United States policy approaches for assessing soil health

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Abstract

There is worldwide recognition of the need for a more holistic vision of soil health and for the development of tools to guide soil conservation policy, management and restoration. To meet this need, United States (US) conservation programs in the US Food, Conservation, and Energy Act of 2008 (the farm bill), including the Conservation Stewardship Program (CSP) and the Environmental Quality Incentives Program (EQIP), have recognized soil quality in their efforts to promote soil conservation. The first soil quality assessment in CSP was based on the Soil Conditioning Index (SCI), a simple linear model used to predict trends in levels of soil organic matter (SOM). Other efforts mandated by Congress include the Conservation Effects Assessment Project (CEAP), which entails both watershed monitoring and process modeling efforts. While these intense efforts are resulting in environmental outcome estimates at large scales, for conservation on the ground, such intense efforts are not practical. Even the simple model, SCI has now been replaced by a practice-based tool in CSP. Initial validation efforts, comparing practice-based tools with measured soil data showed good representation of soil outcomes. Practice-based assessment tools, validated and calibrated using measured data, are practical, easy to use, well-accepted by producers, and representative of both conservation effort and outcome.

Key Words

Soil Quality; Soil Health; Practice-based Assessment; US Policy.

Introduction

To meet mandates in the current US farm bill for the Conservation Stewardship Program, a practice-based resource assessment tool, the 'Conservation Measurement Tool' (CMT) was developed. Although the original tool for this purpose, the SCI, is technically well-documented within Natural Resources Conservation Service (NRCS) for predicting soil carbon trend under a specific management and climate, many individuals and groups voiced concerns about the SCI's use. Frequently mentioned concerns involve low SCI scores for organic and specialty crop production systems or systems in warmer climates, despite strong conservation efforts. Additionally, while SOM is a primary measure of soil quality, it is not a complete measure of a soil's ability to provide ecosystem services or functions. To address key ecosystem functions and services of soil (i.e. soil quality) and improve equitable application of CSP, a Soil Quality (SQ) Eligibility Tool was developed, based on conservation practices applied. The new tool was combined with an existing water quality tool and called the Soil and Water Eligibility Tool (SWET). Initial efforts to validate the soil portion of the SWET compared the tool outcomes with SCI values and measured soil carbon. The 2008 farm bill stipulated the use of a "conservation measurement tool" to determine CSP eligibility. Therefore, the SWET was combined with practice-based tools for other resources to form the CMT. The ensuing tool combined multiple practice-based tools to estimate resource outcomes for eight concerns, including soil quality and soil erosion. Validation of the CMT is underway.

Methods

The SQ portion of the SWET was calibrated and validated exhaustively in comparison with the SCI. We compared SCI & SWET results from hundreds of hypothetical scenarios, with differing combinations of tillage, rotation, cover crops and amendments management, repeated in 10 representative states, each centrally located in one the 10 US Department of Agriculture, Economic Research Service climatic regions for the US.

The SWET was then validated in comparison with measured soil quality data for medium- and long-term research plots. Shown here are those from Iowa (IA) and California (CA), for organic and conservation tillage systems experiments. In each state, one organic systems experiment and one tillage comparison experiment was selected for use (Andrews *et al.* 2007a). Each system experiment differed by location, treatment, crop, replication number and plot size. We compared SWET outcomes for treatments at the experimental sites with multiple measured soil quality parameters. We also compared outcomes with other tools: the SCI and the Soil Management Assessment Framework (SMAF), a well-validated tool used by USDA-Agricultural Research Service to interpret measured soil parameters in terms of soil function (Andrews *et al.* 2002). Comparisons were made using JMP by SAS (Cary, NC) for ANOVA, t-tests, Student's t means comparisons tests and non-parametric ranking methods.

