SURVEY OF SOIL CARBON AND NUTRIENT SERVICES IN AUSTRALIAN APPLE ORCHARDS

Roberta Gentile[1], Charlotte Robertson[1], Karen Mason[1], Siva Sivakumaran[1], Carlo van den Dijssel[1], Marcus Hardie[2] and Brent Clothier[1]

[1]The New Zealand Institute for Plant & Food Research Limited, Palmerston North, NZ
[2]Tasmanian Institute of Agriculture, Hobart, Australia

Introduction

The Australian apple and pear industry is the third largest horticultural industry in Australia. To quantify the sustainability of orchard management, a better understanding of soil carbon, nutrient availability and soil health in Australian apple orchards is required. In these duplex soils, ridging is a common practice in orchards, where topsoil is transferred from the alley and mounded in the tree row to increase rooting depth and maintain aeration. Thus, a soil sampling protocol was established that accounted for the spatially complex system of an orchard by sampling in the tree row, wheel tracks and the grassed alley, to determine if this practice leads to a stratified distribution of soil carbon stocks or health measurements. Our objective was to conduct a survey of Australian apple orchard soils to establish the soil's carbon status and determine the relationships between soil carbon and soil health parameters.

Methods

Soils from the main orcharding regions in Australia were sampled including Donnybrook and Manjimup in Western Australia, Adelaide Hills in South Australia, Orange and Batlow in New South Wales, Shepparton in Victoria, and the Huon Valley and Tamar in Tasmania (Figure 1).

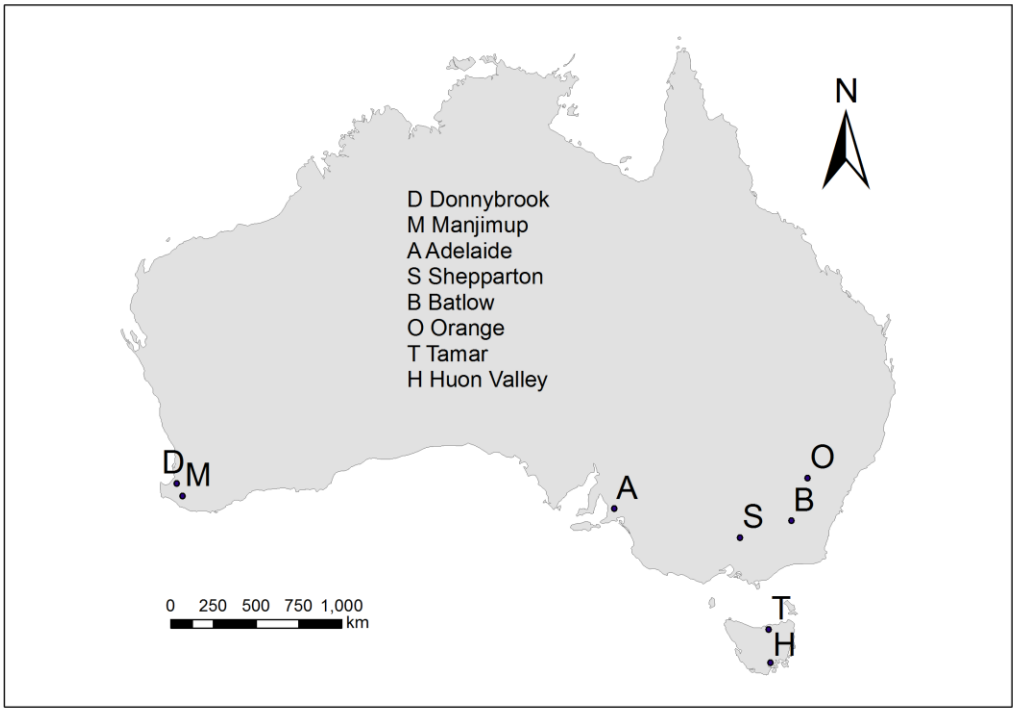

Figure 1. Map of orchard site locations.

A field sampling protocol was established based on intensive sampling at the initial sites in Shepparton and the Huon Valley. In one of the initial orchard blocks, soil carbon stocks followed the surface relief and showed a distinction in soil carbon with depth due to ridging practices. Therefore, as a conservative strategy, a stratified design was used to sample the orchards with sampling positions in the tree row, wheel track, and mid-alley. These were sampled along three randomly selected transects within the orchard block, yielding nine sampling position per orchard. At each sampling location, bulk density and disturbed soil samples were collected at multiple depth increments. Intact soil cores (48 mm diameter × 56 mm length) for bulk density measurements were centered at depths of 10, 20, 30 and 40 cm. Disturbed soil samples for laboratory analyses were taken at depths of 0-10, 10-20, 20-30, 30-50 and 50-70 cm. The bulk density at 40 cm was used as an estimate of bulk density further down the soil profile and carbon stocks at the 50-70 cm were extrapolated to 1-m depth.

