BEYOND T: GUIDING SUSTAINABLE SOIL MANAGEMENT

A Report of an Expert Consultation Facilitated by the Soil and Water Conservation Society

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SOIL AND WATER CONSERVATION SOCIETY

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The Soil and Water Conservation Society (SWCS) is a nonprofit scientific and educational organization that serves as an advocate for natural resource professionals and for science-based conservation policy. SWCS fosters the science and art of soil, water, and environmental management on working lands to achieve sustainability. SWCS members promote and practice an ethic that recognizes the interdependence of people and their environment.

SWCS would like to acknowledge the generous support of the Wallace Genetic Foundation, whose contribution underwrote the research, writing, and publication of this report.

Workshop participants have reviewed and commented extensively on this report, and every effort has been made to ensure that the report accurately reflects their views and judgment. Participants, however, have not been asked to individually or officially sign off on the findings, conclusions, and recommendations presented here. The content of this report is solely the responsibility of SWCS.

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EXECUTIVE SUMMARY

Scientists, conservation advisors, and producers recognize the need for a more comprehensive and integrated approach to soil management that (1) considers the multiple production and ecological functions soil provides, (2) evaluates multiple factors of soil degradation, (3) provides standards or thresholds for managing soil to sustain its multiple production and ecological functions, and (4) results in more comprehensive recommendations for soil management and conservation. The Soil and Water Conservation Society (SWCS) undertook a project, funded by the Wallace Genetic Foundation, to help accelerate the development of more comprehensive soil assessment, management, and planning tools. This report summarizes the results of an expert consultation held May 22–24, 2007, at the Lied Conference Center of the Arbor Day Foundation in Nebraska City, Nebraska, to recommend actions to move toward more comprehensive soil assessment, management, and planning tools.

This report has been developed in collaboration with those participating in the expert consultation. The participants were not, however, asked to formally sign on to or endorse the report. They participated as individuals and experts, not as official representatives of their agencies or organizations. The content of this report is solely the responsibility of SWCS.

More Comprehensive System Needed

Participants agreed that soil conservation standards and tools that enable a more comprehensive assessment of management and conservation systems on multiple production and environmental endpoints are needed to meet the conservation challenges we face today.

The most widely used soil conservation standard in the United States is the Soil Loss Tolerance Standard (T). The most widely used soil conservation planning tools in the United States are the Revised Universal Soil Loss Equation version 2 (RUSLE2) and the Wind Erosion Equation (WEQ). Taken together, T, RUSLE2, and WEQ have made possible dramatic improvements in soil conservation and erosion control since they were developed, but they do not address the full range of ecosystem services provided by soils. Specifically these tools only (1) account for one type of soil degradation, erosion, but do not address salinization, compaction, organic matter depletion, and other important threats to soil resources, (2) account for the effect of soil erosion on soil depth and productivity, and (3) evaluate soil management according to what is thought to be an acceptable rate of soil loss; they do not estimate the full extent to which soil resources are being improved through management.

Current Tools Get Us Part of the Way to the System We Need

Participants in the consultation discussed the capabilities of an ideal system of soil conservation standards and planning tools. The capabilities clustered into three categories: (1) soil assessment and monitoring, (2) soil management and conservation planning, and (3) conservation program management. Participants also agreed an ideal system must be capable of assessing and managing the off-site environmental effects of soil management as well as on-site effects on productivity. Participants evaluated the strengths and weaknesses of the Soil Conditioning Index (SCI) and the Soil Management Assessment Framework (SMAF) and recommended improvements to both tools to enhance their capabilities to contribute to an ideal system.

Improving the Soil Conditioning Index

The SCI is a tool used to predict the effect of soil management on the trend in soil organic carbon. The SCI is a predictive tool that allows the user to compare the performance of alternative management and conservation systems based on their predicted effects on soil organic carbon. SCI can and does contribute to more comprehensive conservation planning, and SCI values can be and are used to augment T when evaluating the performance of conservation systems. SCI appears to work well on pasture and in cropping systems with simpler rotations of more traditional crops in rain-fed areas, land uses that represent much of the agricultural landscape in the United States. Finally, SCI can and has been used in national or regional level assessments of trends in soil quality.

SCI, however, evaluates only one indicator of soil quality—soil organic carbon. In addition, SCI has not been subjected to significant peer review in the scientific community, and the applicability and performance of SCI has not been widely tested, at least in some important agricultural regions of the United States. There is particular uncertainty about the performance of SCI when applied to irrigated systems and to cropping systems with diverse rotations and inputs of carbon and nitrogen, especially when such systems involve multiple field operations or organic amendments.

