Using Meta-Analyses to assess pedo-variability under different land management

Obade Vincent de Paul and Rattan Lal

The Ohio State University

INTRODUCTION

The conflicting information on the status of soil quality changes necessitates a comprehensive approach that can combine soil property data into a credible soil quality index. Soil quality, encompassing combination of chemical, physical and biological components, is influenced by site-specific land use and management practices (Lal, 2009; Stockmann et al., 2013). The variability in soil quality can be attributed to; (i) the complexity and spatial variability of soil properties, and (ii) limitations of the approaches used. For example, insufficiency in sample density and size of field data used in the statistical analyses, may lower the accuracy, and lead to inappropriate conclusions. A larger sample size that captures the important details and heterogeneity of the field processes at different spatial resolution with limited uncertainties is a necessity when modeling such scenarios. However, due to costs (including site accessibility), it is not always feasible to establish large experiments, nor probable to effectively filter unwanted details/parameters (e.g., soil processes) necessary to quantify soil quality under different scenarios and depths to obtain a consistent overall output. Since soil property measurements cannot be done logistically or economically for every soil, transition or boundary between different soil layers, and resolutions, approaches are required for accurately integrating the soil physical, chemical and biological properties (De Vos et al., 2005). It is in this context that meta-analyses can be a useful tool. Meta-analyses is a statistical approach focused on contrasting and combining results from different independent studies (Hothorn and Everitt, 2006), and may, therefore, allow for comprehensive evaluation and synthesis of soil characteristics within the soil profile. Furthermore, meta-analyses generates results in formats that identify common patterns or processes, and address a set of related research hypothesis, and is applicable with minimal trials or dataset (Miguez and Bollero, 2005). The objective of this study is to demonstrate the application of meta-analytic methods to integrate, and quantitatively describe the effects of management practices on key soil physical and chemical properties which influence soil quality.

MATERIALS & METHODS

- 204 soil samples were obtained between April and May, 2012 at 0-10, 10-20, 20-40, 40-60 cm depths from 5 sites within Ohio, USA (Table 1 and Figure 1).
- Management: Conventional Tillage (CT), No Till (NT), and Natural Vegetation (NV).
- Soil Organic Carbon (SOC), Bulk Density (ρ_b), Electrical Conductivity (EC), pH, Available Water Capacity (AWC) were determined.
- DerSimonian Liard (DSL) meta-analyses model was computed using R 2.15.1

Hypotheses: Soil property characteristic values are higher in CT compared with NT.
It was tested using the Odds Ratio Function (OR) ∝ CT/NT ($p < 0.05$).
If the OR > 1 then the hypothesis holds true.
NV had no crops, and was used as a control in the meta-analyses.
A multiple regression was computed to visualize the spatial variability of the OR.

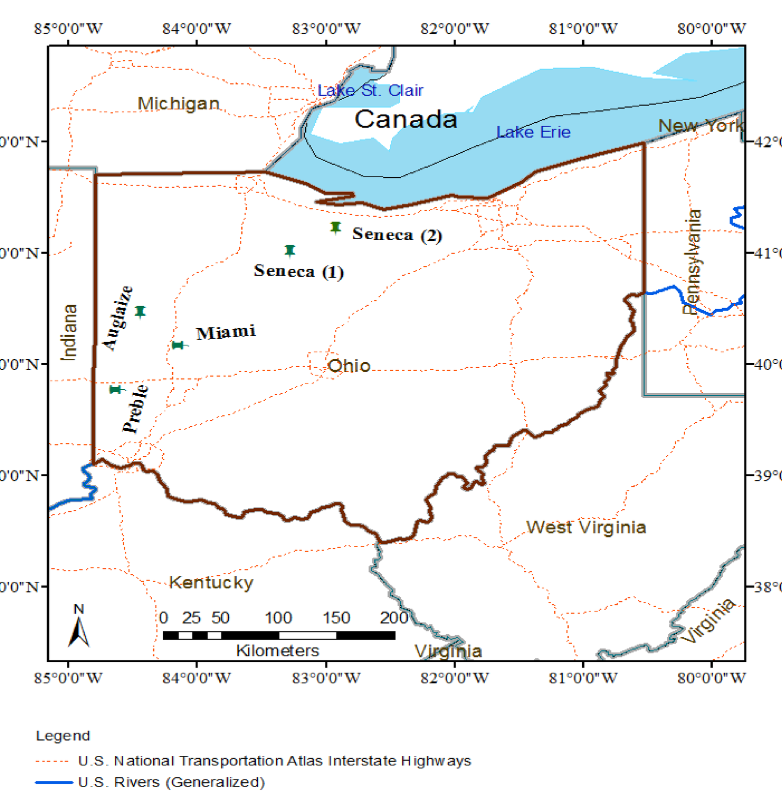


Figure 1. Study site and sampling locations within the state of Ohio, USA.

