USDA Soil Characterization Database: Trends in Soil Organic Carbon and Total Nitrogen Considering Historical Methods Changes

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Introduction

Understanding how soils are changing under shifts in climate and land use is important to help ensure we can manage soils to maintain productive capacities of our agricultural systems. While site-specific studies on soil change are not uncommon, broad-scale, long-term monitoring of U.S. agricultural soils has not been undertaken. The USDA-NRCS National Cooperative Soil Survey Soil Characterization Database (NSCD) includes soil information collected on soil profiles since the 1950s. While sampling has not been repeated at any NSCD profile sites, it is still tempting to use NSCD data to identify trends in key soil properties. This work is a cautionary note about use of NSCD data for this purpose. In 2016, the NSCD was reported to provide evidence that soil total nitrogen stocks have been increasing across the Mississippi basin (Van Meter et al., 2016). Here, we report on an analysis of NSCD data from the U.S. Corn Belt that reaches the opposite conclusion.

Methods

The approach used featured the following:

- Analysis was focused on the two soil orders that dominate agricultural landscapes of the Corn Belt (Mollisols and Alfisols). Profile data were further segregated by moisture regime (Aquic and Udic). Non-farmed soils (i.e., lacking Ap surface horizon) were also analyzed as a reference. Presence/absence of Ap indicated crop production as current land use with >90% accuracy.
- For soil organic carbon (SOC), and total nitrogen (TN) concentrations, changes in analytical methodology were considered by establishing linear calibration equations between wet and dry combustion methods and 'correcting' wet combustion results to remove bias between methods. Correcting TN data required access to KSSL data archives not available on line; wet combustion techniques were used at KSSL prior to 1995. Horizon data were converted from concentration to mass using NSCD bulk density data then interpolated to 0-20, 20-60, and 60-100 cm depth increments.
- Stepwise regressions were run to evaluate: 1) the influence of latitude, longitude, clay content, and sampling date on SOC, and; 2: the influence of SOC and sampling date on TN. Because an increase in SOC can create a sink for soil TN, trends in C:N ratios were also determined. C:N may indicate a soil's susceptibility to N leaching losses (Schipper et al., 2004).

Results

Figure 1. Locations of sampled profiles. Mollisol and Alfisol dominate NSCD-characterized soil profiles across the U.S. Corn Belt (counties with >20% land cover under corn or soybean production). (n=1323)

