# Towards a consistent Soil Quality Index

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## Introduction and Rationale

Sustainable use and management of soil resources is important for: (i) food, feed, and energy security, (ii) socioeconomic development, (iii) filtering pollutants from agricultural run-off and leaching, and (iv) cushioning the earth against the adverse impacts of climate change (Lal, 2009). Thus, transparent, systematic, repeatable and accurate measures of soil quality status are required for gauging soil quality *vis à vis* agronomic yields, environmental quality, and for repairing degraded soils.

Soil quality is defined as "the capacity of a specific kind of soil to function, within natural or managed boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al.,* 1997). Soil Quality Indices (SQIs) are models designed to synthesize soil resource information into a format understandable to decision makers (Wienhold *et al.,* 2004). This study: (i) outlines qualitative and quantitative soil quality assessment methods, and (ii) demonstrates a new SQI technique for rating soil quality under diverse land management.

## Experimental Procedure

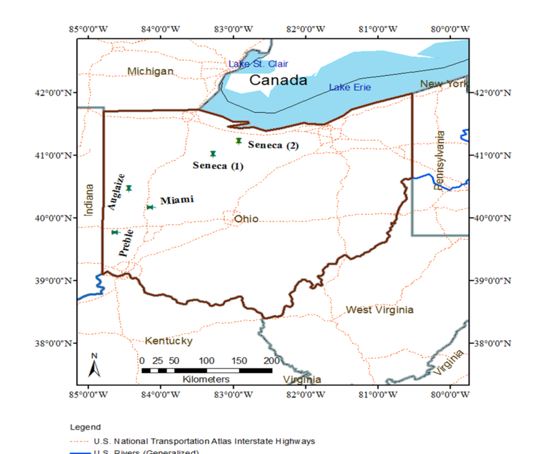


**Figure 1.** Field sites in Ohio, USA.

**Table 1.** Sampling locations, crop sequence, management practices. 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

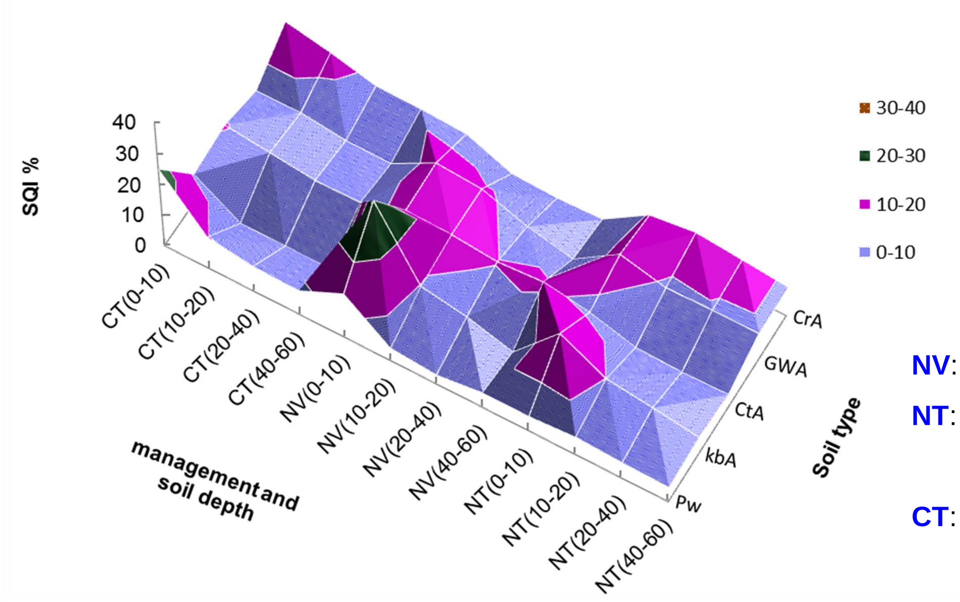
- 204 soils sampled within Ohio, USA at 0-10, 10-20, 20-40, 40-60 cm depth increments (Figure 1 and Table 1).
- soil physical and chemical properties determined.
- SQI modeled by Partial Least Squares Regression (PLSR)
  ***Hypothesis** (p<0.05)***:
  land management determines site specific soil quality

## Results and Discussion

(i) Soil quality assessment methods

| Qualitative (e.g., by visual observation) | Quantitative |
|---|---|
| Soil Color:<br>(i.e., darker soils assumed to be of relatively higher quality). | Soil Physical, Chemical and Biological properties<br>(e.g., Soil Organic Matter, Texture, Bulk density, Water Holding Capacity, pH, Aggregate Stability, Electrical Conductivity; Earthworm count), Soil depth.<br>*http://soilquality.org/indicators.html* |
| 1. Soil Tilth: (good quality soils have clods broken easily on tillage),<br>2. Compaction (good quality soils have no hard pan; have little resistance to plough on tillage)<br>*http://pubs.cas.psu.edu/FreePubs/pdfs/uc170.pdf* | 1. Soil Erosion, Pollution<br>2. Soil Tensile Strength/Stability for construction, or civil works |
| Water Infiltration and drainage (e.g., good quality soils drain well, compared with poor quality soils that exhibit slaking and surface sealing, reduced water infiltration and increased runoff and erosion). | Models derived using Mathematical and Statistical methods.<br>Examples: Soil Management Assessment Framework (SMAF), Pedo-Transfer Functions (PTFs) and other regression models. |
| | Agricultural Productivity (i.e., yields). |
| **Hybrid methods:** USDA Soil Quality Test Kit and Interpretive Guide; Cornell Soil Health Testing. | |