Current efforts to validate the entire CMT use data-mining programming techniques to develop a database of management practices and measured properties that represent resource concerns. This database is supporting meta-analysis of management practice effects on natural resource outcomes to summarize the data into overall effects. Computer science tools have developed rule sets for this analysis. Rule sets include development of key terms and protocols to transform or normalize the data for use in the meta-analysis and other comparative analyses. This technique is uniquely applicable to this validation because the CMT is to be applied across the US and will allow us to compare tool outcomes with a plethora of research results from around the US. Discrepancies between the NRCS tool outcomes and the statistical-rules we have developed will identify areas in need of more focused study or changes to the CMT. Other agency tools will likely benefit from this protocol for validation (e.g. EQIP ranking, RUSLE2 and SCI).

Results

Linear regression analysis of SWET and SCI outcomes for all management scenarios combined showed strong coefficients of determination (R^2), within each state (Figure 1 Only two states shown selected to maximize contrast: Tennessee, with warm, wet climate and weathered soils, and North Dakota, with cool, dry climate and deep, high SOM soils). Figure 1 again illustrates the strong influence of climate on tool outcome, and especially the determination of CSP eligibility using current SCI thresholds and those proposed for the SWET.

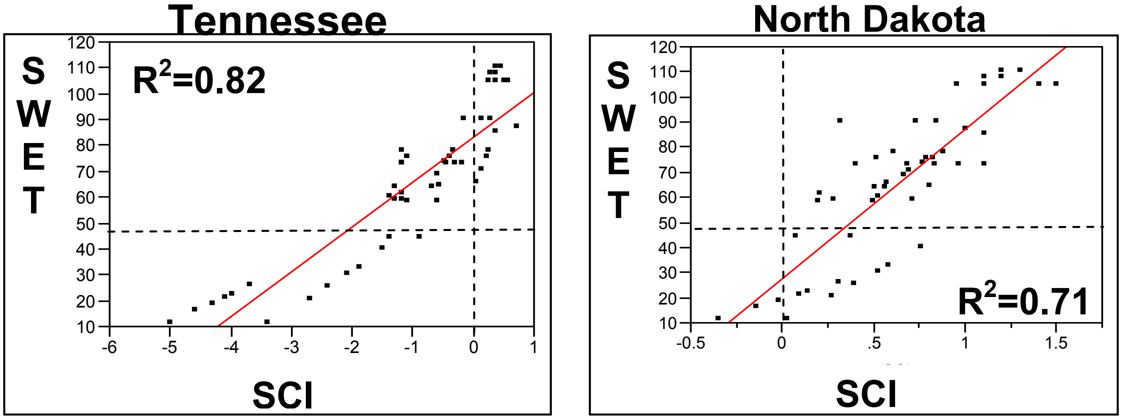

Figure 1. Comparison of SCI and SWET v.1 eligibility outcomes in states with highly contrasting climates and soils.

Although the hypothetical management scenarios were identical in each state, climatic differences inherent in SCI outcomes resulted in large differences in eligibility. In Figure 1, the vertical dotted lines show policy- and expert-determined cut-offs for eligibility using SCI (again for identical management scenarios under different climatic conditions). Horizontal dotted lines illustrate the approximate cut off for eligibility using SWET, which has no climatic component but was determined by expert opinion of effects of practices and to some extent practice interactions. For points in the upper right quadrant, both tools agree that system is eligible; for the lower left, both agree about ineligibility. For TN, many systems are ineligible using SCI but eligible with SWET (upper left quadrant); in ND, more systems are eligible using SCI than with SWET (lower right quadrant). Despite strong correlation between the tool outcomes within a given climate, eligibility is greatly affected by climate using SCI, due to model effects on decomposition and yield, while SWET considers only practices applied.