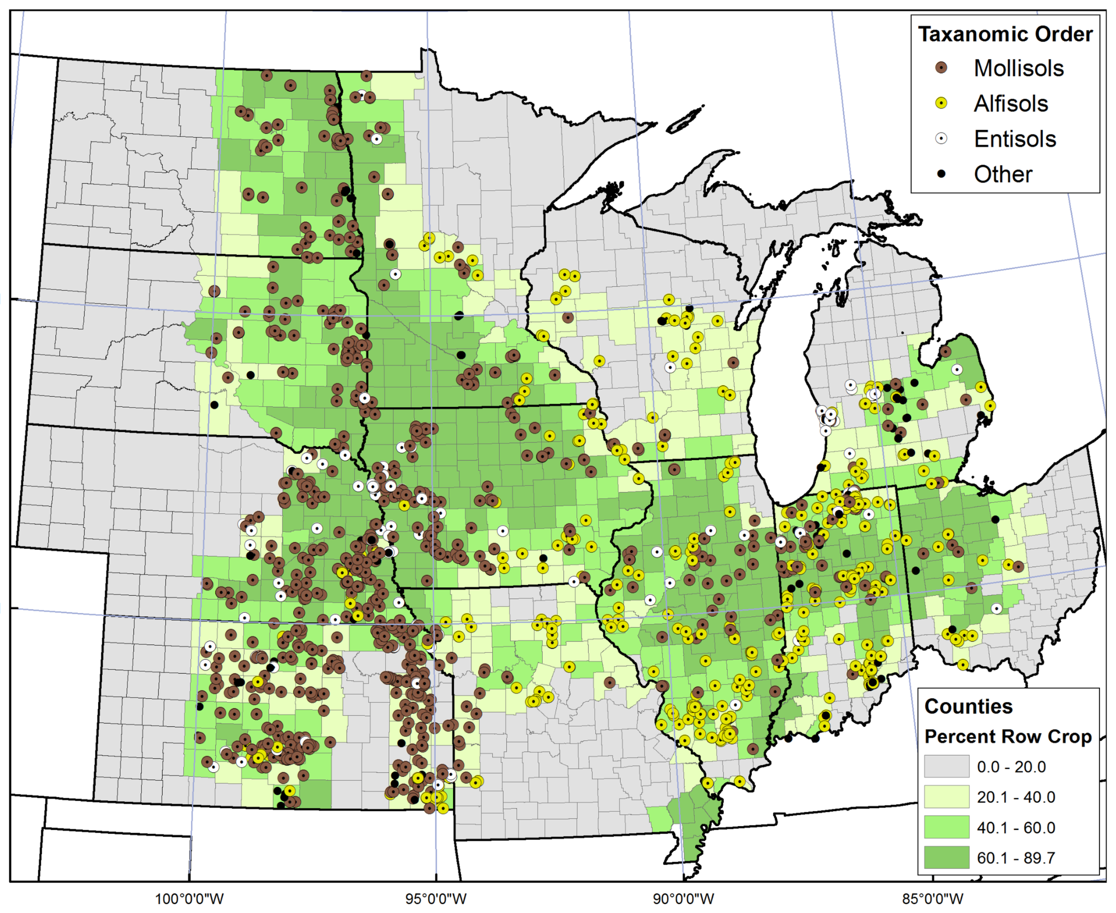


Figure 2. Calibrations between wet and dry digestion methods for SOC and TN.
For SOC, slope < 1.0 and intercept > 0.0 (p<0.05)
For TN, intercept >0.0 (p<0.05)