Participants recommended the following steps be taken to improve SCI:

1. Develop and publish in the scientific peer-reviewed literature documentation of the development and evolution of SCI.
2. Use carefully selected studies already in the scientific literature to regionalize SCI inputs and processes to reflect differing crop varieties, different soils, and other regional characteristics and to assess the performance of SCI in irrigated systems and in diverse and nontraditional cropping systems.
3. Use the Conservation Innovation Grants program and other grant programs as vehicles to encourage additional testing, validation, and improvement of SCI.
4. Facilitate the collection of literature into a common, public database that supports SCI inputs and coefficients.

Improving the Soil Management Assessment Framework

SMAF is a tool for assessing and monitoring soil quality following three basic steps: (1) indicator selection, (2) indicator interpretation, and (3) integration into an overall soil quality index value. SMAF was designed as and is best used as a soil assessment tool. It provides a comprehensive snapshot of current soil conditions that can be used to suggest opportunities for improving soil quality. The interpretations of multiple indicators in SMAF are accessible to nonscientists, are tied directly to the goals specified by the user, and enable the integration of productivity and environmental concerns. SMAF can be used to monitor changes in soil quality if repeated measurement and interpretation of the same selected indicators are made at the same location.

SMAF does not enable the user to predict the effect of changing management and conservation systems on soil quality, which limits its application to conservation planning. The most important factor, however, limiting its application is the requirement to measure and sample indicator values at the site to be assessed. In addition, a limited number of scoring functions have been developed to date and a limited but growing number of validation studies have been conducted to test the framework under various management systems and locations.

Participants recommended the following steps be taken to improve SMAF:

1. Place highest priority on exploring options to use modeled values—rather than measured values—as inputs to SMAF and on options to simplify or reduce the number of measured indicators that are required to complete the assessment.
2. Increase the number and accuracy of scoring curves available to interpret measured indicators by building a common, public database to help develop and calibrate scoring curves.
3. Work with commercial soil testing laboratories to incorporate soil quality interpretations into their programs and to collect and measure data that would enable interpretation of additional indicators.
4. Enrich the interpretive text that accompanies each indicator report.

Current and Potential Roles for SCI and SMAF

SCI and SMAF are complementary tools with different strengths and weaknesses. Both tools, either individually or in combination, fall short of the ideal system outlined by participants in the expert consultation. SCI and SMAF can take us closer to the ideal system immediately given their current strengths. If improved as recommended above, the two tools can make an even more important contribution to building the ideal system.

SCI and SMAF in Soil Assessment and Monitoring

SCI is already being used in conjunction with the USDA Natural Resources Conservation Service (NRCS) National Resources Inventory to conduct national and regional assessments of trends in soil carbon as part of the USDA Conservation Effects Assessment Project (CEAP). SCI in national and regional assessments can and should be used now to report the proportion and location of acres on which management is likely degrading, sustaining, or building soil carbon. The indicator interpretation step of SMAF was successfully modified to interpret modeled data for carbon in the National Nutrient Loss and Soil Carbon Database Report for CEAP. SMAF is currently being tested as a soil quality monitoring tool in CEAP watershed studies. The results of those tests should be carefully considered in developing plans for wider use of SMAF in assessing and monitoring change in soil resources at regional and national scales.

SCI and SMAF in Soil Management and Conservation Planning

Both SCI and SMAF can and should be used now to enable producers and their advisors to consider factors in addition to soil erosion that should be part of a more comprehensive conservation plan.

SCI is a predictive tool and therefore already is and should continue to be used to evaluate the relative performance of alternative conservation practices and systems available to producers. SCI values already are and should continue to be used to augment T when evaluating whether current management is adequate to protect and enhance soil resources. SCI, if linked through a common interface with other tools such as phosphorus indices, would expand the number of endpoints affected by soil management that could be evaluated as part of the planning process.

SMAF has not been developed as a predictive tool to date, which will limit its use in conservation planning. Participants concluded the feasibility and desirability of trying to turn SMAF into a predictive tool remains an open question. Participants did agree, however, that SMAF has the potential to serve as a soil benchmarking tool that could inform soil conservation planning by identifying other important factors that should be considered during the planning process.

SCI and SMAF in Conservation Program Management

Participants urged caution when attempting to use SCI or SMAF to set quantitative standards for eligibility to participate in conservation programs or to scale payments based on estimated or measured changes in dynamic soil properties. Unless SCI or SMAF results are adjusted to common baseline conditions, soil types, and climates, payments based on an increment of change in a SCI or SMAF score will result in payments flowing to those producers whose baseline conditions, soil types, and climates make it easy to produce large changes in SCI and SMAF scores. Such payments may have little relation to the cost the producer incurs in sustaining soils that are already in good condition or in producing the improvement in soil resources, which will raise questions about the fairness and credibility of the resulting payment schedule. Participants recommended using SCI and/or SMAF to identify conservation practices and systems that will most improve soil resources at the lowest cost and give those practices and systems priority within the appropriate conservation programs. Actual payments should be related to the cost of applying the selected practices and systems. Participants were encouraged to learn that NRCS was developing the Soil and Water Eligibility Tool (SWET) as a more appropriate tool for determining eligibility and payment rates for conservation programs.

