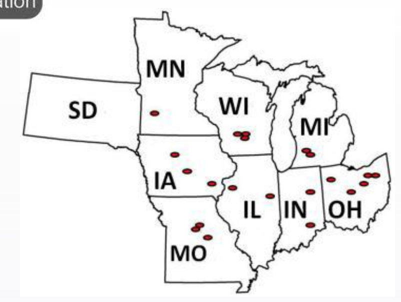
Investigating the Impact of Different Land Management Practices On Soil Quality

Vincent Obade, Rattan Lal, and Toru Nakajima



Introduction

The consequences of soil quality deterioration (e.g., climate change or food security), are among the major global concerns (IPCC 1997; Lal, 2004). Soil quality is defined as "the capacity of a soil to sustain biological productivity, maintain environmental quality, and support human habitation" (Doran and Zeiss, 2000; NRCS, 2012). Soil organic carbon (SOC) is one of the key soil properties that influences plant growth, water holding capacity (WHC), soil structure, soil fertility (Bartholomeus et al., 2011, Lal, 2004, Sa and Lal, 2009). This research investigated management-induced differences in soil quality. The principal management systems considered are the no till (NT) with or without manure (M) and cover crops (CC), natural vegetation (NV e.g., forest), and conventional tillage (CT). The hypothesis is that the "soil organic carbon (SOC) concentration is the highest under NT management among all cropland systems because of a high input of biomass C to the surface and lower fluxes". The overall aim of this study is to develop standard approaches for quantifying SOC stocks in relation to management, and develop soil quality indices (SQI) based on key soil properties.

Materials and Methods

204 soil samples at different depths (i.e., 0-10, 10-20, 20-40 and 40-60 cm) were collected at similar landscape positions under different land management, and from different locations (i.e., Miami, Seneca, Preble and Auglaize counties) within the state of Ohio, USA during April, May, August, and September, 2012. The soils types sampled were the *CrA (crosby silt loam), kbA (kibbie fine sandy loam), GWA (Glynwood silt loam), CtA (Crosby Celina loams),* and *Pw (Pewamo silty clay loam)*. Soil bulk density, penetration resistance, soil moisture content, water infiltration rate, and retention were measured. Other information gathered includes the land use history, and management practices, and crop yields.

Statistical analyses were conducted using SAS 9.2, and R 2.15.1. through the following approaches:

1. The variation in soil properties under the different land management was analyzed by ANOVA.
2. The SQI was derived by normalizing the Harvest Index (HI) for each crop (i.e., corn and soybean) because HI values were *assumed* to be *highly correlated* with soil quality. The SQI model was developed with land management *assumed* to be the major driving force influencing soil quality variables (e.g., SOC, dry bulk density, total porosity). Multiple linear regression was used to derive the SQI model.