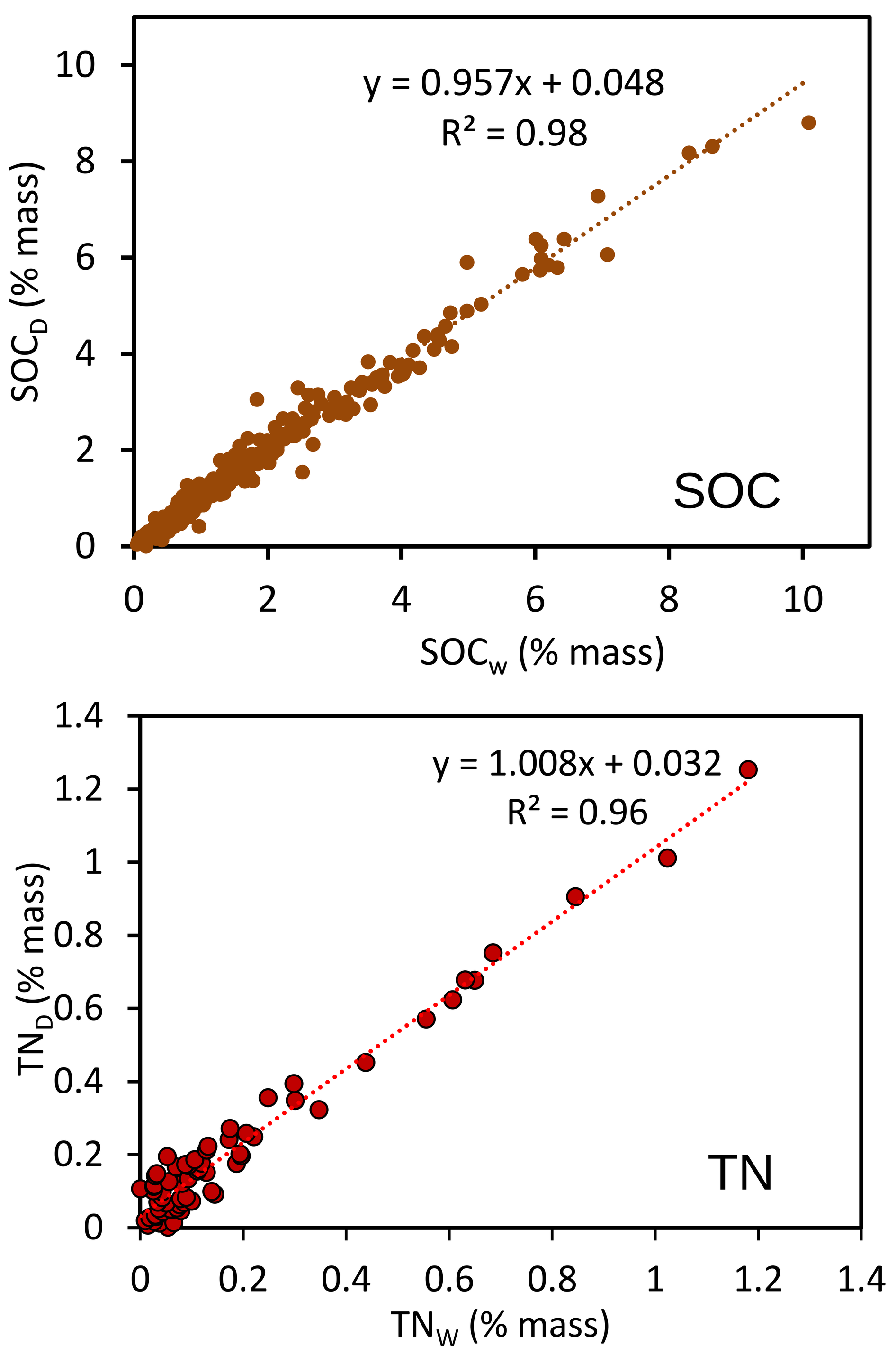


Table 1: TRENDS in SOC. Generalized stepwise regression results indicating significance of spatial coordinates (for latitude and/or longitude), soil texture (% clay), and sampling date on SOC stocks determined from NSCD profile data are shown below. Profile data are grouped by surface horizon (farming history), depth increment, soil order, and moisture regime. Note SOC stocks are more consistently related to spatial coordinates and texture than to sampling date, but that increasing SOC stocks were found where date was significant.
Notation: sign (+ or -) indicates whether coefficient is greater or less than zero; single sign indicates different than zero at p<0.05, double sign differs from 0.0 with p<0.01.

Sfc Horizon	Depth	Alfisols				Mollisols				Aquic Moisture Regime				Udic Moisture Regime			
		Spatial	%Clay	Date	R^2	Spatial	%Clay	Date	R^2	Spatial	%Clay	Date	R^2	Spatial	%Clay	Date	R^2
Ap	0-20	++			0.13	++	++		0.43	+			0.17	++	++		0.32
	20-60	-	++	++	0.11	++	++	+	0.17	++	++	++	0.18	--	++	++	0.33
	60-100		++		0.13		++		0.17	+	++		0.19	--	++	+	0.29
No Ap	0-20		+		0.08	++	++		0.33	++	++	+	0.44	--	++		0.32
	20-60		++		0.17	++	++	++	0.38	++	++	++	0.59	--	++		0.43
	60-100	++	++		0.60	++	++		0.31	++	++		0.47	--	++		0.43

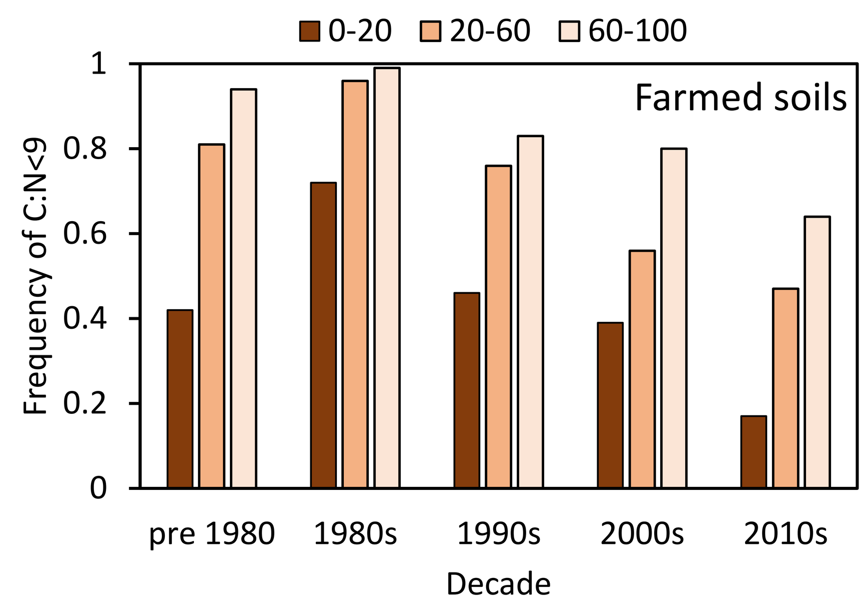
Table 2: TRENDS in TN. Regression results indicating slope coefficient of Ln (TN) with Ln (SOC), and significance of sampling date when entered into regression with ln (SOC). NSCD profile data are grouped as described for Table 1. Note trends of decreasing TN stocks are indicated wherever sampling date is significant, and that these decreasing temporal trends are more consistently significant for farmed than non-farmed soils in the Corn Belt.
Notation is as given above for Table 1.