Disturbed soil samples were processed in the laboratory for chemical and biological analyses. Samples were 2-mm sieved and a subsampled dried to obtain gravimetric water content. Soil health analyses included organic carbon and total nitrogen by LECO CN analyser, mineral nitrogen (Keeney and Nelson, 1982), hot water extractable carbon (Ghani et al., 2003), and dehydrogenase activity (Chandler and Brookes, 1991). Additionally, anaerobic mineralisable nitrogen (Curtin and Campbell, 2006) was measured on the surface (0-10 cm) soil samples.

Results

Soil carbon stocks

Soil carbon stocks in the Australian apple orchards showed wide variation and ranged from 7.0 to 16.9 kg C m^{-2} (Figure 2). There was no significant spatial stratification of carbon stocks to 1-m depth with ridging at any of the sites subsequently sampled after the initial Shepparton and Huon Valley sites (Figure 3). Although, the Tamar orchard showed a strong trend for higher carbon stocks under the tree row than in the alley.

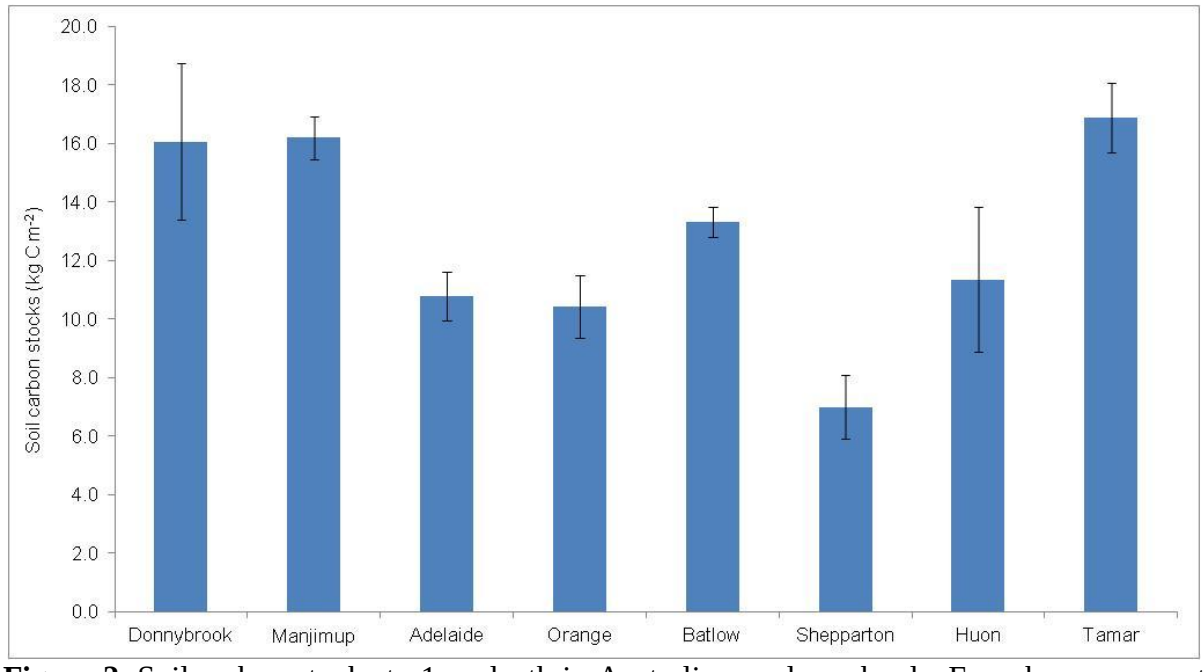

Figure 2. Soil carbon stocks to 1 m depth in Australian apple orchards. Error bars represent standard deviations.

