ORGANIC CARBON STOCK IN KIWIFRUIT SOILS OF NEW ZEALAND

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Background

1. Soil is a major natural component which sequesters huge amounts of carbon.
2. The impact of kiwifruit production on greenhouse gas emissions was estimated in New Zealand with a lifecycle assessment based carbon footprint analysis following the PAS2050 framework.
3. However, this framework does not consider the kiwifruit soil as a source or sink of atmospheric CO_2.

Objectives

1. To determine the effect of land management on organic carbon stock in an Allophanic soil.
2. To estimate the effect of climate on the organic carbon pool of different management systems.
3. To compare the spatial and vertical variability of carbon in kiwifruit soils.

Materials and Methods

In this study three management practices (organic, biological and conventional) were selected from three agro-ecological zones (Katikati: 37º36'S 175º56'E; Tauranga: 37º43'S 176º06'E and Te Puke: 37º47'S 176º23'E), located in the Bay of Plenty, North Island of New Zealand. The Katikati sites are approximately 19 km north-west of the Tauranga sites, with the Te Puke sites 28 km to the east of the Tauranga sites. Katikati sites ranged from 15 to 20m, Tauranga sites ranged from 20 to 48m and Te Puke sites ranged from 7 to 12m above sea level. The biological, conventional and organic sites are all within a kilometre of each other in each region. Sites were also included from nearby pastoral and arable land to use as paired samples.

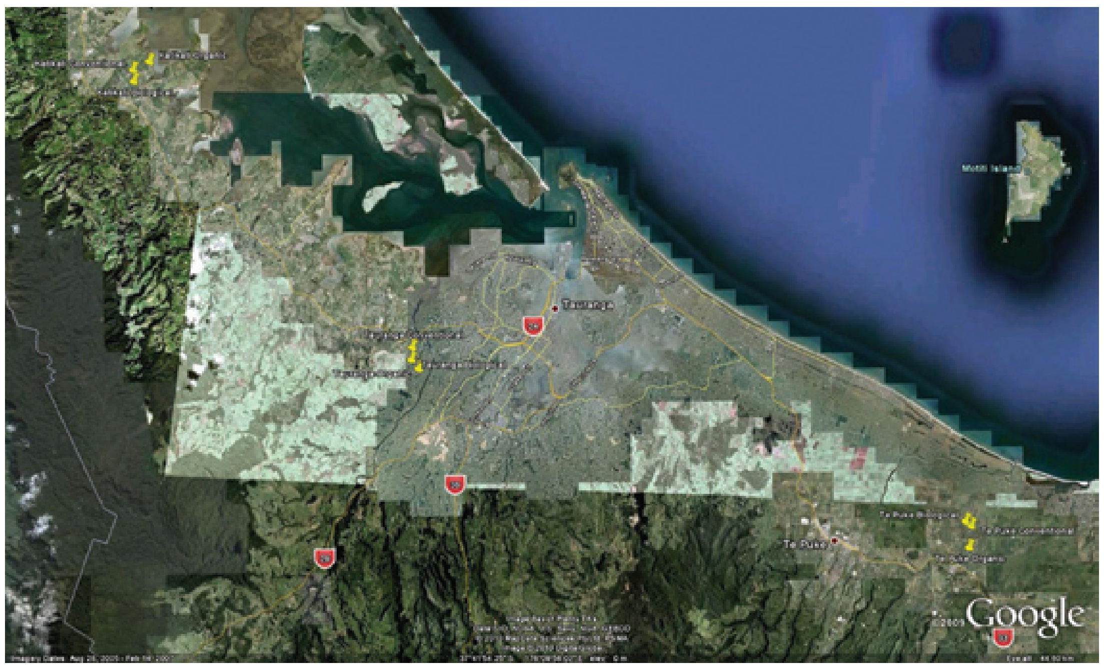

Fig. 1. Location and distribution of the nine sampled orchards

Soils of all experimental sites are classified as Allophanic Orthic Pumice soils (Vitrads/Vitricryands An-disol, USDA; Mollic Andosol, FAO) formed predominantly from ryolitic tephra between ~ 4,000 and 40,000 years ago during the region's geographic history of periodic volcanic eruptions. Three sampling plots (bays) of 5 m x 4 m were randomly selected within each site for soil collection at 0-5cm, 5-10cm and 10-15cm depth. In kiwifruit orchards, soil samples were collected from between the vines along the row (vine row); in the middle of the sward between the rows (grass alleyway) and from the area that machinery travels along between the rows (wheel tracks) using a Daiki Soil Sampler with a 100cc core (Daiki Rika Kogyo Co., Ltd., Japan) in August 2008 and 2009.

Materials and Methods (cont.)

Soil organic carbon was measured using three recognised methods: wet chemistry (Walkley and Black 1934), dry chemistry (TruSpec® CHN Determinator, LECO Corp., St Joseph, MI, USA) and loss-on-ignition (Kalra and Maynard 1994) for the 81 soil samples, collected from the different kiwifruit orchards. Based on the results, a regional regression equation was developed to estimate SOC from loss-on-ignition (LOI) at 300ºC for 4 hours (Rahman et al. 2009), as LOI is popular as a rapid, easy and inexpensive method. Carbon storage was estimated as: Carbon stock (t ha^{-1}) per soil layer = carbon (%) x bulk density (Mg m^{-3}) x layer depth (m) x 10, 000 (m^2 ha^{-1}). The relative proportion of carbon in the kiwifruit orchard and pastoral land to the 10-15cm deep sample from the arable land was calculated. Coefficient of variation (CV), standard deviation (SD), kurtosis and skewness were calculated to compare the variability of differences. The least significant differences (LSD) test was used to determine whether differences between means were statistically significant.

