Crop Rotation and Tillage Impact on Soil Nutrients

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Abstract

The impact of tillage and crop rotation variations (2000 vs. 2009) on soil macro-and micronutrient contents was evaluated at the Ohio Agricultural Research and Development Center's Northwest Experiment Station, Custar, Ohio. A randomized complete block experiment in 2 tillage (no-till, NT vs. chisel plow, CT) x 5 crop rotations (corn, soybean, corn-soybean, soybean-wheat, and corn-soybean-wheat) in factorial arrangement was laid-out in the field in 2000. Composite soil core samples at 0-30 cm depth were randomly collected from GPS guided locations in 2000 and 2009, processed, and analyzed for pH, electrical conductivity, cation exchange capacity, bulk density, total C (C) and N (N), available P (P) and S, exchangeable K, Ca, Mg, Fe, Mn, Cu, Zn, B, and Mo. Results showed that pH, K, Fe, Mn, Cu, Zn, B, and Mo decreased and bulk density, C, and N increased in both CT and NT over time. However, the Fe content was significantly lower but the B content was higher in CT than NT. Soil pH and bulk density changed over time but was not significantly impacted by crop rotation. However, C, N, P, K, Ca, and S content was impacted by crop rotation. The C and N contents were higher in soybean and corn-soybean-wheat rotation but P was higher in continuous soybean. In contrast, the S was higher in soybean-wheat rotation. While Fe and Zn contents were significantly decreased in corn-soybean, Mn content was lower in corn-soybean-wheat. Lowest B was measured in continuous corn. Mo was significantly decreased in continuous soybean followed by continuous corn and corn-soybean rotations. Nutrient indices, calculated based on macro- and micronutrient concentration, was significantly impacted by tillage and crop rotation.

Introduction

Sustainable soil management practices are important to sustain crop growth. Conventional tillage (CT) incorporates crop residue into the soil, disrupts soil aggregates, and increases soil aeration, enhances biological activity, and accelerates loss of soil organic matter (Islam and Weil 2000, Aziz 2010). In contrast, no-till has been increasingly used for crop production during the past decade due to significant environmental advantages over CT. Moreover, there has been a marked shift from continuous corn cropping to corn-soybean rotations. What effects do these changes in crop rotation and tillage systems have on crop yields? Therefore, understanding the impact of management practices on soil nutrients is essential in developing best management practices and prediction tools for sustainable crop production.

Objectives

To evaluate the temporal effects of tillage and crop rotation (2000 vs. 2009) on macro- and micronutrient content and nutrient index based on antecedent bulk density and equivalent mass of soil.

Materials and Methods

The study was conducted at the Ohio Agricultural Research and Development Center's Northwest Experiment Station at Custar, Ohio. A randomized complete block design with 2 tillage (no-till, NT vs. chisel plow, CT) x 5 crop rotations (corn, soybean, corn-soybean, soybean-wheat, and corn-soybean-wheat) in factorial experiment was laid-out in 2000. Nutrients (NPK) applied from 2000 to 2009 were spread uniformly on all plots.

Composite soil samples at 0-30 cm depth were collected from GPS guided locations in 2000 and 2009, 2-mm sieved, air-dried and analyzed for pH, electrical conductivity (Ec), cation exchange capacity (CEC), bulk density (ρb), total porosity (St), total carbon (TC) and nitrogen (TN), available phosphorus (P) and sulfur (S), exchangeable potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), and molybdenum (Mo).

Nutrient stock was calculated by multiplying with the concurrently measured ρb (variable soil mass). An additive approach, based on "higher values of nutrients are better indicator of nutrient availability" was used to calculate the nutrient index.

Results and Discussion

Soil properties and nutrient content varied significantly by tillage and crop rotation without an interaction. Soil pH, CEC and St decreased and ρb increased over time in both conventional (CT) and no-till (NT) (Table 1). Soil pH decreased and ρb increased over time in response to crop rotation (Table 2). The TC, TN, K, Ca, and Mg content increased and Fe, Mn, Cu, Zn, B, and Mo content decreased in both CT and NT over time (Table 3 - 5). However, the Fe content was significantly lower but the B content was higher in CT than NT (Table 4).

The TC, TN, P, K, Ca, and S content were significantly impacted by crop rotation (Table 6). The TC and TN contents were higher in continuous soybean and corn-soybean-wheat rotation. Likewise, P was significantly higher in continuous soybean than any other crop rotation treatments. In contrast, the S content was higher in soybean-wheat rotation (Table 7). The Fe, Mn, Cu, Zn, Mo, and B decreased significantly over time by crop rotation (Table 7 and 8). Fe and Zn content in corn-soybean rotation decreased significantly over other treatments. The greatest decrease in Mn content was in corn-soybean-wheat rotation. Lowest Cu and B content was measured in continuous corn. The Mo content was significantly decreased in continuous soybean, continuous corn and corn-soybean rotations.

