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Management Systems Impact on Soil Aggregate Protected Carbon and Nitrogen Accumulation

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Abstract

Continuous no-till with cover crops is important to support sustainable agriculture. A field study was established at Piketon, Ohio to determine the long-term effects (2005 to 2013) of tillage and cover crops on soil aggregate size distribution, aggregate stability and C and N protection. Treatments included corn-soybean rotation with conventional tillage (CT-CS), corn-soybean rotation with continuous no-till (NT-CS), and corn-soybean-wheat-cover crop rotation with continuous no-till (NT-CSW-CC) and replicated three times. Composite soil samples were collected from 0 to 90 cm depth at 15 cm increments, processed and analyzed for bulk density, aggregate size distribution from 0.053 to 0.125, 0.250, 0.50, 1.0, 2.0 and 5.0-mm, macro- and microaggregate stability, mean weight diameter (MWD), geometric mean diameter (GMD), and total C and N content of aggregate size distribution. Results showed that NT significantly increased macroaggregates, MWD and GMD, and aggregate stability and decreased bulk density compared with CT. Likewise, higher content of total C and N was measured in macroaggregates of NT. The effect of NT with cover crop was more pronounced on aggregate properties and C and N protection than on CT-CS and NT-CS. Irrespective of treatments, aggregate stability and C and N content decreased with depth.

Introduction

Increasing concerns regarding soil and environmental degradation with conventional agriculture have warranted need for management practices that enhance agricultural sustainability (Kong et al. 2007). Management practices based on integration of continuous NT with cover crops in agronomic crop rotation have been suggested to improve soil quality for economic crop production.

Soil organic matter (SOM) is the composite indicator of soil quality since it has widespread effects on soil biology, chemical properties and physical stability (Haynes 2005; Ekrem et al. 2013). Soil aggregation is one of the key physical properties for SOM protection. Elliot (1986) reported that aggregates especially macroaggregates form transient/ temporary C and N pools by stabilizing C and N within their structure and release C and N upon breakdown; therefore, aggregate turnover is important for SOM dynamics and nutrient availability to plants.

Soil aggregate properties are sensitive to changes in management practices. CT is often linked to soil structural degradation and hence, depleting SOM content. In contrast, NT improves soil structure by accumulating C and N and hence aggregation. Integrating cover crops in NT is suggested as one of the management tools to enhance NT performance.

The objectives of the study were to compare the impacts of management systems based on NT and CT, with and without cover crops, in corn-soybean rotation on: (1) soil aggregate size distribution and aggregate stability, (2) aggregate associated C and N contents, and (3) the relationship of aggregate stability with C and N contents.

Materials and Methods

A field experiment in randomized complete block design was established on Omulga silt loam (Fine-silty, mixed, mesic Typic Fragiudalfs) at Ohio State University South Centers at Piketon, Ohio in 2005. Treatments included the following: Conventionally-tilled corn-soybean (CT-CS), Continuous no-till corn-soybean (NT-CS), and Continuous no-till corn-soybean-wheat with cereal rye/Cowpea (NT-CSW-CC). Treatments were replicated three times in 30 m x 20 m plots.

Composite soil samples were collected from 0-90 cm depth at 15 cm intervals from geo-referenced sites in each replicated plot, 5-mm sieved, air-dried at room temperature (~25^{0}C), and analyzed for aggregate size fractionation. The <5-mm air-dried soil was fractionated for 0.053, 0.125, 0.25, 0.5, 1, 2 and 5-mm aggregates, respectively by a modified wet sieving technique. After oven-drying, total C and N content of aggregates were determined by the Elementar® CN analyzer. Several aggregate stability parameters such as macro- (MaA) and microaggregate (MiA) stability, mean weight diameter (MWD), geometric mean diameter (GMD), and aggregate ratio were calculated.

Data were statistically analyzed using SAS in a 3 x 5 factorial arrangement. Simple and interactive effects of management treatments and depth on dependent variables were separated by LSD at p<0.05 unless otherwise mentioned. Regression and correlation analyses between macroaggregate stocks and aggregate associated total C and N stocks were performed using SigmaPlot®.

Results and Discussion

Results showed that management systems have significantly affected the aggregate size distribution at different depths of soil (**Table 1**). Averaged across depth, NT-CSW increased (16 to 40%) the 2000, 1000- and 500-mm aggregates, respectively compared with CT-CS. However, the ≤250-mm aggregates did not vary among the management systems. Irrespective of management systems, the 250 to 2000-mm aggregates decreased and 53 to 125-mm aggregates increased with depth. Among the aggregates, the 1000- and 2000-mm size aggregates significantly influenced by management system x depth.