(ii) SQI derived experimentally




***SQI (<10 cm depth)***
**NV**: kbA (32%)> $P_w$ > GWA > CtA > CrA
**NT**: kbA> CrA ≈ GWA> CtA ≈ $P_w$
***SQI (<20 cm depth)***
**CT**: $P_w$ >CrA > CtA > GWA> kbA

**Figure 2.** Soil Quality Index (SQI) for specific soil types and management

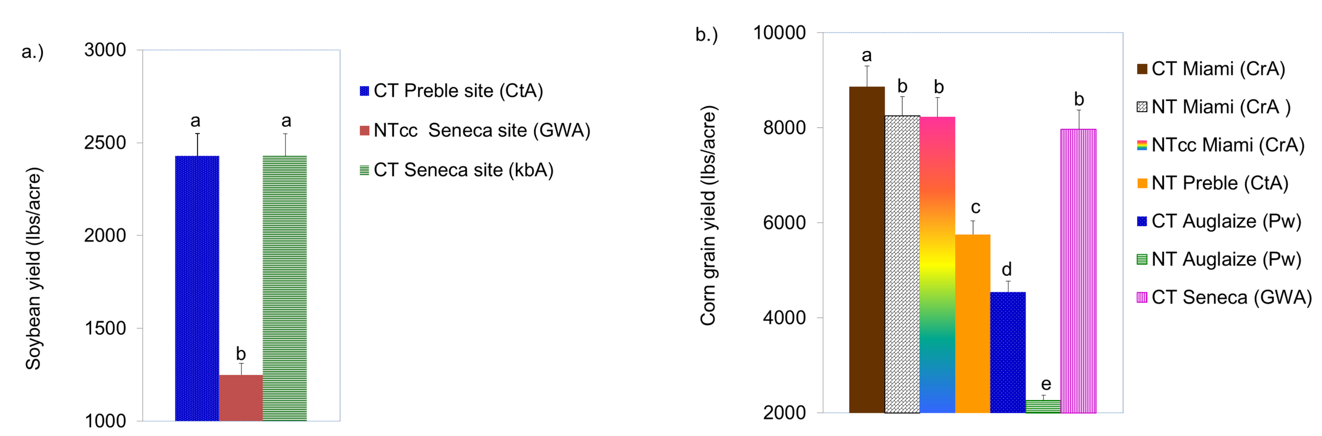



**Figure 3.** Grain yield for each site for (a) Soybean (*Glycine max (L.) Merr.)*, and (b) Corn (*Zea mays L.*). Error bars indicate the standard error from the mean (Different letters denote significant differences between sites at the 0.05 probability level). Although, three seasons yield data is preferentially required, the harvest data for the year 2012 was used for comparison with the soil data sampled within the same GPS point location within the same year.

**Table 2.** $R^2$ for mean SQI versus corn (*Zea mays L.*) and soybean (*Glycine max (L.) Merr*.) yields (Mg/ha) for the year 2012**.**

| | $R^2$ |
|---|---|
| Corn (Mg/ha) & SQI (%) | 0.74 |
| Soybean (Mg/ha) & SQI (%) | 0.89 |

## Results and Discussion

- Figure 3 shows that the NT and CT managed soils had the highest corn yields in CrA soils, followed by GWA, CtA and $P_w$ soils, in 2012.
- CT managed CTA and kbA soils had the highest soybean yields, followed by the GWA soils.
- Besides management (i.e., NT, CT); other factors that affect agricultural yields include: crop hybrids, microbial activity, pests menace, insolation, planting dates, fertilizer application and intake rates, and the weather variability.
- SQI proposed beneficial in providing single value comparative assessment of soil quality.
- Although important in soil quality assessment, this SQI does not directly factor the biological properties because of: (i) inaccuracies in earthworm counts (i.e., by hand), (ii) difficulty in accounting microbial species diversity, and (iii) difficulty in interpreting the soil respiration tests. Biological properties can indirectly be inferred from other soil properties (e.g., SOC).
- Because, the year 2012 was a drought year, this SQI approach will be tested with data from subsequent years to determine its efficacy.
- A user friendly version of this SQI model to be freely available. Model input is laboratory measured soil physical and chemical property data.

## Conclusions

This study exemplifies a simple yet comprehensive SQI model that can be useful for: (i) monitoring soil quality dynamics versus yield, (ii) understanding the link between the "cause and effect" of land management decisions on soil quality and productivity, (iii) diagnosing and restoring degraded soils. A key finding in this study is that the $P_w$ soil were generally of a higher quality than CtA, kbA, GWA and CrA, respectively. Because one field can have several soil types, the major limitation is the inherent SQI scalar uncertainty when continuously mapping, or predicting SQI in unsampled locations.

## References

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