Results

1) Management effects on soil properties

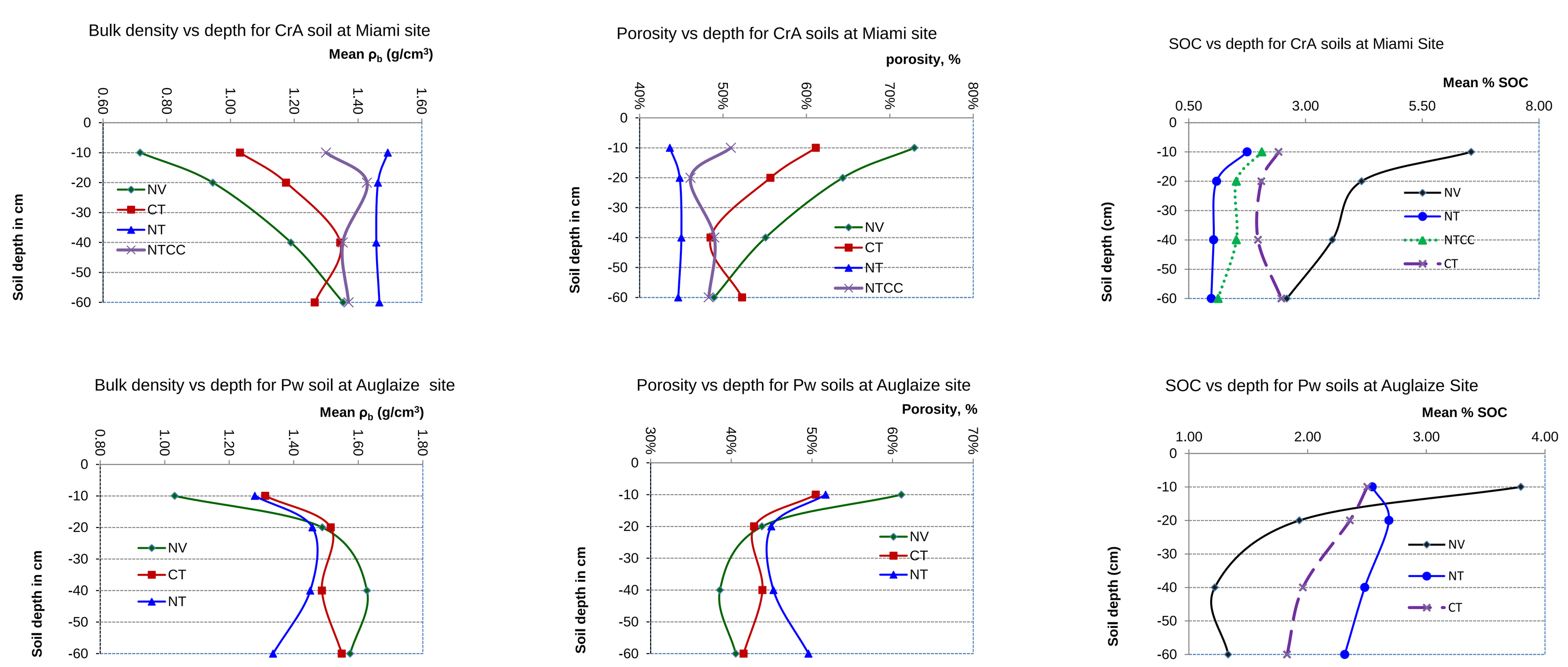


Fig. 1. Land management effects on CrA and Pw soils.

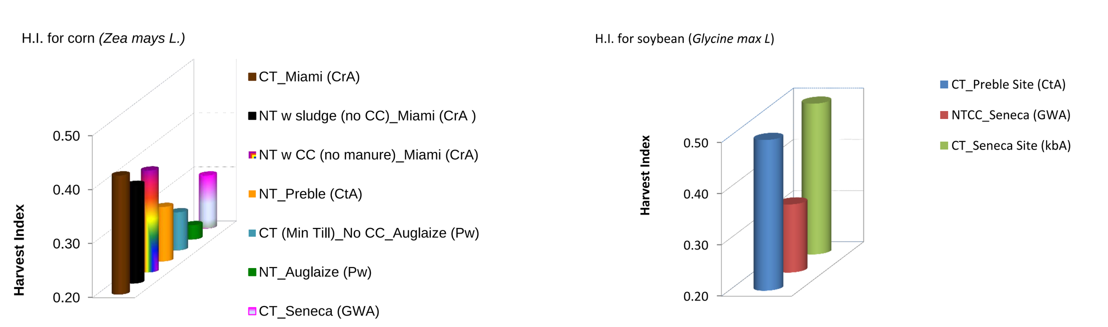


Fig. 2. Harvest Index for Corn and Soybean

Table 1. Correlation analyses

Corn fields	*depths*	ρ_b	*AWC*	*porosity*	*SOC*	*HI*
depths	1.0					
ρ_b	0.2	1.0				
AWC	0.1	-0.6	1.0			
porosity	-0.2	-1.0	0.6	1.0		
SOC	-0.3	-0.5	0	0.5	1.0	
HI	0	-0.4	0.4	0.4	-0.2	1.0

Soybean fields	*depths*	ρ_b	*AWC*	*porosity*	*SOC*	*HI*
depths	1.0					
ρ_b	0.3	1.0				
AWC	-0.1	0.5	1.0			
porosity	-0.3	-1.0	-0.5	1.0		
SOC	-0.2	-0.7	-0.4	0.7	1.0	
HI	0	-0.4	-0.4	0.4	-0.2	1.0

2) ANOVA

Table 2. ANOVA of soil properties based on land management.