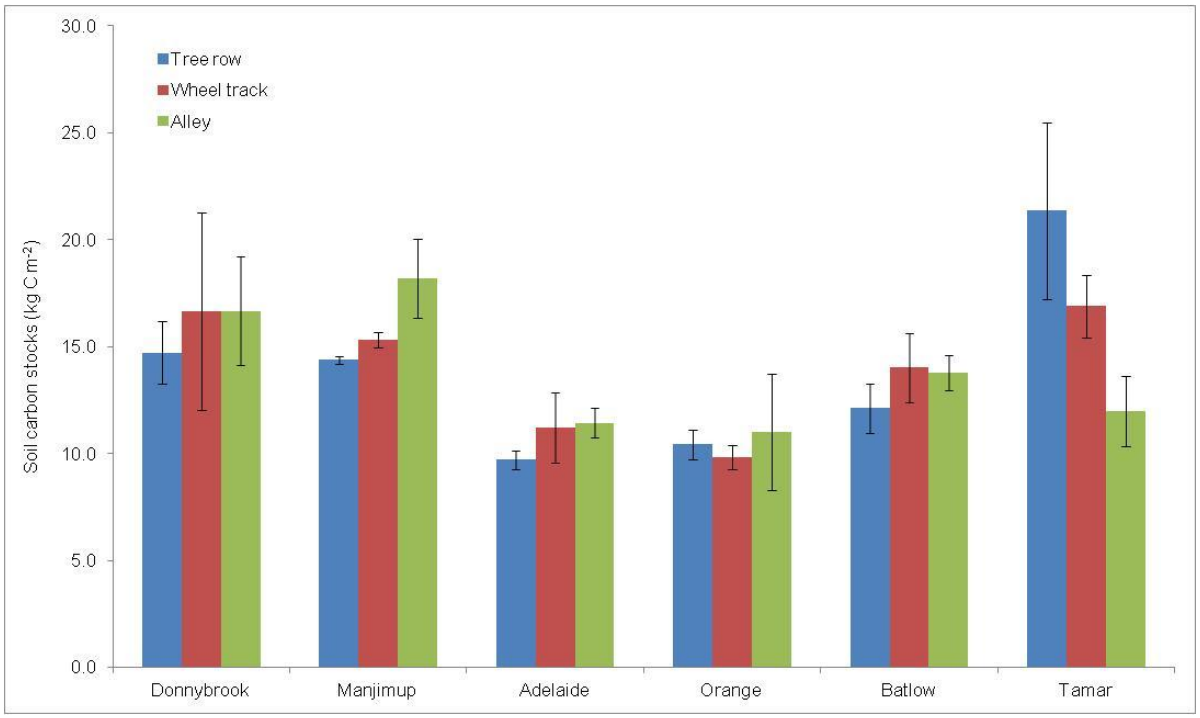

Figure 3. Spatial distribution of 1 m soil carbon stocks along the sampling transects in Australian apple orchards. Error bars represent standard deviations.

Soil health parameters

All of the soil health parameters declined rapidly with soil profile depth (Table 1) for all of the orchard sites. There was a wide range of values for the soil health parameters in the topsoil (0-10 cm) between the orchard sites (Table 2). The Adelaide Hills and Tamar orchards tended to have the highest indicators of soil carbon and microbial activity.

Positive relationships were observed between the soil health parameters (Table 3). There were strong correlations correlations between organic carbon, total nitrogen, hot water carbon, dehydrogenase activity, and anaerobic mineralisable nitrogen. Mineral nitrogen was relatively weakly correlated with any of the other measured soil health parameters, except for total nitrogen.

Conclusions

Australian apple orchard regions exhibit a wide variation in soil carbon stocks and can contain up to 17 kg C m^{-2} in the top 1 m. These duplex orchard soils show strong relationships between soil health parameters, which may serve as indicators for soil carbon regulation and nutrient supply services. Remaining analyses of apple orchard soils from Gippsland, Victoria and Stanthorpe, Queensland will complete the survey of the main orcharding regions in Australia.

Table 1. Soil profile depth distributions for soil health characteristics in an apple orchard at Donnybrook, Western Australia.

Profile depth (cm)	Organic carbon (mg C g^{-1} soil)	Total nitrogen (mg N g^{-1} soil)	Mineral nitrogen (µg N g^{-1} soil)	Hot water carbon (µg C g^{-1} soil)	Dehydrogenase activity (µg TPF g^{-1} soil d^{-1})
0-10	27.68 (10.00) a	1.83 (0.71) a	10.54 (4.34) a	499 (115) a	2.80 (4.26) a
10-20	23.82 (4.13) a	1.39 (0.21) b	5.92 (1.43) b	427 (130) a	0.26 (0.77) b
20-30	15.08 (4.72) b	0.85 (0.22) c	2.73 (2.33) c	217 (156) b	0.12 (0.27) b
30-50	8.38 (3.15) c	0.45 (0.37) d	1.07 (0.95) c	125 (141) b	0.46 (0.95) b
50-70	4.82 (1.18) c	0.25 (0.30) d	0.94 (0.90) c	128 (118) b	1.27 (0.90) b

Values are means (standard deviations). Different letters indicate significant differences among depths (P<0.05).