Table 1: Tillage effects on basic soil properties

Tillage Systems	pHw (1:2)	Ec (μS/cm)	CEC ()	ρb (g/cm3)	St (%)
CT2000	6.5a	259.3a	278a	1.54b	41.9a
CT2009	6.1b	245.0b	267b	1.71a	35.5b
NT2009	6.1b	260.1a	260c	1.69a	36.2b

Table 2: Crop rotation effects on basic soil properties

Crop Rotation	pHw (1:2)	Ec (μS/cm)	CEC ( )	ρb (g/cm³)	*St* (%)
CS_{2000}	6.5a	259a	278ab	1.54b	41.9a
C_{2009}	6.0b	254a	277ab	1.67a	37.0b
S_{2009}	6.0b	262a	270b	1.72a	35.1b
CS_{2009}	6.2ab	252a	286ab	1.70a	35.8b
SW_{2009}	6.2ab	271a	291a	1.67a	37.0b
CSW_{2009}	6.0b	282a	291a	1.71a	35.5b

Table 3: Tillage effects on soil total C and N, available P and exchangeable K content

Tillage System	TC	TN	CN	P	K
	___ (Mg/ha)___		ratio	___(kg/ha)___	
CT_{2000}	75.0b	8.3b	9.0a	133a	863.1b
CT_{2009}	99.9a	11.3a	8.8a	136a	888.5a
NT_{2009}	99.7a	11.3a	8.8a	139a	896.6a

Table 4: Tillage effects on soil exchangeable Ca, Mg, Fe and Mn, and available S content

Tillage System	Ca	Mg	S	Fe	Mn
	___(Mg/ha)___		________(kg/ha)_______		
CT_{2000}	14.0b	1.8b	292.5a	800.8a	67.1a
CT_{2009}	19.9a	2.1a	303.1a	719.8c	35.6b
NT_{2009}	17.1a	2.1a	305.4a	753.1b	35.7b

Table 5: Tillage effects on soil exchangeable Cu, Zn, and Na, and available boron and molybdenum content

Tillage System	Cu	Zn	B	Mo	Na
	_________________(kg/ha)_____________				
CT_{2000}	24.8a	13.5a	7.7a	0.46a	184.5b
CT_{2009}	22.2b	8.7b	7.0b	0.32b	209.6a
NT_{2009}	22.3b	8.9b	6.7c	0.34b	197.2c

Table 6: Crop rotation effects on soil total C and N, available P and exchangeable K content

Crop Rotation	TC	TN	CN	P	K
	__(Mg/ha)__		ratio	___(kg/ha)___	
CS_{2000}	75.0	8.3	9.0	133.0	863.1
C_{2009}	99.5	11.2	8.9	148.0	935.8
S_{2009}	106.5	12.0	8.9	262.3	1046.7
CS_{2009}	96.9	11.0	8.9	113.4	854.3
SW_{2009}	96.4	11.1	8.7	121.8	882.0
CSW_{2009}	104.8	11.6	9.0	143.5	897.5

Table 7: Crop rotation effects on soil exchangeable Ca, Mg, Fe and Mn, and available S content

Crop rotation	Ca	Mg	S	Fe	Mn
	__(Mg/ha)__		_______(kg/ha)________		
CS_{2000}	14.0	1.8	292.5	800.8	67.1
C_{2009}	16.1	2.3	291.1	755.3	30.9
S_{2009}	14.0	2.1	289.0	741.3	29.1
CS_{2009}	17.4	2.0	311.2	707.2	39.9
SW_{2009}	18.1	1.9	322.4	716.4	49.0
CSW_{2009}	16.2	2.1	290.0	790.7	23.4

Table 8: Crop rotation effects on soil exchangeable Cu, Zn, and Na, and available boron and molybdenum content

Crop rotation	Cu	Zn	B	Mo	Na
	_______________(kg/ha)________________				
CS_{2000}	24.8	13.5	7.7	0.46	184.5
C_{2009}	22.2	10.4 6.	7.0	0.32	224.9
S_{2009}	22.0	11.9	7.2	0.30	229.4
CS_{2009}	23.2	8.2	7.0	0.33	197.9
SW_{2009}	22.0	8.6	6.8	0.36	198.7
CSW_{2009}	21.1	8.4	6.6	0.32	200.0

Soil nutrient index, calculated based on macro- and micronutrient content, was significantly impacted by tillage (Fig. 1) and crop rotation (Fig. 2). The values of nutrient index were significantly lower in CT_{2009} compared with their initial values measured in CT_{2000}. The nutrient index values in NT_{2009} were not significantly different compared to CT_{2000}. The nutrient index decreased in all crop rotation treatments over time. The decrease was more pronounced in continuous soybean and corn-soybean-wheat rotation.