SCI will likely continue to be the tool used to help manage and direct conservation programs given its operational advantages. Therefore, it is imperative that USDA improve SCI as recommended above. NRCS must strengthen its support for SCI if any of the opportunities outlined above are to be seized. Currently, there is not a secure institutional home for SCI within NRCS, and one staff person is solely responsible for updating and maintaining the RUSLE2 databases on which SCI depends.

Coordinated Strategy Needed

As outlined above, using SCI and SMAF as currently developed can bring us closer to the comprehensive soil assessment and management system we need. We are, however, still falling short of the ideal system outlined by participants in the expert consultation.

USDA must develop a coordinated a plan in collaboration with current and potential partners in academia, federal, state, and local agencies, as well as nonprofit and for-profit entities to improve both SCI and SMAF in a coordinated fashion that plays to unique strengths of each tool. Such a coordinated plan should focus on those investments in improving SCI or SMAF that will have the most immediate impact on our ability to assess and plan for conservation of soil resources. Such a plan must look for opportunities to reduce the cost of data collection and to link SCI and/or SMAF with other tools that can contribute to a comprehensive approach to conservation planning and soil management. A suite of existing or developing tools, each with its own unique strengths, linked through a common interface with geographic information system capability may well be the most efficient approach to building an ideal system. A coordinated plan will make the best use of people and money to advance toward the capabilities of an ideal system.

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INTRODUCTION

In 1993, the National Research Council identified protection of soil quality as "a fundamental goal of national policy." In the 15 years since that report was published, much has been accomplished toward that goal. Indicators of soil quality have been proposed for use in the United States, Canada, Great Britain, the European Union, and New Zealand. The scientific basis for recognizing and quantifying the comprehensive services soil provides in agro-ecosystems is maturing. Advances in information technology make more integrated approaches to assessing and managing soil easier to implement.

At the same time, concerns about the limitations of current tools and standards for sustainable soil management have grown. The credibility and utility of the Soil Loss Tolerance Standard (T)—the most widely used and officially recognized standard for "acceptable" rates of soil erosion in the United States—have been called into question. Factors such as compaction, loss of biological activity, and salinization among others are increasingly recognized as threats to soil resources that can be as or more important than soil erosion. Scientists, practitioners, and producers have recognized the need for a more comprehensive and integrated approach to soil management that (1) considers the multiple production and ecological functions soil provides, (2) evaluates multiple factors of soil degradation, (3) provides standards or thresholds for managing soil to sustain its multiple production and ecological functions, and (4) results in more comprehensive recommendations for soil management and conservation.

It appears that research and technology have advanced to the degree that it is possible to build such a comprehensive system to inform sustainable soil management. Such a system could help producers, technical advisors, regulators, and researchers monitor and assess the impact of management on soil resources and make more effective recommendations for improving soil management to support specific soil functions. The number of soil sensors available and forthcoming is large and promises to make it possible to address the challenges posed by spatial and temporal variability in soil. There is not complete consensus yet regarding the concept of soil quality or the utility of soil quality as a guide for soil management. There is, however, broad agreement on the importance of more integrated and comprehensive assessment and management of dynamic soil properties.

Soil and Water Conservation Society Project

The Soil and Water Conservation Society (SWCS) undertook a project, funded by the Wallace Genetic Foundation, to help accelerate the development of a soil quality planning tool that (1) reasonably predicts the effects of management practices on the improvement or degradation of soil quality and (2) enables soil conservationists to recommend changes in management that will meet current environmental and economic objectives as well as sustain or enhance options for future generations.

SWCS undertook two activities as part of this project:

- A literature review to assess the current state of scientific agreement and disagreement about the concept of soil quality and soil quality indicators, as well as the state of development and use of more comprehensive soil management planning tools, assessment tools, and standards.
- An expert consultation to discuss strengths and weaknesses in the two most widely used current tools and to make recommendations for improving those tools.

SWCS published the literature review as *SWCS Special Publication 2007-001: Framework for Sustainable Soil Management Literature Review and Synthesis*. The literature review can be found on the SWCS Web site (www.swcs.org).

This report summarizes the results of the expert consultation held May 22–24, 2007, at the Lied Conference Center of the Arbor Day Foundation in Nebraska City, Nebraska.

Expert Consultation Process and Participation

Participants in the expert consultation were selected because of their direct experience working with and/or testing the Soil Conditioning Index (SCI) and the Soil Management Assessment Framework (SMAF). Our literature review indicated these were the two most widely used tools to date that enable more comprehensive assessment and management of soil. Participants were also briefly introduced during the expert consultation to two additional tools currently under development: the Soil and Water Eligibility Tool (SWET) intended for using in determining eligibility for USDA conservation programs and an as-yet-unnamed user-friendly geospatial model intended to enhance conservation planning. Participants focused their discussion, however, on SCI and SMAF as currently used in the United States.