Sfc Horizon	Depth	Alfisols			Mollisols			Aquic Moisture Regime			Udic Moisture Regime		
		Ln – Ln slope	Date	R^2	Ln – Ln slope	Date	R^2	Ln – Ln slope	Date	R^2	Ln – Ln slope	Date	R^2
Ap	0-20	0.86	--	0.81	0.89	--	0.91	0.84	--	0.87	0.91	--	0.89
	20-60	0.74	--	0.52	0.79	--	0.77	0.72	--	0.75	0.72	--	0.69
	60-100	0.70		0.41	0.73	--	0.60	0.67		0.50	0.73	-	0.60
No Ap	0-20	0.89	-	0.76	0.92		0.80	0.93		0.77	0.95		0.91
	20-60	0.96	-	0.51	0.83		0.81	0.78		0.80	0.84		0.73
	60-100	1.00		0.61	0.73	-	0.61	0.63		0.60	0.89		0.72

Table 3. Rank (Spearman) correlations between sampling date and SOC, TN, and C:N ratio by depth for soil groupings. Increasing C:N ratios among farmed soils in upper (<60 cm) profiles suggests declines in TN susceptibility to leaching. Note increasing trend for SOC, TN and C:N in non-farmed aquic Mollisols!

		Alfisols		Mollisols	
Depth (cm)	Variable	Aquic	Udic	Aquic	Udic
		Farmed soils – Ap surface horizon			
0-20	SOC	x	x	x	-0.18**
	TN	x	x	x	-0.24**
	C:N	0.29**	0.30**	0.27**	0.26**
20-60	SOC	0.28**	x	x	x
	TN	x	x	x	-0.12*
	C:N	0.36**	0.29**	0.33**	0.40**
60-100	SOC	0.19*	x	x	x
	TN	x	x	x	x
	C:N	x	x	x	0.15*
		Non-farmed soils – surface horizon not Ap			
0-20	SOC	x	x	0.43**	x
	TN	x	x	0.43**	x
	C:N	0.40*	x	0.25*	x
20-60	SOC	x	x	0.39**	x
	TN	x	x	0.35**	x
	C:N	x	x	0.35**	x
60-100	SOC	x	-0.44*	x	x
	TN	x	x	x	x
	C:N	x	x	x	x

Figure 3. Frequency at which C:N ratios were <9.0 by decade. Note declines among farmed NSCD profiles. See Schipper et al (2004) for discussion of C:N ratio as indicator of stability of soil TN stocks.



Concluding comments

This analysis suggests slow improvement among farmed soils dominant across the Corn Belt, which is consistent with documented improvements in N use efficiency in the region (Vitousek et al., 2009), and known benefits of decreased tillage intensities.

A caution against measuring soil change using soils data that lack location-specific re-sampling is warranted.

Resampling NSCD profile locations could be a starting place to initiate a monitoring effort to understand ongoing changes in the soil resource across the Corn Belt.

Citations!

Schipper, L.A., H.J. Percival, and G.P. Sparling. 2004. An approach for estimating when soils will reach maximum nitrogen storage. Soil Use and Management. 20:281-286.

Tomer, M.D. D.E. James, L.A. Schipper, and S. A. Wills. 2017. Using USDA's National Cooperative Soil Survey soil characterization data to detect soil change: A cautionary tale. Soil Sci. Soc Am J. in press.

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Vitousek, P.M., R. Naylor, T. Crews, M.B. David, L.E. Drinkwater, E. Holland, and eleven others. 2009. Nutrient imbalances in agricultural development. Science. 324:1519-1520.