Links Among Soil Forming Factors, Land Management and Soil Health: A Case Study and Demonstration for Use in the Classroom and Field.

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Introduction

This demonstration used in an undergraduate Soil Ecology course and for outreach in soil health builds upon and integrates basic principles of crop and soil sciences presented in prerequisite courses. Such information includes the soil forming factors that create a catena, a sequence of soil series occurring on a slope where parent material and climate are uniform. The material presented introduces the concept of soil health and is followed by a demonstration during which indicators of soil health are used to assess inherent soil properties associated with soil forming factors and dynamic soil properties that are dependent upon land management.

Soil health is defined as "the capacity of a soil to function within ecosystems and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health" (Doran and Parkin, 1994). Various soil attributes (physical, chemical, and biological) that respond to land management and vary in space and time determine soil health. Inherent or use-invariant soil properties change little or not at all with management forming over geological time: soil texture, type of clay, depth to bedrock and drainage class. Dynamic or management dependent soil properties are affected by management and natural disturbances during a growing season, decade or century: mineralizable nitrogen (N) & carbon (C) (biological), pH (chemical) and aggregate stability (physical).

Objectives

Use indicators of soil health to assess differences in a soil catena planted to a complex crop rotation in zero-tillage for over a decade:

(1) Make side-by-side comparisons of different soil series of the catena;
(2) compare problem areas in a field to non-problem areas;
(3) Determine the impact of over 10 years of land management on each soil series within the catena.

Methods

The Catena (Fig 1. & 2) is located on the Thilmony Family Farm that has been in operation for over a century (1884 to present). The catena is planted to a wheat, corn, soybeans rotation and is in zero-tillage management for over 10 yr.

- **Buse loam** (Fig. 3) on eroded knobs with a convex slope of 5% but **slopes range from 3 to 60%.** Fine-loamy, mixed, superactive, frigid Typic Calciudolls.
- **Barnes loam** (Fig. 4) on till plains, slopes **0 to 25%.** Fine-loamy, mixed, superactive, frigid Calcic Hapludolls.
- **Svea loam** (Fig. 5) on concave positions on till plains & slopes **0 to 25%.** Fine-loamy, mixed, superactive, frigid Pachic Hapludolls.
- **Tonka silt loam** (Fig. 6) in closed basins & depressions **slopes 0 to 1%,** poorly drained, slowly permeable. Fine, smectitic, frigid Argiaquic. Argialbolls.
- **Hamerly loam** (Fig. 7) somewhat poorly drained with slopes of **0 to 3%** on convex slopes surrounding shallow depressions & on slight rises on till plains. Fine-loamy, mixed, superactive, frigid Aeric Calciaquolls.

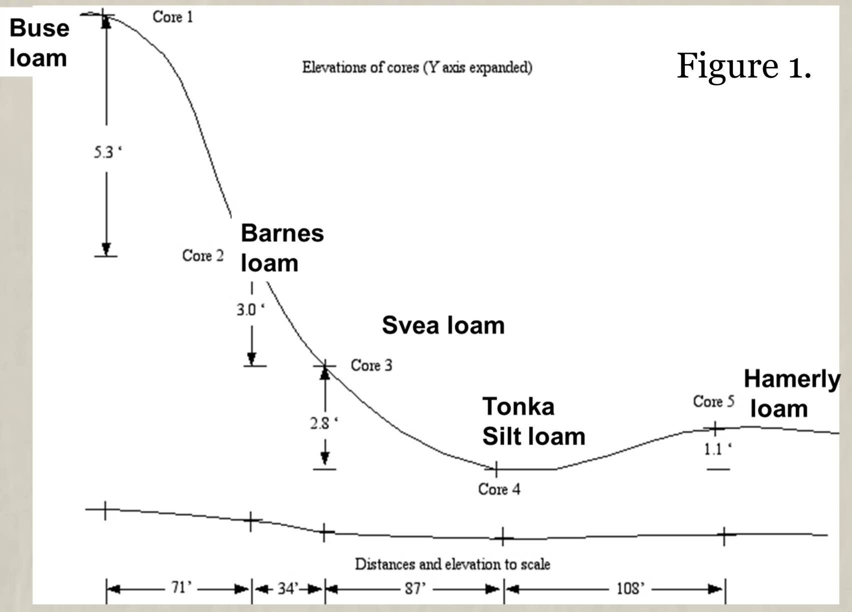


Figure 1.