Participants met for three days at the Lied Conference Center of the Arbor Day Foundation in Nebraska City, Nebraska. An agenda for the meeting and a list of participants are provided in the appendix to this report. The meeting was organized into four sessions:

First Day: Afternoon Session
- Briefings and presentations regarding the history, development, and current status of SCI and SMAF and introduction to SWET and the geospatial planning tool.
- Identified the key issues needed to be address in the consultation.

Second Day: Morning Session
- Clarified what specific purposes and deliverables we want from a suite of soil quality standards and tools.
- Clarified the characteristics and capabilities such standards and tools must meet to achieve the stated purposes and produce the stated deliverables.

Second Day: Afternoon Session
- Assessed the strengths and weaknesses of current tools.
- Identified actions that can and should be done in the short term to improve capabilities.
- Identified actions needed to reach long-term goals.

Third Day: Morning Session
- Reviewed, critiqued, and revised a rough draft of preliminary conclusions and recommendations.

This report has been developed in collaboration with the participants in the expert consultation. It represents, to the best of our ability, an accurate report of the insights gained during the course of the consultation. Consultation participants were not, however, asked to formally sign on to or endorse the report. They participated as individuals and experts, not as official representatives of their agencies or organizations. The content of this report is solely the responsibility of SWCS.

WHY BEYOND T?

Participants in the expert consultation agreed that more comprehensive approaches to soil assessment and management are possible and needed—a view our literature review indicates is shared by most scientists and practitioners. Participants outlined the limitations of our traditional tools and discussed the capabilities of an ideal tool as the starting point for the consultation.

Limitations of Traditional Tools

The most widely used and federally supported soil conservation standard in the United States is the Soil Loss Tolerance Standard (T). The T value is generally interpreted as an estimate of the maximum rate of soil erosion that can occur on a specific soil type and still sustain a high level of crop productivity over the long term.

The most widely used and federally supported soil conservation planning tools in the United States are the Revised Universal Soil Loss Equation version 2 (RUSLE2) and the Wind Erosion Equation (WEQ). RUSLE2 is an updated version of the Universal Soil Loss Equation that estimates long-term, average annual sheet and rill erosion based on a set of factors including soil type, slope length and steepness, climate, cropping systems, and conservation practices. RUSLE2 allows users to evaluate how well different management and conservation systems reduce the risk of erosion. WEQ estimates the amount of wind erosion based on factors including soil type, field size, field direction, wind speed, cropping system, and conservation practices.

Taken together, T, RUSLE2, and WEQ have made possible dramatic improvements in soil conservation and erosion control since they were developed. Indeed, the progress we have made in soil erosion control demonstrates the value of an established and generally agreed upon soil conservation standard and the existence of a planning tool that allows comparisons of the performance of a range of soil conservation practices and systems according to that standard.

T, RUSLE, and WEQ, however, do not address the full range of ecosystem services provided by soils. As a result, these tools alone cannot address the multiple environmental challenges that now confront producers, their advisors, and policy makers. Specifically these tools:

- Only account for one aspect of soil degradation—erosion. The effect of management on key factors such as organic matter level, compaction, biological activity, and water holding capacity are not directly quantified or compared to a specific standard.

- Only account for the effect of soil erosion on soil depth and productivity. The risks posed to other critical ecological and environmental services are not assessed.
- Evaluate soil management according to an acceptable rate of soil erosion—a negative standard; they do not estimate the extent to which soil resources are being improved, and there is growing concern T values may be too high in many cases.

Participants agreed that soil conservation standards and tools that enable a more comprehensive assessment of management and conservation systems on multiple production and environmental endpoints are needed to meet the conservation challenges we face today.

Capabilities of an Ideal System

Participants in the consultation discussed the capabilities of an ideal system of soil conservation standards and planning tools as the first step toward evaluating the strengths and weaknesses of SCI and SMAF. The capabilities clustered into three categories: (1) soil assessment, (2) soil management and conservation planning, and (3) conservation program management. Participants also agreed an ideal system must be capable of assessing and managing the off-site environmental effects of soil management as well as on-site effects on productivity.

Soil Assessment

Participants stressed the importance of distinguishing between "inherent" soil properties and "dynamic" soil properties when thinking about the purpose of soil assessment in an "ideal" system. The soil assessment system envisioned by the participants would focus on dynamic soil properties, which are those properties that change in response to human use and management of soil such as organic matter. In contrast, inherent soil properties are those that result from the five soil forming factors (parent material, climate, topography, time, and biota) and are more resistant to change in response to human use and management of the soil. For example, the levels of organic matter, a dynamic soil property, can increase in response to tillage practices and plant production systems, but the total amount of organic matter that a particular soil can accrue is constrained by soil texture, an inherent soil property.