Management systems significantly influenced the aggregate stability at different depths of soil (Fig. 1a and b). The MaA increased by NT-CSW than NT-CS and CT-CS, respectively (Fig. 1a). Likewise, NT-CS had higher MaA than that of CT-CS. The MaA decreased with depth. In contrast, the MiA was higher in CT-CS than in NT-CSW and NT-CS (Fig. 1b). The macro- and microaggregate ratio (AR) was consistently higher in NT-CSW followed by NT-CS and CT-CS. The effect of management systems on AR was more pronounced at surface depth (Fig. 1c). The MWD of aggregates was significantly influenced by management systems and depth without an interaction (Fig. 1d). The NT-CSW had higher MWD over NT-CS and CT-CS. The MWD decreased with depth.

When plotted, the MaA stock had a significant non-linear relationship with both C and N contents (Fig. 2). The MaA accounted for 80% of the variability in aggregate associated total C content. The MaA also accounted for 82% of the variability in aggregate associated total N content. Averaged across all aggregate size fractions, the significant relationship of MaA stock with C and N suggested that C sequestration and N accumulation are influenced by soil aggregation. A similar response of both C and N with MaA have indicated that C and N stoichiometrically linked to each other in soil organic matter.

Table 1: Management systems impact on aggregate size distribution at different depths of soil

Mgt. Sys.	Depth (cm)	Aggregate size (mm) distribution (%) 2000	1000	500	250	125	53
CT-CS		5.4b	3.8b	6.1b	9.9a	24.9a	16.1a
NT-CS		6.0ab	5.1a	9.2a	11.4a	25.3a	13.4a
NT-CSW		6.4a	5.4a	10.2a	11.5a	24.2a	14.5a
			System x depth				
CT-CS	0-15	10.5$^{\delta}$	6.6$^{\delta}$	7.7^{ns}	12.3^{ns}	17.8$^{\delta}$	9.9^{ns}
	15-30	7.4	4.7	7.3	11.0	28.9	18.5
	30-45	4.3	3.5	6.8	10.5	31.9	19.1
	45-60	4.2	3.0	5.9	9.3	17.6	19.3
	60-75	3.3	2.5	5.1	8.2	22.4	15.5
	75-90	2.9	2.3	4.0	7.8	30.7	14.5
NT-CS	0-15	12.3	9.0	13.8	16.2	13.3	6.0
	15-30	6.4	5.8	11.8	13.6	29.9	14.6
	30-45	5.2	5.2	9.5	12.4	31.5	17.0
	45-60	4.5	4.2	8.5	10.2	23.9	15.4
	60-75	3.9	3.5	6.7	9.0	27.0	12.6
	75-90	3.4	2.9	5.2	6.9	26.0	14.6
NT-CSW	0-15	16.1	8.7	14.7	15.6	9.3	4.3
	15-30	9.0	7.1	12.6	13.5	26.3	13.8
	30-45	4.6	5.8	10.2	12.2	33.4	20.0
	45-60	3.9	4.8	9.5	11.5	28.3	17.9
	60-75	3.2	3.3	7.7	8.3	24.4	16.7
	75-90	1.8	3.0	6.7	7.7	23.3	14.5
LSD$_{p\leq0.0}$5	Depth	3.1	1.9	1.6	2.3	ns	ns

CT-CS=Conventional tillage corn-soybean, NT-CS=No-till corn-soybean, and NT-CSW=No-till corn-soybean-wheat with cover crop. Means separated by same lower case letter in each column were not significantly different among systems at p<0.05. δ=Indicates significant interaction. ns=Indicates non-significant interaction.

Table 2: Management systems impact on carbon concentration in aggregates at different depths of soil

Mgt. Sys.	Depth (cm)	C (g/kg) in aggregate size (mm) fraction 2000	1000	500	250	125	53
CT-CS		6.3b	6.2a	5.5a	5.3a	4.5a	3.1a
NT-CS		6.3b	6.0a	5.5a	4.8a	4.0a	3.2a
NT-CSW		7.5a	6.6a	5.8a	5.4a	4.4a	3.6a
			System x depth				
CT-CS	0-15	12.3$^{\delta}$	12.6^{ns}	13.0$^{\delta}$	13.7^{ns}	12.5^{ns}	9.6^{ns}
	15-30	7.8	8.4	8.1	8.1	6.9	3.1
	30-45	6.0	6.3	5.1	4.2	3.1	2.1
	45-60	4.3	3.8	2.8	2.3	1.9	1.4
	60-75	4.2	2.8	2.0	1.7	1.3	1.1
	75-90	3.2	3.0	1.9	1.6	1.4	1.1
NT-CS	0-15	14.5	12.6	12.7	10.9	10.6	9.0
	15-30	7.1	8.1	7.9	7.7	5.5	3.7
	30-45	5.5	5.4	4.0	3.6	2.5	1.9
	45-60	4.8	4.0	3.3	3.1	2.3	1.7
	60-75	3.3	3.0	2.6	2.1	1.7	1.5
	75-90	2.8	3.0	2.2	1.7	1.4	1.4
NT-CSW	0-15	15.7	14.8	14.4	12.8	11.8	10.2
	15-30	9.4	8.9	8.3	8.7	6.5	4.6
	30-45	6.1	5.7	4.5	4.5	2.9	2.2
	45-60	5.1	4.0	2.8	2.5	2.0	1.7
	60-75	4.0	3.2	2.4	2.0	1.8	1.3
	75-90	4.4	3.0	2.2	1.9	1.6	1.3
LSD$_{p\leq0.0}$5	Depth	2.3	2.0	1.6	2.1	0.7	0.6

