Soil Management Assessment Framework (SMAF): Developing Indicator Scoring Curves for Soil Enzymes

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Rationale

Five years ago, the Conservation Effects Assessment Program (CEAP) was initiated to determine the effectiveness of conservation management practices in maintaining or improving soil, air and water quality. While the initial emphasis has been on water quality, a project was recently initiated to assess the soil quality on the USDA-ARS CEAP Experimental watersheds.

Assessment tools are needed to evaluate management affects on critical soil functions. The SMAF model is being developed to meet this need (Andrews et al. 2002). SMAF uses measured soil indicator data to assess management effects on soil function using the three step process of indicator selection, indicator interpretation, and integration into an index. Currently SMAF has 11 indicators—mostly soil physical and chemical characteristics.

Soil enzyme activities have been suggested as indicators as they reflect critical processes in several nutrient cycles in the soil.

Why make an Assessment?

Soil quality cannot be measured directly because it is an broad, integrative concept. Instead, a variety of proxy measurements are analyzed, which together provide clues about how the soil is functioning. These measurements are called soil quality indicators.

Although the quantity and quality of data may differ, the process of soil quality evaluation follows the same basic steps regardless of the method used: indicator selection and interpretation. Once selected, indicators must be measured and results analyzed. To be useful, this must be followed by appropriate changes in management practices, when needed. Indicators should be reevaluated periodically to monitor trends.

Objective

Develop indicator scoring curves for SMAF for soil enzymatic activity, which may give early indications of trends in soil organic C (SOC) accumulation.

Enzyme Chosen

We wished to develop an indicator curve for an enzyme that was involved in the C cycle. We chose β-glucosidase for several reasons:

- Mediates the last rate limiting step in cellulose degradation. Thus, is important in soil organic matter decompositon.
- Responds to changes in tillage and residue management.
- Is among the most prevalent soil enzyme activities reported in the scientific literature.
- Would be considered along with other organic matter indicatiors such SOC, total N, total Kjedahl N, POM, and microbial biomass.

β-glucosidase indicator curve would contribute to the following SMAF soil functions:

- Nutrient Cycling
- Biodiversity and Habitat
- Filtering & Buffering

No-till soybean into wheat residue. Photo by Tim McCabe, USDA-NRCS.

Scoring Functions

Scoring functions are used widely as decision functions and tools for modeling. Karlen and Stott (1994) first applied this concept to soil indicator interpretation.

Three main scoring curves were used:

- More is better
- Less-is-better
- Mid-point optimum

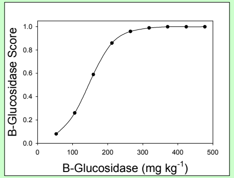
No-till corn in Iowa. Photo by Lynn Betts, USDA-NRCS.

The SMAF uses this same technique but allows for increased variation in curve shape. In all cases, the optimal score would be given when an indicator value represented high function in the particular soil. Most indicators are site-specific, including interpretation based on inherent soil properties.

For development of the indicator curve, we assumed that levels of activity found in undisturbed soil (native vegetation) would have a score at or near 1.0. Long established pasture or no-till would have a high score.

Initial Scoring Function Curve

The initial curve, developed by Wienhold et al. (submitted), was developed from the data of Acosta-Martinez et al. (2003), for the purpose of illustrating the method of SMAF curve development. It did not take into account differences due to inherent soil properties, and was validated using data from similar types of soils. The initial equation developed was:



$$\beta\text{-glucosidase score} = a / (1 + b * \exp(-c * \beta\text{-glucos. activity}))$$

where a = 1.007, b = 48.44, and c = 26.73

β –Glucosidase Activity vs. Soil Organic C Content

Since β-glucosidase is usually significantly correlated with SOC content ($r^2 \approx 0.5$-0.7), we decided use the same inherent properties that are used to modify the SOC indicator: soil order and suborder groupings, textural class, and climate.

Table 1: Soil order groups for the SMAF SOC Factor. Yellow highlights indicate groups represented by data sets used in curve delopment and validation. These classes are used for determining the value of C_1.

Class 1	Class 2	Class 3	Class 4 (Low)	
Andisols	**Andisols**	**Alfisols**	**Andisols**	**Inceptisols**
Aquands	Udands	Aqualfs	Torrands	Cryepts
Gelisols	Ustands	boralfs	Xerands	ochrepts
Histels	**Inceptisols**	Cryalfs	**Aridisols**	tropepts
Turbels	Aquepts	Udalfs	Argids	Udepts
Histosols	**Mollisols**	Ustalfs	Calcids	umbrepts
Fibrists	albolls	Xeralfs	Cambids	Ustepts
Folists	aquolls	**Andisols**	Cryids	Xerepts
Hemists	borolls	cryands	Durids	**Oxisols**
Saprists	cryolls	Vitrands	Gypsids	orthox
Oxisols	rendolls	**Entisols**	orthids	Perox
Aquox	Udolls	Aquents	Salids	Torrox
Spodosols	ustolls	**Gelisols**	**Entisols**	Ustox
Aquods	xerolls	Orthels	arents	**Spodosols**
	Oxisols	**Inceptisols**	fluvents	Orthods
	Udox	andepts	orthents	**Ultisols**
	Spodosols	Anthrepts	psamments	Udults
	Humods	**Spodosols**	Xerents	Ustults
	Ultisols	cryods		Xerults
	Aquults	**Vertisols**		**Vertisols**
	Humults	cryerts		Torrerts
	Vertisols			
	aquerts			
	Xererts			

Table 2: Soil texture groups for the SMAF SOC Factor. Classes 2 -4 are the most prevalent in the data sets used for curve development and validataion. These classes are used for determining the value of C_2.

Texture Class

5=clay with > 40% clay

4= sandy clay, clay loam, silty clay loam, silty clay, or clay (with <40% clay)

3= silt loam, silt

2=sandy loam (with >8% clay), sandy clay loam, or loam

1=sand, loamy sand, or sandy loam (with < 8% clay)

-- *Quisenberry et al., 1993*

Table 3: Soil climate groups for the SMAF SOC Factor, which are based on MLRAs. These classes are used for determining the value of C_3. If the land was irrigated, we used the higher precipitation.

Climate Classes

	(degree days; avg. precipitation)
1	high/high: ≥170 deg dy; ≥550 mm ppt
2	high/low: ≥170 deg dy; <550 mm ppt
3	low/high: <170 deg dy; ≥550 mm ppt
4	low/low: <170 deg dy; <550 mm ppt

New Equation

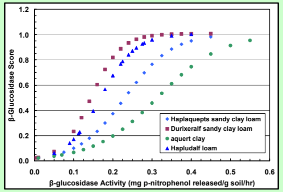
To take into account factors for soil suborder groupings, textural classes, and climate, new equation parameters were developed using several published data sets, where:

a = 1.007

b = 48

$c = (c_1 * c_2) + (c_1 * c_2 * c_3)$

Soil Group		Texture		Climate	
Class	C_1	Class	C_2	Class	C_2
1	2.6	1	2.7	1	1.50
2	4.1	2	1.94	2	1.10
3	6.55	3	1.7	3	0.80
4	9	4	1.5	4	0.30
		5	1.2		



New SMAF indicator scoring curves for β-glucosidase activity taking into account the inherent soil properties (Tables 1-3). The Durixeralf sandy clay loam was similar in properties to the soil used for the initial curve.

Validation

Existing data sets, both published and unpublished, were used to validate these curves. However they will continue to be modified and validated as the soil quality assessment of the ARS Experimental Watersheds progresses.

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