Inherent soil properties are the foundation of soil taxonomy and the evaluation of land use suitability or land capability. Dynamic soil properties should be the foundation of an assessment system that can predict and manage those human-induced changes in soil that affect critical soil functions or ecosystem services such as water flow and retention, solute transport and retention, physical stability and support, retention and cycling of nutrients, buffering and filtering of contaminants, and maintenance of biodiversity and habitat. However, any assessment of dynamic soil properties must be interpreted within the context of the soil environment including inherent soil properties and climate.

Systems designed to assess dynamic soil properties should allow users to identify vulnerabilities and/or limitations of a particular soil that can be affected by particular production and conservation practices and thereby identify soil management opportunities and specific options to address those vulnerabilities and limitations.

The ideal system should enable assessment of dynamic properties at field, farm, watershed, and national scales. Such a system could and should be the basis for (1) tracking changes in the status, condition, and trend in soil resources, (2) recommending changes in soil management to enhance soil resources, (3) evaluating the performance of conservation practices, programs, and policies, and (4) educating producers, professional conservationists, policy makers, and opinion leaders. Such a system may well consist of a combination of linked tools.

Soil Management and Conservation Planning

Recommendations for a change in soil management and conservation are the most important outcomes of a soil assessment and management system. Making such recommendations requires a system that (1) establishes soil management standards or thresholds for dynamic soil properties and that (2) predicts the positive or negative effects of management on those properties and the soil functions and services they provide.

An effective soil assessment and management system must supplement and/or augment T with standards that more comprehensively account for those soil functions and services most important for the particular soil, site, and intended land use. Moreover, soil management standards must also ensure current management sustains the future capacity of the soil for different or additional uses. This means biological, physical, and/or chemical indicators will be needed for each of those functions and services. A change in a selected indicator must be associated with changes in the capacity of the soil to provide the function or service for which the indicator is selected. Ultimately quantitative standards must be established for each indicator. Such standards may identify a single threshold value at which function is stable, an upper and lower limit within which function is stable, or a direction of change that indicates whether the capacity to function is increasing or decreasing.

The ideal system must also be capable of predicting the effect of human use and management on the selected indicators. Predicted change in those indicators should be the basis for evaluating alternative management and conservation systems. Of most importance, however, is that landowners and decision makers must be able to interpret what a change in an indicator means for achieving private and public objectives in soil management and conservation.

Conservation Program Management

A comprehensive soil assessment and management system would also serve to increase the effectiveness of conservation programs by providing a firmer scientific foundation for program rules, regulations, and agency policies. More specifically, a comprehensive soil assessment and management system could and should provide a stronger scientific foundation for (1) directing program funds to particular purposes, regions, or conservation systems by setting program priorities or eligibility criteria and (2) linking payment levels more directly to predicted outcomes.

GETTING BEYOND T

The literature review that SWCS completed as background for this project identified the SCI and SMAF as two promising contemporary tools that could contribute to a comprehensive soil assessment and management system. The SCI is already widely used in the United States to inform more comprehensive approaches to soil management. The focus of the expert consultation was to better understand the strengths and weaknesses of these two tools and make recommendations to improve them and other tools that may be in development.

Development and Status of Current Tools

Participants in the expert consultation began their examination of SCI and SMAF by reviewing and discussing the development history and current status of both tools.

The Soil Conditioning Index

The SCI is a tool used to predict the effect of soil management on soil organic carbon trend as an indication of change in soil condition. Soil organic carbon is nearly universally cited as a primary indicator of soil condition or quality (Kruse 2007).

In 1964, the USDA Soil Conservation Service (SCS), now the Natural Resources Conservation Service (NRCS), published the *Conservation Agronomy Technical Note No. 27, Soil Conditioning Rating Indices*, that proposed a soil condition rating based on research conducted between 1948 and 1959 in a humid region with high clay soils in Renner, Texas (Zobeck et al. 2007). In 1986, A.D. King and others prepared a shorter version of soil condition rating indices through the USDA SCS South National Technical Center in Fort Worth, Texas (USDA SCS 1987).

Between 1986 and 1999, refinements to the index continued through the work of Argabright and Lightle, culminating in the development of a Microsoft Excel software version of the SCI. In 2000, the USDA NRCS Soil Quality Institute, through the work of Norfleet and Hubbs, improved SCI by linking the amount of residue needed to maintain soil carbon to soil texture. Finally, in 2003 the SCI was incorporated into the Revised Universal Soil Loss Equation version 2 (RUSLE2) for use in implementing the new USDA NRCS Conservation Security Program (CSP).

The SCI is based on long-term studies at Renner, Texas, as noted above. Those studies identified a steady state of soil organic matter under a known cropping and tillage system and erosion rate. The SCI is indexed to other locations by using the RUSLE2 model to quantify the climate effects on residue decomposition.