Figure 2.

Buse Loam, Top of Hill Eroded Knob


Figure 3.

Barnes Loam, Side Slope


Figure 4.

Svea Loam, Bottom of Side Slope

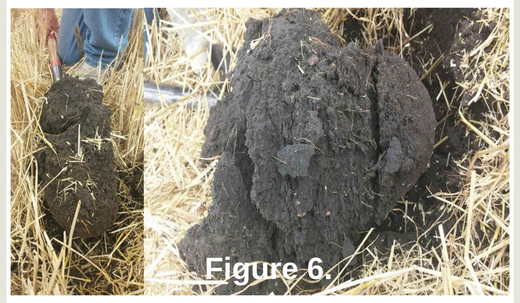


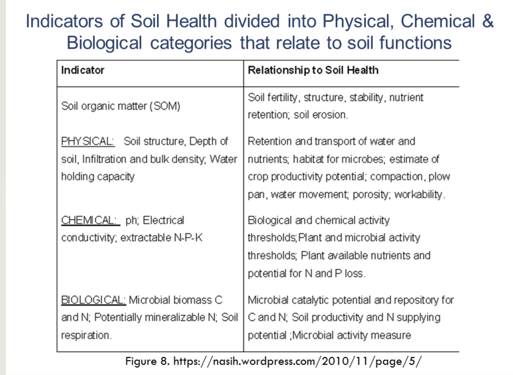
Figure 6.

Tonka Silt loam, depression in field


Figure 6.

Hamerly loam, level field


Figure 7.


Indicators of Soil Health divided into Physical, Chemical & Biological categories that relate to soil functions

This demonstration was used in an upper level undergraduate Soil Ecology class. The course content built upon principles introduced in the prerequisite course, the Introduction to Soil Science. Specifically, we used the same soils previously presented to students in a laboratory to define a soil catena, a sequence of soil series occurring on a slope where parent material and climate are uniform. The first week of soil ecology provides a brief summary of soils that illustrates links among the soil forming factors such as weathering to soil processes controlled by soil biota that include microorganisms. Soil ecology incorporates these concepts by focusing on the role of soil biota in the pedosphere incorporating ecological principles that link soil organisms and plants to biogeochemical processes occurring within the soil in natural and managed ecosystems. Measurements of soil health are then defined, a function of various soil attributes (physical, chemical, and biological) which respond to land management and vary in space and time (Doran and Parkin, 1994) and used to assess the inherent soil health of the soil catena and the variant effects of zero-tillage and crop rotation management (10 yr >).

The demonstration itself spanned 3 class periods: 1. a 50 minute lecture and discussion covering measurements of soil and their use as a tool for land managers that concluded with a description of the soil catena and management practices on the Thilmony farm; 2. the demonstration during which students aided in the collection of soil heath measurements and discussed how to perform individual measurements and 3. a final class discussion in which groups of students interpreted the data collected, providing answers to the discussion questions and presenting them to the class.

Soil Health Measurements

A set of chemical, physical & biological indicators of soil health were measured (Fig. 8 & 9). A soil fertilizer test kit available for purchase in most hardware stores was used to measure: **water extractable Nitrogen (N)**, Inorganic N (NH_4^+ + NO_3^-)-N; **pH** 5:1 dilution in water; plant available **inorganic phosphorus (P)** & exchangeable potassium (K).

Additional measurements included: **permanganate oxidizable organic carbon (POXC)** derived from a modified procedure of Weil et al. (2003). **Slake test** measures the stability of soil when exposed to rapid wetting, a qualitative measure that should be performed on air-dried soil fragments or aggregates.

The amount of **carbon dioxide-carbon (CO2-C) mineralized** mg kg^{-1} was estimated by trapping CO2 using NaOH and back titrating with HCl acid after addition of BaCl2 (Coleman et al., 1978).