Table 1. Comparisons of summary statistics.

	Agro-ecological zone			Management					Depth (cm)			Position		
	KK	TR	TP	KOrg	KBio	KCon	P	AL	0-5	5-10	10-15	AW	WT	VR
Minimum, t ha^{-1}	9.46	9.49	4.47	40.48	34.65	34.97	43.15	27.92	11.86	10.67	4.47	7.68	8.13	7.50
Maximum, t ha^{-1}	26.11	22.95	21.11	61.76	64.67	55.72	57.00	52.04	26.11	20.88	20.88	26.72	31.38	24.43
Mean, t ha^{-1}	18.43	15.41	13.23	49.97	50.64	47.48	49.27	39.33	19.32	15.67	14.12	16.88	17.74	15.40
SD	3.58	3.45	4.09	8.43	9.71	7.27	5.33	8.07	3.30	2.70	4.28	3.73	4.22	3.03
CV, %	19.4	22.4	30.9	16.9	19.2	15.3	10.8	20.5	17.1	17.2	30.3	22.26	24.11	20.13
Kurtosis	-0.01	-0.79	-0.45	-1.67	-0.59	-0.92	-1.63	-0.60	-0.30	-1.03	-0.51	-0.41	-0.49	-0.22
Skewness	0.23	0.37	-0.09	0.50	-0.15	-0.65	0.35	0.20	-0.01	-0.01	-0.56	0.44	0.30	0.16

KK = Katikati; TR = Tauranga; TP = Te Puke; K = Kiwifruit; P = Pastoral; AL = Arable land
Org = Organic management; Bio = Biological management; Con = Conventional management; AW = Alleyway; WT = Wheel track; VR = Vine row.

Table 2. Organic carbon stock (t ha^{-1}) in soils with different management practices of Bay of Plenty.

Soil management	Depth, cm	Katikati	Tauranga	Te Puke	Average
Organic kiwifruit	0-15	60.15	46.04	43.99	50.06
Biological kiwifruit	0-15	61.45	50.52	40.93	50.96
Conventional kiwifruit	0-15	54.64	51.79	39.45	48.62
Kiwifruit	0-15	58.75	49.45	41.46	49.88
Pastoral	0-15	56.19	49.82	45.61	50.54
Arable	0-15	46.30	40.40	30.31	39.00

ANOVA	df	SS	F ratio	Pro>F
Among all management	4	771.22	3.11	0.026
Within Kiwifruit	2	49.96	0.35	0.712
Kiwifruit vs. Pastoral vs. Arable	2	721.27	5.96	0.005
Kiwifruit vs. Pastoral	1	0.07	0.001	0.974
Kiwifruit vs. Arable	1	679.46	9.98	0.003
Pastoral vs. Arable	1	444.12	9.51	0.007

Summary of Results

Results are summarised in Tables 1-2.

1. Biological and organic kiwifruit management systems stored more SOC than conventional system in both Katikati and Te Puke;

2. The conventional kiwifruit system stored more SOC than the other systems in Tauranga;

2. The highest SOC was found in the wheel tracks, followed by the alleyway then the vine row;

3. The highest SOC was recorded in the 0-5 cm layer, and decreased linearly with increased depth;

4. Soil organic carbon stocks varied significantly across regions with the highest in Katikati and the lowest in Te Puke;

5. Organic carbon storage capacity of kiwifruit orchard soils was recorded as ~1.3 times higher than arable soils in the top 15 cm.

Conclusions

This is a baseline study on carbon stocks in kiwifruit soils in the Bay of Plenty of New Zealand. Our preliminary study shows that organic management leads to significantly higher soil carbon storage than conventional kiwifruit management in two out of three regions. Irrespective of regions, there were no significant differences between SOC storage among kiwifruit management systems.

The relative proportion of SOC was significantly higher in kiwifruit orchards than that of arable land, but not significantly different to that of pastoral land. Additionally, kiwifruit have a deeper rooting system than shallow rooted pastoral and arable plants and may sequester higher SOC at depth in kiwifruit orchards than those systems. To maintain potentially high SOC in soils, higher C:N ratio (more lignin and less carbohydrate and protein) and/or lower N:C ratio plant or plant material should be established in the sward or introduced as compost or mulch. The following should to be considered in future research on carbon storage in kiwifruit orchards to mitigate and adapt to climate change: (i) soil process and profile (ii) plant species and management practices (iii) landscape and climate (iv) surveillance site and baseline benchmarks (vi) regional and temporal scale (vii) related and effective soil sampling technique and (viii) cost-effective and rapid SOC estimation method which will help to develop and disseminate guidelines for kiwifruit growers to economically and environmentally sustainable carbon storage. Since undertaking this work, Plus Group is now managing the Sustainable Farming Fund funded Carbon in Orchard Soils Team, investigating the role of different kiwifruit management systems on SOC; and the effect of SOC on kiwifruit production, carbon sequestration and footprints.

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