The SCI estimates the combined effect of three variables on trends in organic matter:

1. Biomass production.
2. Soil disturbance.
3. Soil erosion.

The form of the SCI equation is as follows:

$$(OM \times 0.4) + (FO \times 0.4) + (ER \times 0.2) ,$$

where the OM component accounts for organic material returned to the soil; the FO component accounts for the effect of field operations that stimulate organic matter breakdown; and the ER component accounts for the sorting and/or removal of surface soil material by sheet, rill, and/or wind erosion processes.

The OM component is calculated using the following formula:

$$(RP - MA) / MA ,$$

where RP is the average annual aboveground and belowground biomass returned to the soil (including mulch or manure) and MA is the amount of biomass needed to maintain soil organic matter. MA varies with climate, soil texture, and the ratio of carbon to nitrogen in the crop residue, and therefore varies among regions and locations. These values were obtained by adapting Renner coefficients using results from long-term trials. A texture-based correction is now used to adjust them to other sites. The Renner, Texas, sites had clayey surface textures. These heavier textures inherently retain organics more tightly than coarser textures and therefore need less biomass to maintain their soil organic matter levels (MA).

The FO component accounts for the effect of field operations that stimulate organic matter breakdown. The FO component is based on the Soil Tillage Intensity Rating (STIR), which is a modification of the earlier Soil Disturbance Rating. STIR utilizes the speed, depth, surface disturbance percent, and tillage type parameters to calculate a tillage intensity rating for the system used in growing a crop or a rotation. STIR ratings tend to show the differences in the degree of soil disturbance between systems. The kind, severity, and number of ground disturbing passes are evaluated for the entire cropping rotation. The intensity or severity of disturbance for a specific tillage implement is based on the recommended speed of the operation, depth, surface roughness after use, width of disturbance, and the degree of inversion or mixing. These values range from nearly 0 to nearly 100. A single moldboard plowing operation, for example, has a disturbance rating of nearly 100.

The ER component accounts for the sorting and/or removal of surface soil material by sheet, rill, and/or wind erosion processes. The ER subfactor is based on the Renner site and is adapted to different locations by comparison to the sum of wind and water erosion at Renner. For example, if the sum of wind and water erosion for a site were to equal that of the Renner location, the ER subfactor would be 1. The ER subfactor increases with increasing total erosion in a slight curvilinear relationship to a maximum of 4 representing about 40 tons of annual soil loss.

The SCI considers the upper 10 cm (3.94 in) of the soil surface and is reported as a range of positive and negative values (see figure 1). An SCI of 0 indicates that the combined effects of biomass production, soil disturbance, and soil erosion are maintaining soil organic matter at its current level. A negative score indicates that the current management system is causing soil organic matter levels to decrease. A positive score indicates that the current management system is increasing soil organic matter levels. The SCI is considered a qualitative tool; however, internal NRCS validation efforts have indicated there is a quantitative relationship between a change in the SCI score and the percent change in carbon in long-term agricultural studies across the United States (Norfleet, unpublished data).

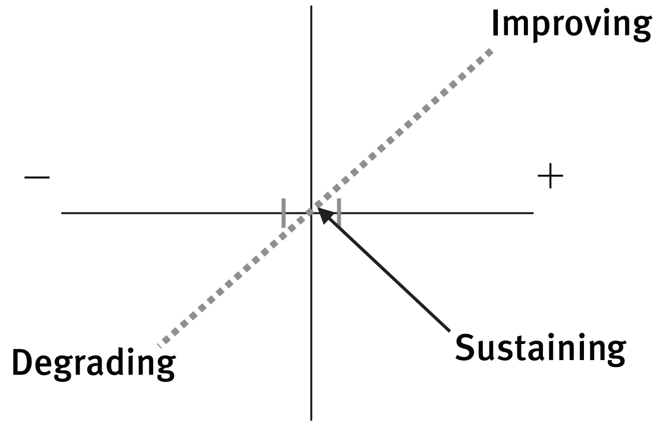

Figure 1. The Soil Condition Index (SCI) Rating

The SCI is widely used in NRCS as part of practice standards and quality criteria. Most recently, SCI was widely employed as part of the eligibility criteria for participation in CSP.

The Soil Management Assessment Framework

SMAF is a tool for assessing and monitoring soil quality. SMAF follows three basic steps: (1) indicator selection, (2) indicator interpretation, and (3) integration into an overall soil quality index value (Andrews et al. 2004).

SMAF uses a series of decision rules to generate for the user a list of suggested soil quality indicators based on the management goals for the site and the soil functions that most influence the capacity of the soil to meet that management goal. If a user chooses waste recycling as his or her management goal, for example, the framework identifies nutrient cycling, water relations, filtering and buffering, and resistance and resilience as critical soil functions related to that management goal. The recommended list of indicators is further refined through evaluation of additional information such as climate, inherent soil properties, cropping system, and other site- or use-specific information (Andrews et al. 2004).