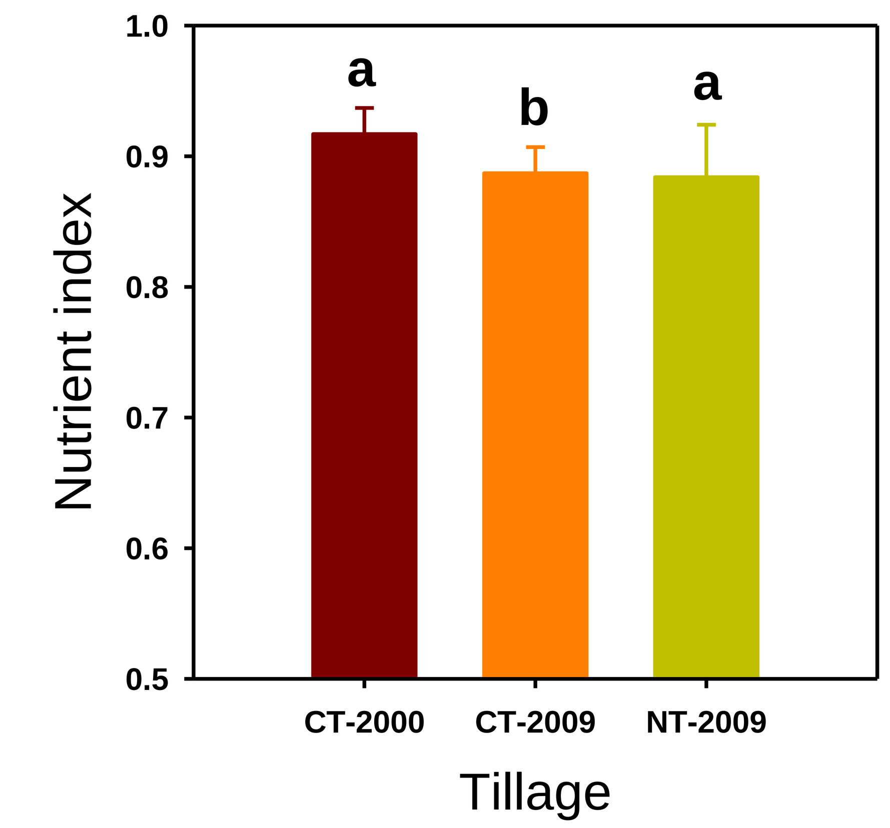

Fig. 1 Temporal effects of tillage on soil nutrient index, calculated based on additive approach

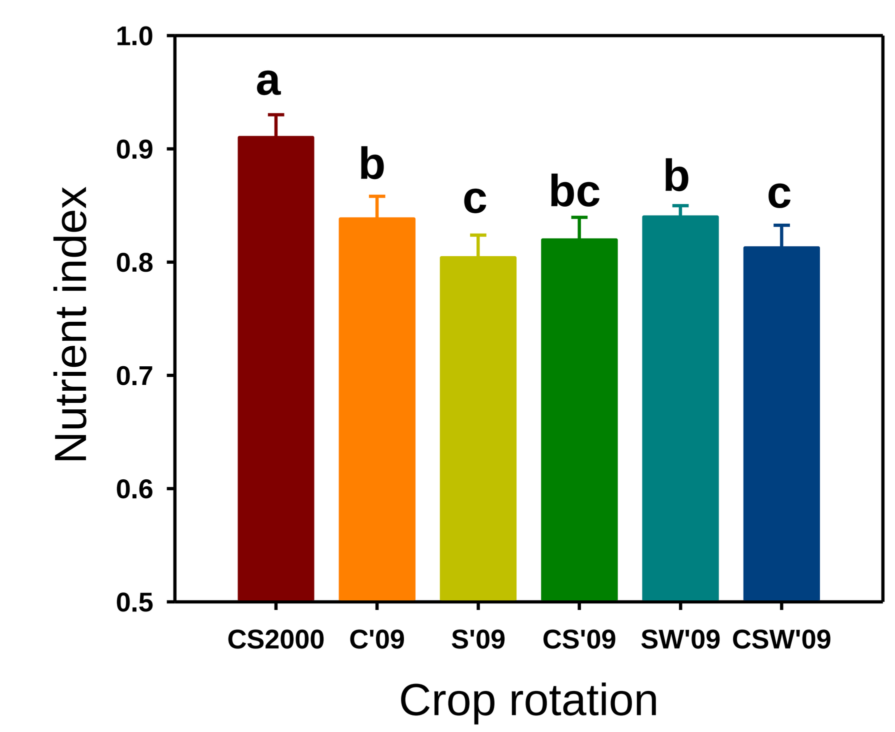

Fig. 2 Temporal effects of crop rotation on soil nutrient index, calculated based on additive approach

Conclusions

Soil bulk density significantly increased by tillage and crop rotation over time. The TC, TN, K, Ca, and S increased but most of the micronutrients content decreased in both CT and NT over time. The nutrient index under CT decreased over time. Averaged across crop rotation, the nutrient index decreased over time.

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