Linking Soil Biological Indicators for Different Soil Types in North Dakota

Umesh Acharya, Amitava Chatterjee
Department of Soil Science, North Dakota State University, Fargo, ND

Six soil biological indicators, (i) chloroform-fumigated microbial biomass carbon (CFMBC), (ii) permanganate Oxidizable C (POXC), and soil CO_2 efflux from laboratory incubation using (iii) alkali base trap (Alkali), (iv) infrared gas analyzer (IRGA), (v) Solvita CO_2-burst (Solvita), and (vi) Solvita labile amino nitrogen (SLAN), were compared for nine different agricultural soils, collected across the Red River Valley (RRV) of North Dakota and Minnesota.

Table 1. Geographical location, soil taxonomic classification, cropping system and basic soil properties (mean) of collected soil samples across the Red River Valley of ND and MN.

Location	Latitude, and Longitude	Soil series	Rotation	WHC g g^{-1}	pH	EC (dSm^{-1})	NO_3-N (mg kg^{-1})	Olsen- P (mg kg^{-1})	SOM (g kg^{-1})	SOC (g kg^{-1})
Ada (MN)	47°31'49.7"N 96°40'88.5"W	Wheatville	Wheat-Corn	0.19	8.53	1.99	6.04	23.0	24.4	29.1
Downer (MN)	46°48'06.3"N 96°32'52.0"W	Elmville	Soybean-Corn	0.20	8.60	2.27	17.3	21.9	22.8	31.3
Embden (ND)	46°51'12.4"N 97°25'48.8"W	Ryan	Wheat-Alfalfa	0.27	7.73	8.69	10.9	68.6	32.2	22.6
Gardner (ND)	47°16'53.8"N 97°05'41.6"W	Fargo	Soybean-Corn	0.20	5.98	1.08	14.4	33.7	25.5	15.1
Glyndon (MN)	46°54′45.0″ N 96°36′35.0″W	Bearden	Corn-Soybean	0.31	8.07	4.09	30.5	49.5	45.7	44.3
Inkster (ND)	48º09'57.3"N 97º43'12.9"W	Inkster	Soybean-Potato	0.16	5.64	0.99	9.68	71.5	28.9	16.3
St. Thomas (ND)	48°34'05.7"N 97°27'01.9"W	Glyndon	Wheat-Sugar beet-beans	0.25	7.06	2.83	33.5	50.4	31.7	26.5
Walcott (ND)	46°31'45.3"N 96°54'14.3"W	Fargo	Soybean-Corn	0.38	7.77	2.99	25.7	66.5	44.3	27.8
Dilworth (MN)	46°55'10.6"N 96°39'05.6"W	Wheatville	Soybean-Wheat	0.34	8.21	2.67	20.7	16.3	39.1	39.8

Methods

During fall 2016, soil samples of 0-15 cm depth were collected using a bucket-auger from nine different agricultural fields across the Red River Valley of North Dakota and Minnesota. Details about sampling sites are presented in Table 1. Soil samples were air-dried, passed through 2 mm sieve. Samples from each site were divided into five subsamples for the laboratory analysis. Basic soil properties were analyzed as outlined in 'Recommended Chemical Soil Test Procedures for the North Central Region' (Station, 1988).

Soil Biological Indicators	Methods
CFMBC	Duplicate set of 20 g of air-dry subsamples were incubated for 7 days at 50% of WHC. First set of soil was fumigated with chloroform in the dark for 72 hours and extracted with 50 ml of 0.5M K_2SO_4. Extracts were analyzed for dissolved organic carbon using the Shimadzu TOC Analyzer. The difference in DOC values of the fumigated and non-fumigated soil samples with a correction factor (Kc) of 0.45 (Vance et al. 1987).
POXC	The POXC was analyzed as described by Weil et al. (2003). Briefly, 2 g of air-dried soil was treated with18 ml of deionized water and 2 ml of 2M $KMnO_4$, vigorously shaken for 2 minutes. Tubes were placed in the dark area precisely for 10 minutes, and 0.5 ml of supernatant from the upper 1 cm of the suspension transferred fast to a second tube containing 49.5 ml of deionized water and was inverted to mix. The diluted solution was measured for its absorbance in a spectrophotometer, set at 550 nm wavelength. The values for $KMnO_4$-C were determined using the following equation: POXC (mg kg^{-1}) = [0.02 mol L^{-1}- (a+b× absorbance)] × (0.02 L solution/wt. of soil)
Alkali-CO_2	50 g of air-dried soils were weighed into a 0.5L mason jar, and deionized water was added to bring soil at 50% WHC. For alkali trap method, 20 ml of 0.5 M NaOH in the vial was inserted in the jar and incubated for 4 days at 25°C. the vial containing NaOH was titrated with 0.5 M HCl to determine CO_2 by evolved during incubation (Anderson, 1982).
IRGA-CO_2	Incubated soils was used to determine soil CO_2 efflux using IRGA, Li-800 (LI-COR Bioscience, Lincoln, Nebraska, USA), after 5 days of incubation. Headspace CO_2 concentration (mg kg^{-1}) was converted to CO_2-C µg $g^{-1}day^{-1}$ using ideal gas equation.
Solvita-CO_2 Burst	For Solvita gel system, (Woods End Laboratories, Mt. Vernon, ME), 40 g of air-dried soils at 50% WHC were incubated for 24 hrs. Solvita-CO_2 probe was inserted into the glass jar. The detector reading was observed in CO_2 mg kg^{-1} using Digital Color Reader (DCR).
SLAN	Similar to above, NH_3 probe was used to determine SLAN (mg NH_4-N kg^{-1}).