Table 3. a-d) Select soil properties and tool outcomes for the four experiments.* The measured parameters selected here include total organic carbon (TOC) for each experiment and the parameter with the highest correlation coefficient compared with the SMAF score: percent macroaggregates (Macroagg%); potentially mineralizable nitrogen (PMN); microbial biomass carbon (MBC); and bulk density (Db).

a. IA Organic Transition

Function	C seq.	Physical	Overall SQ	FB Tools	
Indicator	TOC	Macroagg	SMAF	SWET	SCI
Trt	(g/kg)	(%)			
C-S	24.9a	20.3b	78.3b	37 (fail)	-0.02 (fail)
C-S o/A	26.3a	21.7b	77.7b	69 pass	0.33 pass
C-S-o/A-A	26.1a	26.6a	81.6a	74 pass	0.35 pass

b. CA SAFS Organic, Low Input

Function	C seq.	Nutrient	Overall SQ	FB Tools	
Indicator	TOC	PMN	SMAF	SWET	SCI
Trt	(g/kg)	(mg/kg)			
Conv-2yr	9.6c	…..	92.6ab	9 (fail)	0.24 pass
Conv-4yr	9.9c	18.1b	90.8b	21 (fail)	-0.21 (fail)
Low-input	11.0b	21.5b	91.8ab	34 (fail)	-0.03 (fail)
Organic	12.0a	41.5a	94.7a	52 pass	0.21 pass

c. IA Tillage

Function	C seq.	Nutrient	Overall SQ	FB Tools	
Indicator	TOC	MBC	SMAF	SWET	SCI
Trt	(g/kg)	(mg/kg)			
CT	16.7b	273.1a	73.1a	21 (fail)	0.30 pass
MT	19.2a	325.0a	77.0a	51 pass	0.73 pass

d. CA Tillage & Cover Crops

Function	C seq.	Physical	Overall SQ	FB Tools	
Indicator	TOC	Db	SMAF	SWET	SCI
Trt	(g/kg)	(g/cm^3)			
CTno	5.4b	1.3a	71.9a	13 (fail)	-1.10 (fail)
CTcc	7.6ab	1.3a	72.8a	50 pass	-0.79 (fail)
RTno	5.9b	1.2b	75.5a	42 (fail)	0.16 pass
RTcc	10.4a	1.3a	75.0a	94 pass	0.51 pass

*different letters denote significantly different outcomes among system treatments.

Experimental plot results showed strong correlation between SWET & SCI at two of four experimental sites. At both IA experimental sites the SCI and SWET outcomes exhibited identical relative rankings for the treatments. SCI outcomes were relatively lower compared with SWET for both conventionally tilled (CT) systems at the CA Till and cover crop (cc) experiment. There was only a slight difference in overall relative ranking of the treatments by the two tools: SWET ranked reduced till (RT) slightly lower than CT with cover crop (CTcc), whereas SCI ranked RT much higher than CTcc. However, the largest differences were seen in the CA organic systems experiment. The conventional 2-yr (conv-2yr) tomato-wheat rotation was ranked higher than the other three systems by the SCI, presumably due to the presence of a high-residue crop, wheat, every other year. SWET ranked conv 2-yr lowest compared with the other three systems. The SMAF scores were only marginally correlated with the SWET and SCI outcomes.

When tool results were examined in relation to the measured parameters (Table 3), SWET outcomes were found to be more similar to soil TOC results than SCI in 3 of 4 experiments, using a simple ranking technique. In the fourth, the IA organic transition, where the SWET and TOC ranking was slightly different, the TOC results were not significantly different and, therefore, assigning different ranks may have been inappropriate. Nevertheless, for this experiment the SCI and TOC ranks were in agreement. Similarly, in this same experiment, IA ORG, there was less correlation between SMAF and its most representative single indicator and the two farm bill tools, than was seen in the other three. These results suggest that both tools, particularly the SCI, may benefit from additional calibration using data from experiments with organic amendments and cover crops. In general, however, these results indicate that SWET provides an adequate representation of soil quality outcome in the conditions tested (Andrews *et al*. 2007b).

Conclusions

Initial validation efforts show that practice-based tools can be as effective or in some cases more effective at predicting soil health outcomes than empirical models. Process-based models, like EPIC/APEX, used for Conservation Effects Assessment Project, may eventually replace the current practice-based tools. However, a user-friendly interface and validation of newly added practice subroutines will need to be accomplished first. In the meantime, well-validated, practice-based tools are the current 'standard of care' for the US Conservation Stewardship Program.

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