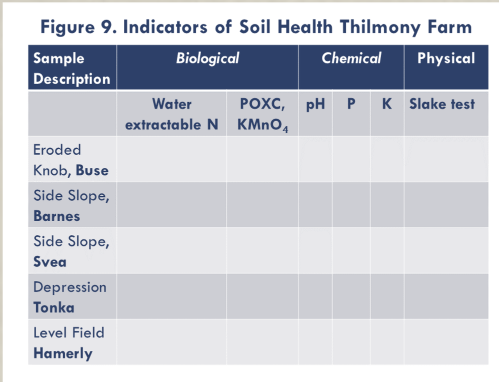


Figure 9. Indicators of Soil Health Thilmony Farm

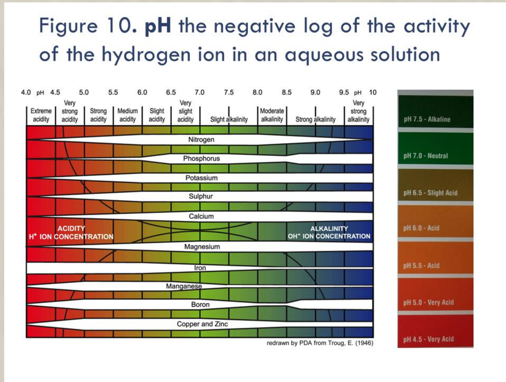


Figure 10. **pH** the negative log of the activity of the hydrogen ion in an aqueous solution

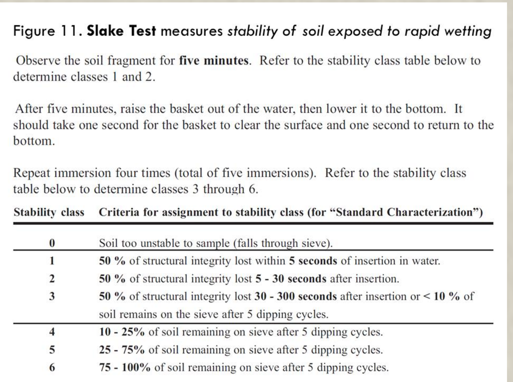
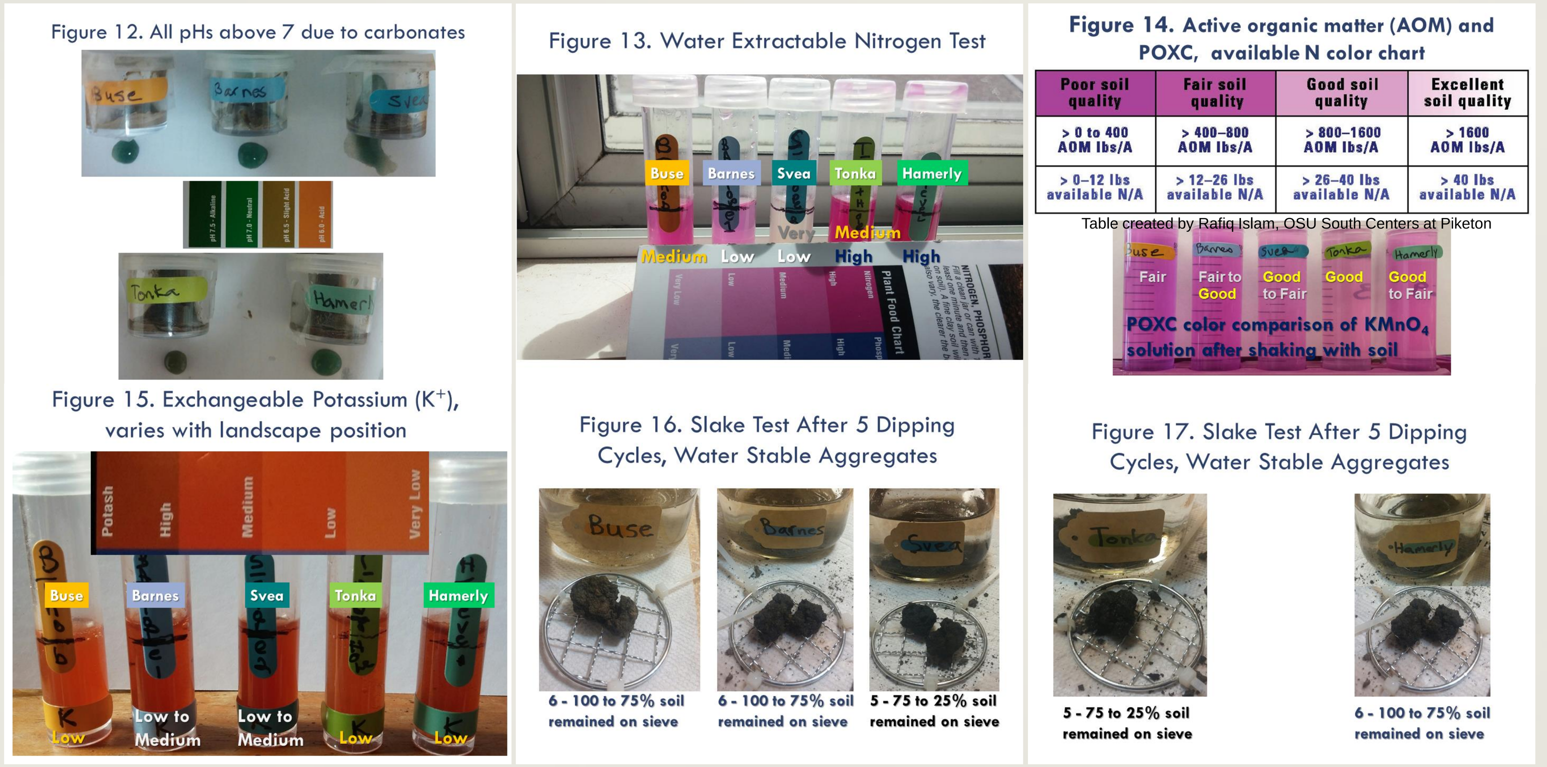