Table 2. Soil health characteristics at 0-10 cm soil depth for all Australian apple orchard sites.

Site	Organic carbon (mg C g^{-1} soil)	Total nitrogen (mg N g^{-1} soil)	Mineral nitrogen (µg N g^{-1} soil)	Hot water carbon (µg C g^{-1} soil)	Dehydrogenase activity (µg TPF g^{-1} soil d^{-1})	Anaerobic mineralisable nitrogen (µg N g^{-1} soil)
Donnybrook	27.68 (1.00) bc	1.83 (0.71) b	10.54 (4.34) bc	499 (115) d	2.80 (4.26) c	4.44 (5.54) cd
Manjimup	32.83 (6.86) ab	2.15 (0.57) ab	15.98 (6.42) b	538 (204) cd	8.41 (6.86) bc	3.98 (5.55) cd
Adelaide Hills	33.08 (7.07) ab	2.46 (0.57) a	5.33 (2.33) c	964 (282) a	25.48 (12.23) a	25.79 (18.31) a
Orange	20.18 (5.00) d	1.86 (0.47) b	13.51 (9.75) bc	885 (231) ab	12.29 (5.68) b	10.77 (5.23) cd
Batlow	24.52 (3.12) cd	1.78 (0.26) b	10.21 (4.15) bc	715 (282) bc	3.33 (1.84) c	1.97 (3.95) d
Shepparton	20.82 (4.11) d	2.15 (0.34) ab	39.65 (23.88) a	574 (107) cd	11.98 (7.68) b	11.37 (8.88) bcd
Huon Valley	36.33 (4.42) a	2.68 (0.44) a	40.44 (13.70) a	540 (118) cd	13.12 (3.86) b	12.36 (11.39) bc
Tamar	32.47 (6.42) ab	2.59 (0.54) a	7.41 (6.74) bc	1048 (307) a	23.48 (8.27) a	21.10 (10.07) ab

Values are means (standard deviations). Different letters indicate significant differences among sites (P<0.05).

Table 3. Correlation coefficients for soil health characteristics in Australian apple orchards.

	Organic carbon	Total nitrogen	Mineral nitrogen	Hot water carbon	Dehydrogenase activity
Organic carbon	-				
Total nitrogen	0.9182	-			
Mineral nitrogen	0.4314	0.5037	-		
Hot water carbon	0.6207	0.7092	0.2344	-	
Dehydrogenase activity	0.6341	0.7352	0.3201	0.6353	-
Anaerobic mineralisable nitrogen	0.4093	0.5950	0.0702	0.5536	0.7978

Acknowledgements
We thank Justin Direen and Steve Paterson for technical assistance in soil sampling, and Dr Sally Bound for designing and executing the biochar trial. The Australian Apple & Pear Orchard Productivity Program, PIPS (Productivity, Irrigation, Pests and Soils) is the Horticulture Australia Ltd and Apple and Pear Australia Ltd flagship program designed to integrate research effort and provide a dynamic interface with industry, through co-investment and shared management. Collaborators on this project include the Tasmanian Institute of Agriculture and the Department of Primary Industries Victoria. This project has been funded by HAL using the apple and pear levy, voluntary contributions from industry and matched funds from the Australian Government.

References
Chandler, K., and P.C. Brookes. 1991 Is the dehydrogenase assay invalid as a method to estimate microbial activity in copper contaminated soils? Soil Biol. Biochem. 23:909-915.

Curtin, D. And C.A. Campbell. 2006. Mineralizable nitrogen. In: Carter, M.R., and E.G. Gregorich (eds.) Soil sampling and methods of analysis. 2nd ed. CRC Press, Boca Raton, pp 599-606.

Ghani, A., M. Dexter, and K.W. Perrot. 2003. Hot-water extractable C in soils: a sensitive measurement for determining impacts of fertilisation, grazing and cultivation. Soil Biol. Biochem. 35:1231-1243.

Keeney, D.R., and D.W. Nelson. 1982. Nitrogen–inorganic forms. In: Page, A.L., R.H. Miller, and D.R. Keeney (eds.) Methods of soil analysis, part 2. Chemical and microbiological properties, 2nd edn. American Society of Agronomy and Soil Science Society of America, Madison, pp 643-709.