The list of suggested soil quality indicators is then grouped according to its association with each critical soil function (see figure 2). The user makes the final determination of the indicators that will be used to assess strengths, limitations, or vulnerabilities of the soil in relation to his or her management goals. SMAF indicators and functions could also be specified for use by multiple users at a regional scale.

Interpretation of the selected indicators requires (1) measuring the values of each indicator using standard methods for the near surface (0 to 15 cm [0 to 5.91 in]) and (2) using a sampling design to collect the measurements that is appropriate for the area to be assessed (Andrews

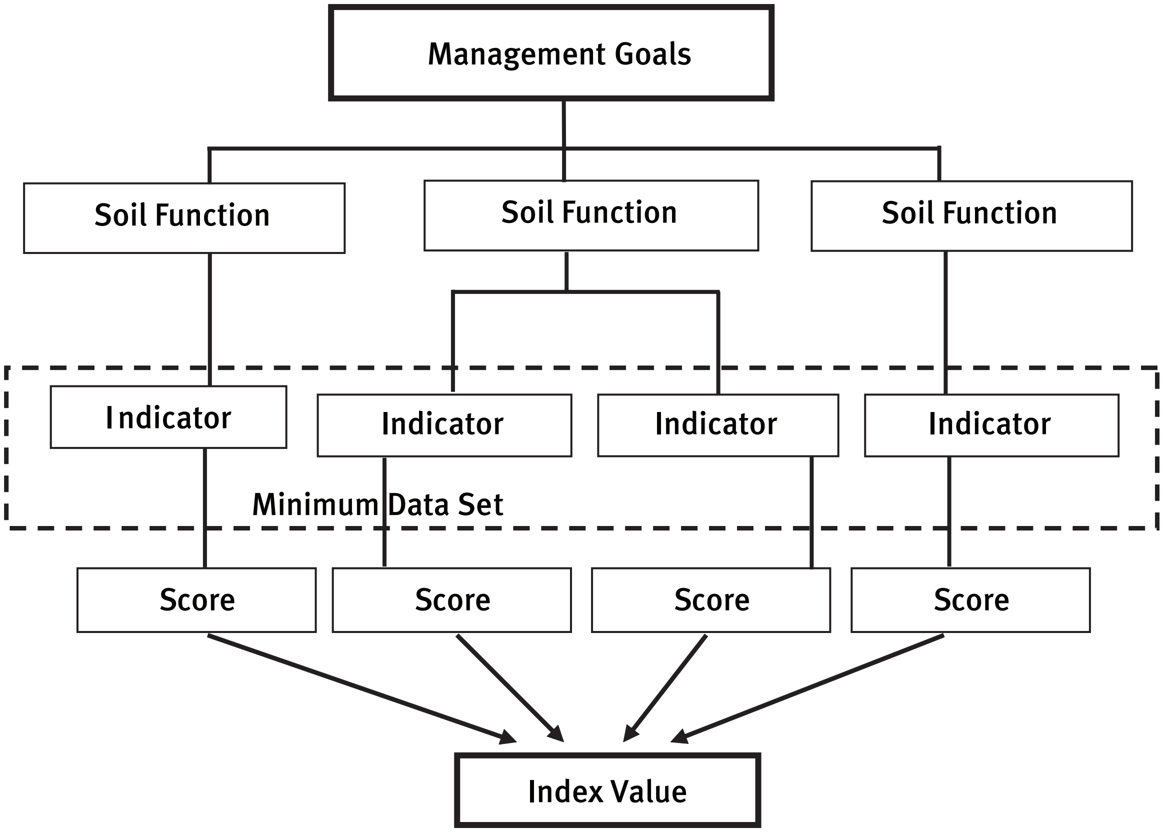

Figure 2. The Soil Management Assessment Framework

et al. 2004). Once the measured values are secured, they are transformed into unitless values through the use of "scoring curves." Each SMAF scoring curve consists of an algorithm or logic statement with alternative algorithms. The algorithms are quantitative relationships between the measured values of an indicator and the capacity of the soil to perform the function for which the indicator was selected. Each measured indicator is given a score between 0 and 1 that represents the associated level of function—a score of 1 represents the highest potential function for that particular soil and climate, meaning the measured soil property indicates no impairment of the related function(s) needed to meet the designated management goals (Andrews et al. 2004).

The final step in SMAF integrates all of the individual indicator scores into a single, additive index value, which is meant to be an overall assessment of soil quality (Andrews et al. 2004).

Strengths, Weaknesses, and Opportunities for Improvement

Participants in the expert consultation spent most of their time discussing the strengths and weaknesses of each tool compared to the capabilities of the ideal system outlined earlier in this report. Their discussion of strengths and weaknesses helped identify the most promising opportunities to improve SCI and SMAF.

The Soil Conditioning Index

Participants identified several strengths, two primary weaknesses, and several opportunities to improve SCI.