Figure 11. **Slake Test** measures stability of soil exposed to rapid wetting

Results & Discussion:



Questions for Discussion:

- Which soil health parameters vary the most and why?
- Are high levels of chemical indicators ideal?
- How do the soil health indicators relate to landscape position and erosion?
- How might 10 years of residue management effect the values of the soil health indicators measured?
- Which soil health parameters appear to vary due to inherent properties (soil texture) vs dynamic (management zero-till and crop biomass)?

Table 1. Indicators of Soil Health Thilmony Farm

Sample Description	Biological		Chemical			Physical
	Water extractable N	POXC, $KMnO_4$	pH	P	K	Slake test
Eroded Knob, **Buse**	Medium to Low	Fair	7.5	High	Low	6
Side Slope, **Barnes**	Low to Very Low	Fair to Good	7	High	Med to Low	6
Side Slope, **Svea**	Very Low	Good to Fair	7	High	Med to Low	5
Depression **Tonka**	High to Medium	Good	7.5	High	Low	5
Level Field **Hamerly**	High to Medium	Good to Fair	7	High	Low	6

Students concluded that soil health was generally high on the Thilmony farm and varied mainly due to inherent properties related to soil texture and landscape position. Despite implementation of conservation practices soil health was reduced likely by erosion on the knob and side slope. These landscape positions contained less topsoil which resulted in lower water extractable N and POXC. In contrast, the eroded soils contained more extractable K due to the erosion of topsoil layers. High P levels in all soils required monitoring and was the result of fertilization and mineralogy.

Conclusions

Students successfully integrated lower level outcomes presented in Introduction to Soils, a prerequisite with higher level outcomes in Soil Ecology, illustrated by the concept of soil health to understand the biology, chemistry, and physics controlling soil processes and made informed decisions that addressed how land management alters these processes. Student success was demonstrated by:

- Their ability to successfully measure soil health of field sites using a suite of biological, chemical, and physical indicators during the demonstration.
- Completion of discussion questions and class participation verifying students could complete comparisons of different soil series within a catena; compare problem areas in a field to non-problem areas; and determine the impact of >10 yr of land management on each soil series within the catena.

The impact of such demonstrations in part is to illustrate to students and the public the value of land grant training and its potential benefit to growers and the public at large.

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References

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