COMPARISON OF THREE METHODS TO ESTIMATE ORGANIC CARBON IN ALLOPHANIC SOILS IN NEW ZEALAND

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Background

1. Soil sequesters huge amounts of carbon derived from organic and inorganic sources.
2. Soil organic carbon (SOC) has to be periodically measured for the study of ecology, soil science and climate change.
3. Carbon in soil samples is converted to carbon dioxide in the laboratory and this is then measured directly or indirectly by different methods.
4. Many methods used for estimating SOC are time consuming and costly.
5. Loss-on-ignition (LOI) has been considered as a rapid, inexpensive and convenient method for estimating SOC, which involves dry combusting samples at high temperature in a muffle furnace.

Objective

The objective of this study was to establish a NZ kiwifruit specific regression equation to estimate SOC from LOI.

Materials and Methods

We collected 121 allophanic soil (Vitrads/Vitricryands Andisol, USDA; Mollic Andosol, FAO; Ando Soil, Japanese system) formed predominantly from rhyolitic tephra between ~ 4000 and 40,000 years ago during the region's geographic history of periodic volcanic eruptions) samples from three regions (Katikati: 37^{o}36S 175^{o}56E; Tauranga: 37^{o}43S 176^{o}06E and Te Puke: 37^{o}47S 176^{o}23E) of kiwifruit orchards in the Bay of Plenty area of New Zealand with organic, biological and integrated management systems. Soils were collected from 0-90 cm depth with three increments (viz. 0-15, 15-30 and 30-90cm) by core method with opening a pit (Blake and Hartge, 1986). Soils were air dried and sieved through 2mm sieve. Processed soils were analysed for organic carbon by three recognised methods: wet chemistry-wet acidified rapid dichromate oxidation (Walkley & Black, 1934), dry chemistry-dry combustion (TruSpec® CHN Determinators, LECO Corp., St. Joseph, MI, USA) and loss-on-ignition (LOI). Soils were analysed for LOI by factorial design with combinations of three different ignition temperatures (300, 400 and 600^{o}C) and four time durations (2, 3, 4 and 6h). We placed oven dried (Gardner, 1986) soil samples in CEM disposable crucible and performed LOI in CEM Phoenix Microwave Furnace (Model #905410, CEM Corporation, Matthews, CA 28106, USA). Based on the results, a kiwifruit-specific regression equation was developed to estimate SOC from LOI with optimum ignition temperature and duration.

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

Results

A NZ kiwifruit-specific regression of SOC measured by LOI (300^{o}C, 2h) versus LECO which was assumed here to have no error yields for the topsoil (0-50 cm; SOC typically > 1%; SOC = -0.60833+0.57201*LOI) an R^2 of 0.94 (SD = 0.41 % SOC) and for the subsoil (50-100 cm; SOC typically < 1%; SOC = -0.38314+0.32517*LOI) an R^2 of 0.45 (SD = 0.17% SOC). The regression of SOC for 0-15 cm soils established by LOI (400^{o}C, 3h) had an R^2 of 0.903 (Table 1). On the other hand, regressions established by LOI (300^{o}C, 3h) for SOC of 15-30 cm and 30-90 cm of soils had R^2 of 0.777 and 0.748, respectively. Irrespective of soil depths, the relationship between SOC measured by LOI (300^{o}C, 3h) and LECO was established by a linear equation as: SOC = 0.5663*LOI-0.7589 with an R^2 of 0.9217 which is highly significant at 1% level. Our results shows very poor relationship between LOI and LECO with higher temperatures and soil depths (Table 1), indicating LOI analysis on allophanic soils for subsoil or surface soils should involve lower temperatures. Furthermore, we found the best correlation between LOI-LECO for temperature-duration is 300^{o}C and 2h for optimum combination to estimate SOC from LOI for surface allophanic soils.

Table 1. Predicting SOC (y) from LOI (x) at various temperatures and durations.

Temperature	Duration	SOC (y) = mLOI + c					
		m		c		r^2	
oC	hr	A*	B**	A	B	A	B
				0-15cm			
300	2	0.744	0.494	1.620	0.191	0.805	0.822
300	3	0.890	0.595	-0.169	-1.035	0.654	0.676
300	4	0.885	0.586	-0.442	-1.120	0.590	0.591
300	6	0.868	0.573	-0.395	-1.110	0.593	0.598
400	2	0.593	0.382	2.600	0.976	0.447	0.428
400	3	0.969	0.750	-2.536	-3.7045	0.704	0.903
400	4	0.925	0.615	-2.016	-2.233	0.721	0.738
400	6	0.945	0.618	-2.402	-2.356	0.744	0.734
600	2	0.825	0.556	-1.695	-2.122	0.834	0.845
600	3	0.809	0.551	-2.442	-2.694	0.832	0.858
600	4	0.798	0.541	-2.347	-2.602	0.849	0.870
600	6	0.828	0.560	-2.875	-2.950	0.834	0.851
				15-30cm			
300	2	0.527	0.429	2.279	0.387	0.631	0.776
300	3	0.445	0.353	2.542	0.666	0.661	0.777
300	4	0.435	0.346	2.416	0.559	0.618	0.726
300	6	0.457	0.384	2.177	0.236	0.435	0.570
400	2	0.223	0.217	3.645	1.272	0.107	0.189
400	3	0.248	0.205	3.351	1.288	0.173	0.219
400	4	0.262	0.235	3.203	0.988	0.204	0.305
400	6	0.278	0.239	3.032	0.913	0.241	0.330
600	2	0.191	0.065	3.676	2.428	0.244	0.110
600	3	0.158	0.088	3.832	2.270	0.153	0.175
600	4	0.141	0.081	3.974	2.208	0.131	0.168
600	6	0.138	0.069	3.995	2.324	0.120	0.115
				30-90cm			
300	2	0.298	0.221	1.245	0.414	0.220	0.621
300	3	0.314	0.198	1.129	0.464	0.368	0.748
300	4	0.372	0.159	0.714	0.534	0.456	0.424
300	6	0.351	0.127	0.725	0.642	0.299	0.200
400	2	0.115	0.026	1.784	1.102	0.055	0.014
400	3	0.152	0.000	1.565	1.229	0.105	0.000
400	4	0.028	-0.061	2.187	1.559	0.003	0.070
400	6	0.054	-0.052	2.031	1.524	0.010	0.051
600	2	0.004	-0.041	2.318	1.479	0.000	0.043
600	3	0.016	-0.019	2.229	1.361	0.003	0.020
600	4	0.009	-0.028	2.272	1.424	0.001	0.041
600	6	-0.008	-0.045	2.399	1.555	0.000	0.063

*A: Wet combustion- Walkley & Black, 1934; B**: Dry combustion-LECO CHN auto analyser

Conclusions and Recommendations

This analysis shows that the LOI method is well suited as a cost-effective method for the analysis of SOC in NZ kiwifruit systems, and may be for other allophanic soils, especially for topsoil with higher accuracy than subsoil.

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