CT-CS=Conventional tillage corn-soybean, NT-CS=No-till corn-soybean, and NT-CSW=No-till corn-soybean-wheat with cover crop. Means separated by same lower case letter in each column were not significantly different among systems at p<0.05. δ=Indicates significant interaction. ns=Indicates non-significant interaction

Table 3: Management systems impact on N concentration in aggregates at different depths of soil

Mgt. Sys.	Depth (cm)	N (g/kg) in aggregate size (mm) fraction 2000	1000	500	250	125	53
CT-CS		0.53c	0.50b	0.52b	0.52b	0.46c	0.35c
NT-CS		0.63b	0.57b	0.59a	0.57b	0.51b	0.41b
NT-CSW		0.73a	0.67a	0.66a	0.66a	0.57a	0.47a
			System x depth				
CT-CS	0-15	1.21^{ns}	1.14^{ns}	1.11^{ns}	1.24^{ns}	1.21$^{\delta}$	0.94^{ns}
	15-30	0.72	0.62	0.71	0.61	0.52	0.36
	30-45	0.41	0.41	0.52	0.42	0.41	0.32
	45-60	0.39	0.42	0.34	0.31	0.33	0.27
	60-75	0.40	0.34	0.34	0.27	0.26	0.24
	75-90	0.22	0.24	0.27	0.22	0.22	0.23
NT-CS	0-15	1.43	1.15	1.23	1.19	1.16	0.97
	15-30	0.72	0.71	0.81	0.80	0.65	0.47
	30-45	0.41	0.44	0.42	0.45	0.41	0.35
	45-60	0.47	0.42	0.40	0.42	0.36	0.30
	60-75	0.43	0.40	0.37	0.40	0.32	0.30
	75-90	0.31	0.34	0.32	0.34	0.30	0.28
NT-CSW	0-15	1.62	1.54	1.51	1.35	1.24	1.14
	15-30	0.94	0.83	0.92	0.91	0.77	0.60
	30-45	0.51	0.52	0.53	0.61	0.43	0.35
	45-60	0.45	0.44	0.42	0.40	0.41	0.33
	60-75	0.46	0.41	0.40	0.37	0.41	0.32
	75-90	0.41	0.38	0.41	0.36	0.36	0.31
LSDp<0.05	Depth	0.12	0.20	0.13	0.21	0.17	0.16

CT-CS=Conventional tillage corn-soybean, NT-CS=No-till corn-soybean, and NT-CSW=No-till corn-soybean-wheat with cover crop. §Means separated by same lower case letter in each column were not significantly different among systems at p<0.05. δ=Indicates significant interaction. ns=Indicates non-significant interaction.

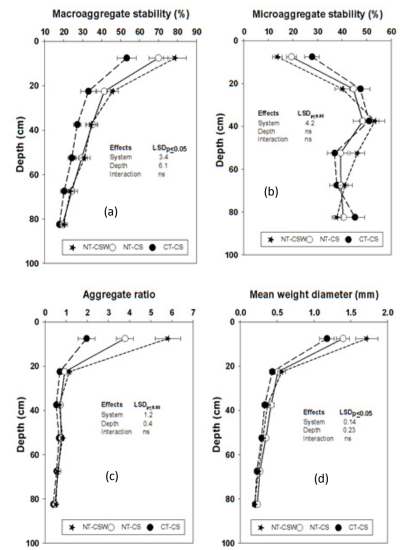

Fig. 1: Management systems effect on (a) macro- and (b) microaggregate stability, (c) aggregate ratio and (d) mean weight diameter of soil

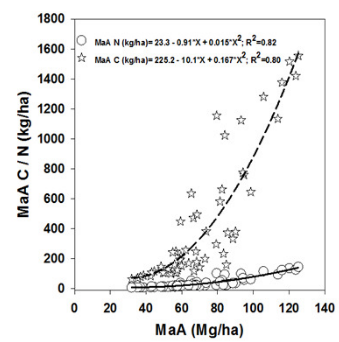

Fig. 2: Relationship between macroaggregate stock (MaA) and macroaggregate carbon (MaA C) and nitrogen (MaA N)

Conclusions

Continuous NT corn-soybean-wheat with cover crop (NT-CSW) significantly increased larger size aggregates, MaA, AR, and MWD of aggregates compared with NT (NT-CS) and CT (CT-CS) corn-soybean rotation. Likewise, aggregate associated C and N content significantly increased in NT-CSW than in both NT-CS and CT-CS. The significant relationship of MaA with C and N suggested that C and N sequestration are influenced by soil aggregation and C and N stoichiometry.

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