Table 1). The storage values for Farm A are the most similar, but the broad scale ASRIS value is 25% less than that determined from farm scale information. The difference for Farm C is 33% and for Farm B it is 82%. The differences are similar or much greater than those found by Frogbrook *et al.* (2009) who found differences of 8% and 45% for areas in Scotland and Wales respectively when comparing field survey data with information from the national UK database. The differences in this study are likely to be mainly due to soils mapped at the farm scale are not included as components in the broad scale ASRIS information. This is most obvious on Farm B which had the largest discrepancy, where 246 ha of Vertosols (33% of total farm area) were mapped at the farm scale but these were not identified in the ASRIS data (Table 1). Clay rich Vertosols have much higher soil carbon contents than sandy loam to loamy sand textured Kurosols and Tenosols in Tasmania (Cotching *et al*. 2002). Other factors likely to have contributed to the differences are attributed depth, soil carbon and/or bulk density values in the ASRIS data are derived from similarly mapped land system polygons which are not representative of soils on these specific farms.

The ASRIS data used in this study was drawn from detailed soil maps and/or soil profile descriptions with all necessary analytical data which cover 9.9% of Tasmania. These areas are concentrated in the more intensively used agricultural areas in the northern Midlands and the northwest coast and cover the three pilot farms used in this research. The soil carbon data was either based on a single measurement in the land unit tract, or based on direct measurements of similar soils in the same land unit type.

Table 1. Farm soil carbon storage determined from ASRIS data and farm scale measurements.

Farm	Map unit area (ha)	Soil order# composition (%)	Soil layer	Layer thickness (m)	Soil organic carbon (%)	Bulk density (T/m^3)	Carbon (T/ha)	ASRIS soil carbon (T CO_2e)	ASRIS farm soil carbon (T CO_2e)	Farm scale soil carbon (T CO_2e)*
A	460	De 45, Ku 30, Hy 25	1	0.24	2.05	1.4	68.9			
			2	0.06	0.80	1.4	6.7	127,512	127,512	170,454
B	22	De 60, Ch 40	1	0.14	1.30	1.2	21.8			
			2	0.16	0.37	1.3	7.7	2,339		
	696	So 65, Te 35	1	0.14	0.88	1.3	16.0			
			2	0.16	0.11	1.4	2.5	47,161		
	38	Te 100	1	0.14	1.30	1.2	21.8			
			2	0.16	0.37	1.3	7.7	4,115	53,616	302,300
C	42	De 100	1	0.13	8.22	0.8	85.5			
			2	0.04	4.55	1.0	18.2			
			3	0.13	1.94	1.2	30.3	20,432		
	263	Fe 100	1	0.15	5.83	0.9	78.7			
			2	0.15	2.92	1.1	48.2	122,546	142,978	214,463

*data from Table 1; # Ch=Chromosol, De=Dermosol, Fe=Ferrosol, Ku=Kurosol, Hy=Hydrosol, So=Sodosol, Te=Tenosol

This means that for the reconnaissance scale ASRIS data, at best soil carbon data from one site has been applied to the whole polygon, and so it is not surprising that there are significant differences with the greater intensity of sampling and attribution used in this study. In other agricultural areas of Tasmania where reconnaissance soil maps and profile descriptions with incomplete analytical data were available (17.5%), or in native and plantation forestry areas and agricultural areas with low intensity use (29%) where reconnaissance soil maps and/or knowledge of similar soils in similar environments are available, the reliability of ASRIS data for calculating soil carbon storage is likely to be relied on with even less confidence. The discrepancies in this study are disturbingly large and indicate that the use of broad scale information within ASRIS, which is the Australian national database, can lead to large errors in calculating on-farm soil carbon storage.

Conclusions

The measured farm soil carbon stores were 371 to 699 T/ha CO_2e (101 – 191 T C/ha) across the three farms assessed in this pilot. The highest value occurred on a farm with predominantly Ferrosols and Dermosols, which have high clay contents, are under perennial irrigated pasture for dairying, and have a mean annual rainfall of 1242 mm. The lower soil carbon stores occurred on Kurosols, Sodosols and Tenosols which have sandy loam surface textures, are used for cropping and have mean annual rainfalls of 560 – 760 mm. The largest property (753 ha) and had the greatest soil carbon store (302,300 T CO_2e) but the smallest property (305 ha) had a greater soil carbon store (213,445 T CO_2e) than the 460 ha property (170,454 T CO_2e) due to a combination of soil type, land use and climate. This study demonstrates that farmers are custodians of a large ‘bank’ of soil carbon which is susceptible to degradation and conversion into CO_2 if management is not sustainable.

The calculated farm carbon storage in the upper 30 cm of soils varied depending on the scale of investigation. Broad scale assessment using ASRIS information ranged from being 25 - 82% less than that determined from farm scale information. The differences are disturbingly large and indicate that the use of currently available broad scale information can lead to large errors in calculating farm soil carbon storage. The result is perhaps unsurprising given that the ASRIS data is of relatively small resolution. It must be emphasized that this study sampled three farms in the north and northeast of Tasmania. Additional sampling from other locations, where there are a range of soil types encompassing other land use types and topography, would further contribute to improving the estimates of the amount of carbon held on farms in Tasmania.

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