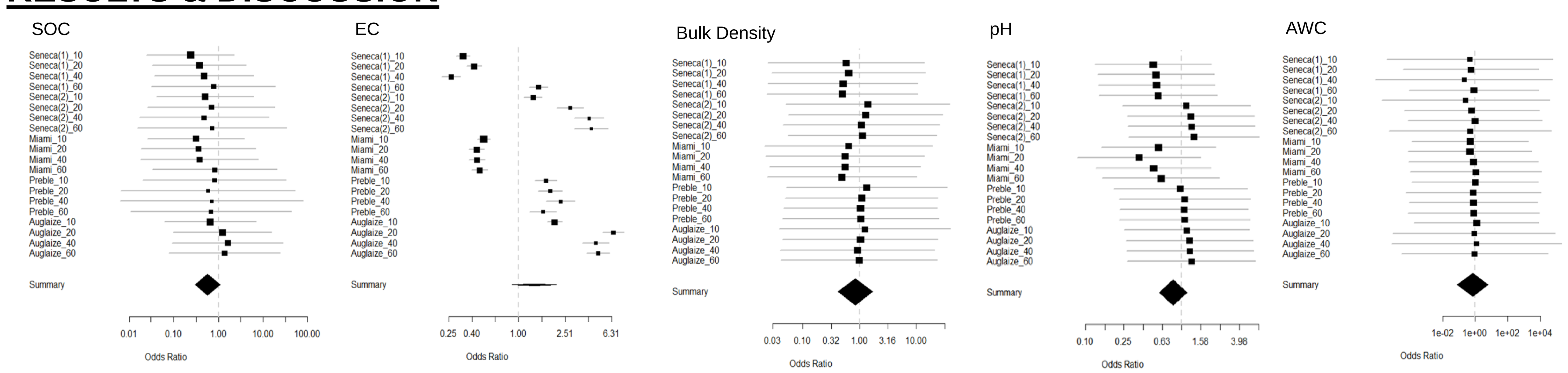
Table 1. Sampling locations, crop sequence, management practices in Ohio. Soil type description follows the *USDA soil classification system*.

Site	Coordinates	Soil Type	Crop Sequence	Management
Miami	40° 10’ 12” N, 84 °07’ 41.7” W	CrA	csc	NV, NT, NTcc, CT
Seneca (1)	41° 00’ 25” N, 85 °16’ 21” W	kbA	ccs	NV, NTccm, NTcc, CT
Seneca (2)	41° 12’ 43” N, 82 °54’ 39” W	GWA	csc	NV, NTcc, CT
Preble	39° 46’ 09” N, 84 °36’ 52” W & 39° 41’ 45” N, 84 °40’ 36” W	CtA	ch	NV, NT, CT
Auglaize	40° 27’ 34.5” N, 84 °26’ 14.8” W	P_w	c	NV, NT, CT

CrA (Crosby silt loam)
kbA(Kibbie fine sandy loam)
GWA (Glynwood silt loam)
CtA (Crosby Celina silt loams)
P_w (Pewamo silty clay loam)
cc: cover crop
m: manure

CT: Conventional Tillage
NT: No Till
NV: Natural Vegetation (e.g., forest)
c: corn
s: soybean
h: hay

RESULTS & DISCUSSION



Overall OR for SOC = 0.57 i.e. CT< NT 95% CI (0.3, 1.11) ;

Overall OR for EC= 1.36 CT> NT 95% CI (0.88, 2.11)

Overall OR for bulk density= 0.84 i.e., CT< NT 95% CI (0.42, 1.7)

Overall OR for pH = 0.81 CT< NT 95% CI (0.59,1.13)

Overall OR for AWC = 0.69 CT< NT 95% CI (0.08, 6.2)

Figure 2. Plots for combined and individual Odds Ratio (OR) for the soil properties. Soil from Seneca (site 1), Seneca (site 2), Miami, Preble and Auglaize sites were sampled at depths of 0 to 10 (shown as 10), 10 to 20 (20), 20 to 40 (40) and 40 to 60 (60) cm