	SOC	ρ_b	Porosity	AWC
Soil types (CrA, kbA, GWA or CtA)	s	s	s	s
Management (NT, CT, NTcc, etc.,)	s	s	s	s
Soil types and Management	s	s	s	s
	s: significant ($p < 0.05$)			
	ns: non significant			
	AWC: Available water content			

The ANOVA (Table 2) shows that there exists some dissimilarity in the effects of the parameters (e.g., SOC, ρ_b, porosity, AWC) influencing soil quality under the different land management.

3) SQI

The SQI models derived from data collected from corn fields are provided in (1), for the fields under soybean (soy) in (2), and combined (3). In this model the nominal variables e.g., management (NT, CT), soil types are computed as ***0 or 1* dummy** coding. The SQI values range from **0 to 1**.

$$SQI_{corn} = 0.6 + 0.4 \times CrA_{soil} + 0.1 \times GWA_{soil} - 0.1 \times NT_{management} \times (SOC) - 0.2 \times NT_{management} \times CrA_{soil}$$

Adj. $R^2 = 0.9$, $p < 0.05$ **(1)**

$$SQI_{soy} = 1 - 0.33 * NT_{management}$$

Adj. $R^2 = 1$ $p < 0.05$ **(2)**

$$SQI_{corn+soy} = -0.51 + 1.3 \times CrA_{soil} + 0.6 \times GWA_{soil} - 1 \times kbA_{soil} - 0.04 \times NT_{management} \times (SOC) - 0.06 \times NT_{management} \times CrA_{soil} - 0.14 \times GWA_{soil} \times NT_{management}$$

Adj. $R^2 = 0.9$, $p < 0.05$ **(3)**

SQI enables the rapid assessment of management factors influencing agricultural land productivity. The results show that the corn field at Miami county had the maximum SQI (i.e., 1) when under the CT and NTcc management; whereas soybean fields at Seneca county site had the highest SQI (i.e., 1) for under CT. For the combined SQI, corn fields at Miami had the highest SQI (i.e., 0.73); however the minimum SQI values were negative, which may be attributed to the HI differences in harvested soy and corn.

It is important to note that crop harvesting in Auglaize was done earlier (August) compared to the other sites (end of September), and this may have impacted on the results. The results shown here are for data collected for one year only. Other factors not incorporated in the model that may influence SQI includes weather, farm inputs e.g., fertilizers, land use history, soil biota, occurrence or severity of pests or plant diseases. This study demonstrates an approach for setting up an SQI model, the accuracy and parameters of which will depend on the statistical robustness (e.g., sample size) of available input data.

Future work

- Investigate the effects of other soil variables (e.g., pH, electrical conductivity (EC)) on the SQI.
- Extrapolate SQI to regional scales.
- Develop a validation approach for the SQI.

References

Bartholomeus, H. et al., 2011. Soil Organic Carbon mapping of partially vegetated agricultural fields with imaging spectroscopy. *International Journal of Applied Earth Observation and Geoinformation*, 13, 81-88.

Doran, J.W., Zeiss, M.R., 2000. Soil health and sustainability: managing the biotic component of soil quality. *Applied Soil Ecology, 15, 3-11*.

IPCC, UNEP, OECD, IEA, 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change; United Nations Environment Programme, Organization for Economic Cooperation and Development, International Energy Agency, Paris, France.

Lal, R., 2004. Soil C sequestration impacts on global climate change and food security. *Science*, 304, 1623-1627.

NRCS, 2012. Soil quality concept, Natural Resources Conservation Service (NRCS).

Sa, J.C.d.M., Lal, R., 2009. Stratification ratio of soil organic matter pools as an indicator of carbon sequestration in a tillage chronosequence on a Brazilian Oxisol. *Soil & Tillage Research, 103, 46-56.*

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