Table 2. Mean (±SD) values of soil biological health parameters of collected soil samples

Location	CFMBC		POXC		SLAN		IRGA	Alkali		Solvita
	mg C kg^{-1}		mg C kg^{-1}		mg NH_4-N kg^{-1}		mgCO_2-C $kg^{-1}day^{-1}$			
Ada	1015	(137)	488	(20.8)	98.6	(7.19)	45.4 (8.31)	108	(6.25)	70.0 (8.63)
Downer	1557	(127)	503	(27.2)	97.0	(14.1)	180 (47.4)	83.3	(2.22)	135 (7.37)
Embdon	1496	(101)	761	(41.7)	109	(17.6)	28.9 (2.74)	44.6	(8.51)	78.2 (8.60)
Gardner	1239	(151)	553	(34.7)	101	(8.40)	97.8 (22.9)	63.8	(2.63)	107 (7.75)
Glyndon	1873	(148)	785	(39.1)	164	(24.0)	77.6 (9.20)	91.1	(9.62)	92.6 (16.1)
Inkster	867.6	(65.6)	226	(82.6)	52.0	(11.7)	32.6 (0.82)	40.5	(1.31)	63.5 (7.96)
St. Thomas	1272	(85.5)	672	(54.5)	144	(14.9)	18.4 (0.61)	64.7	(8.64)	61.8 (9.52)
Walcott	2609	(208)	719	(41.5)	140	(13.6)	75.3 (4.09)	84.9	(7.45)	117 (4.72)
Dilworth	1749	(183)	609	(27.4)	147	(16.7)	47.7 (1.89)	99.3	(5.82)	85.1 (6.07)

Table 3. Pearson correlation coefficient representing relationship among soil properties and soil biological health indicators of soils collected from nine agricultural fields across the RRV. (Bold values indicate significant relationship at 95% significance level)

	IRGA	Alkali	Solvita	SLAN	POXC	CFMBC	pH	EC	NO_3-N	Olsen-P	SOM
Alkali	0.27										
Solvita	**0.91**	0.27									
SLAN	-0.07	0.51	0.12								
POXC	-0.06	0.24	0.19	**0.85**							
CFMBC	0.24	0.35	0.57	0.67	0.67						
pH	0.30	**0.75**	0.31	0.49	0.47	0.43					
EC	-0.26	-0.25	-0.11	0.28	0.66	0.26	0.33				
NO_3-N	0.01	0.18	0.12	**0.81**	0.60	0.55	0.13	0.03			
Olsen-P	-0.44	**-0.71**	-0.27	-0.15	0.09	0.14	-0.48	0.39	0.10		
SOM	-0.25	0.23	0.03	**0.74**	0.62	**0.77**	0.19	0.29	0.64	0.34	
SOC	0.15	**0.73**	0.15	**0.75**	0.49	0.48	**0.76**	0.16	0.51	-0.40	0.58

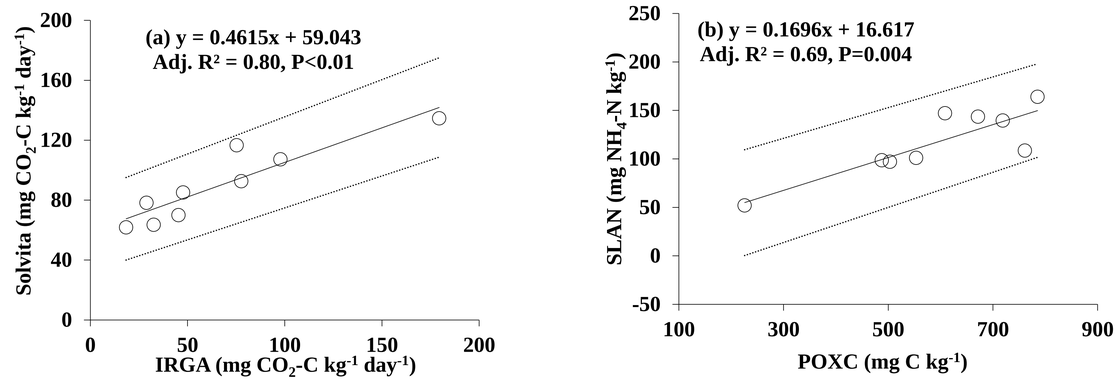

Figure 1. Linear regression relationship between (a) IRGA and Solvita and (b) SLAN and POXC for nine different agricultural soils collected across the Red River Valley of ND and MN

Findings

- Significant relationships were observed in between Alkali with pH and Olsen-P (-0.71), SLAN with SOM, SOC and NO_3-N, POXC and EC, and CFMBC and SOM.
- IRGA had a significant relationship with Solvita (0.91), whereas SLAN had significant relationships with POXC.
- Linear regression relationship among soil biological methods shows a significant relationship between IRGA and Solvita and SLAN and POXC.

Take-home message

No single method was found to comprehensively represent the soil biological health. Each method studies a specific soil C fraction or microbiological function with few overlaps. Soil biological methods can be broadly grouped into three categories, methods to determine (i) labile C pool (Solvita and IRGA), (ii) stabilized organic matter (POXC or SLAN), and (iii) microbial biomass (CFMBC). Researchers should be critical about selecting the particular method(s) based on their objective.

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