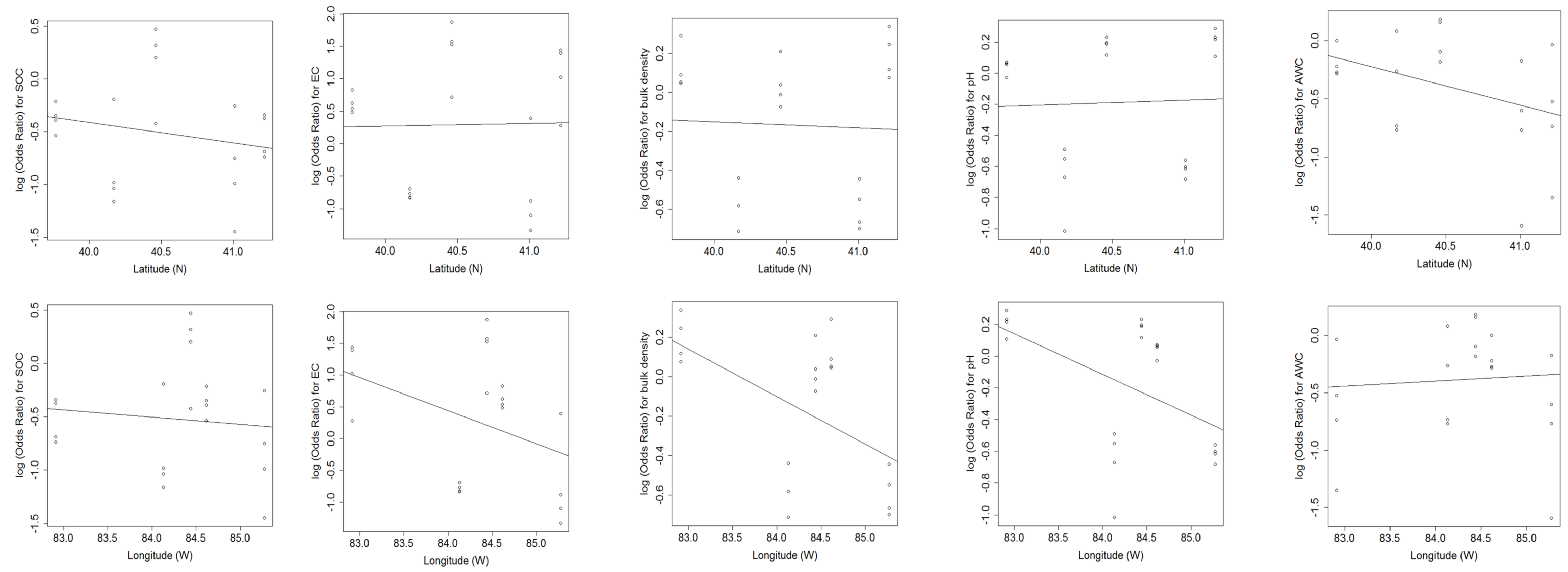


Figure 3. Spatial variation of soil properties. The data on the Y-axes are logarithm to the base 10 of Odds Ratio (OR).

Table 2. Overall Odds Ratio (OR) for selected soil properties.

Soil Properties	Odds Ratio α CT/NT	What could contribute to these differences?
SOC	CT < NT (OR = 0.57)	litter removal (CT) , micro-climate dynamics and aeration influencing soil biota activity (e.g., respiration)
EC	CT > NT (OR = 1.36)	higher Na in CT than NT
ρ_b	CT < NT (OR = 0.84)	CT soils have less bulk density than NT
pH	CT < NT (OR = 0.81)	high soil Fe^{3+}, Mn^{2+}, Al^{3+} in CT , therefore less pH in CT
AWC	CT < NT (OR = 0.69)	NT had more storage pores (0.5-50 μm)

- OR results (Table 2) show that SOC under CT management was lower than that under NT (0.57), a phenomenon attributable to relatively higher surface litter oxidation or removal by accelerated erosion under CT.
- OR for EC (1.36) points to a higher EC under CT than NT managed soil, suggesting that CT had a relatively higher quantity of soluble salts, higher clay content or higher soil fertility.
- Soil ρ_b under CT management was slightly lower than that under NT probably because of: (i) different vehicular traffic or weight of machinery (axle load) creating a variable degree of soil compaction, (ii) different cropping patterns which may have dissimilar soil strength-plant root dynamics within the soil, and (iii) unsimilar freezing/drying weather conditions or microclimate.
- AWC had OR of 0.69, implying a lower AWC in soil under CT than NT, despite soil under CT having low ρ_b (OR = 0.84).

CONCLUSION

The data presented show significant differences in soil properties among management scenarios, and depths, and demonstrated the potential of meta-analyses to conduct comparative assessments for soil properties: (i) within each soil layer, (ii) the whole profile and (iii) for visualizing the spatial variability for each of these soil properties. Soil properties had different depth distributions across the soil profile. However, based on the combined assessment through meta-analyses, soils under CT appeared to be of relatively lower quality than those under NT because of lower SOC, and AWC, but higher EC or salinity. The ρ_b and SOC concentration of soil under CT were lower than those under NT management. Future research will explore the potential of meta-analysis in assessing soil property variability with changes in topography, rainfall and temperature.

REFERENCES

De Vos, B., Van Meirvenne, M., Quataert, P., Deckers, J., Muys, B., 2005. Predictive Quality of Pedotransfer Functions for Estimating Bulk Density of Forest Soils. *Soil Sci. Soc. Am. J.* 69(2), 500-510.

Hothorn, T., Everitt, B.S., 2006. A Handbook of Statistical Analyses using R. Taylor and Francis Group, LLC, Boca Raton, Florida.

Lal, R., 2009. Challenges and opportunities in soil organic matter research. *European Journal of Soil Science* 60(2), 158-169.

Miguez, F.E., Bollero, G.A., 2005. Review of Corn Yield Response under Winter Cover Cropping Systems Using Meta-Analytic Methods. Crop Sci. 45(6), 2318-2329.

Stockmann, U., Adams, M.A., Crawford, J.W., Field, et al., 2013. The knowns, known unknowns and unknowns of sequestration of soil organic carbon. *Agriculture Ecosystems & Environment* 164, 80-99.

This research is part of a regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190 “Cropping Systems Coordinated Agricultural Project (CAP): Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems”
sustainablecorn.org