Strengths

The SCI is a predictive tool, which is by far its most important strength as a soil assessment and management tool. SCI allows the user to directly compare the performance of alternative management and conservation systems based on their predicted effects on soil organic carbon. As such, SCI can and does contribute to more comprehensive conservation planning. SCI values can be and are used to augment T when evaluating the performance of conservation systems and programs.

SCI also has important operational and logistical strengths. It is already incorporated into RUSLE2—the basic conservation planning tool used by NRCS—and is relatively simple to use for personnel already comfortable with using RUSLE 2. The data required are the same as those needed for RUSLE 2 and WEP, the results are easy to understand, and the three model components (biomass, disturbance, soil erosion) tie back to management options. Because of these operational and logistical strengths, SCI is easily adapted to specific locations, crops, and management systems.

SCI appears to work well on pasture and in cropping systems with simpler rotations of more traditional crops in rain-fed areas. Such systems represent much of the agricultural landscape in the United States.

Finally, SCI can and has been used in national or regional assessments of trends in soil quality. The SCI has, for example, been applied to National Resources Inventory points to make national and regional level assessments of the number of acres on which soil carbon is increasing, decreasing, or being sustained under current management.

Weaknesses

SCI suffers from two primary weaknesses. First, the tool evaluates only one indicator of soil quality—soil organic carbon. Soil organic carbon is a critical and integrative indicator of soil quality but is not always the factor limiting soil function. SCI currently cannot provide a more comprehensive indication of the effect of soil management on soil quality.

Second, SCI has not been subjected to significant peer review in the scientific community, and the applicability and performance of SCI has not been widely tested, at least in some important agricultural regions of the United States.

There is particular uncertainty about the performance of SCI when applied to irrigated systems and to cropping systems with diverse rotations and inputs of carbon and nitrogen, especially when such systems involve multiple field operations or organic amendments.

Opportunities for Improvement

The most important short-term opportunity to strengthen SCI is to encourage and facilitate additional validation and sensitivity analysis of the tool. This could be accomplished most readily by taking the following actions:

1. Develop and publish in the scientific peer-reviewed literature documentation of the development and evolution of SCI.
2. Use carefully selected studies already in the scientific literature to regionalize SCI inputs and processes to reflect differing crop varieties, different soils, and other regional characteristics and to assess the performance of SCI in irrigated systems and in diverse and nontraditional cropping systems.
3. Use the Conservation Innovation Grants program and other grant programs as vehicles to encourage additional testing, validation, and improvement of SCI.
4. Facilitate the collection of literature into a common, public database that supports SCI inputs and coefficients.

NRCS will begin implementing the Wind Erosion Prediction System (WEPS) in the spring of 2008. The WEPS model will include SCI in the model interface—a welcome improvement that will enhance the utility of SCI in regions where wind erosion is important.

The SCI should also be strengthened by ensuring users are fully trained and are using and interpreting SCI results appropriately. Many of the problems encountered with SCI during implementation of CSP were found to be caused by improper use of the tool, rather than by flaws in the tool itself.

NRCS must strengthen its support for SCI if any of the opportunities outlined above are to be seized. Currently, there is not a secure institutional home for SCI within NRCS. One staff person is solely responsible for updating and maintaining the RUSLE2 databases on which SCI depends.

The Soil Management Assessment Framework

Participants in the expert panel identified several strengths, two primary weaknesses, and several opportunities to improve SMAF.

Strengths

Currently, SMAF is best used as a soil quality assessment tool that allows users to define their management goals and evaluate multiple soil functions using multiple soil indicators. SMAF does not enable the user to predict the effect of changing management and conservation systems on the selected indicators and the soil functions they represent.

SMAF does enable a comprehensive assessment of soil quality and function based on a suite of physical, chemical, and biological indicators. In short, SMAF provides a comprehensive snapshot of current soil conditions and may provide a model for how dynamic properties might be used in assessment efforts. That snapshot can suggest opportunities for improving soil quality in ways that would facilitate accomplishing the stated management goals.

Interpretation of multiple indicators in SMAF enables the integration of productivity and environmental concerns. Interpretations of the indicators are accessible to nonscientists and are tied directly to the goals specified by the user.

SMAF can be used to monitor changes in soil quality through repeated measurement and interpretation of the same selected indicators at the same location.

Weaknesses

The most important weakness or limitation in using SMAF as an assessment tool is that the current version requires measurement and sampling of indicator values at the site to be assessed. Measurements can be difficult, time-consuming, or expensive to obtain, depending on the particular indicator and the sampling intensity required to adequately represent the spatial characteristics of the site being assessed.

In addition, a limited number of scoring functions (algorithms) have been developed to date and a limited but growing number of validation studies have been conducted to test the framework under various management systems and locations.

Opportunities for Improvement

The most important opportunity to improve the application of SMAF is to find ways to reduce the burden and cost imposed by measuring and sampling selected indicators at each site to be assessed. Participants recommended that a high priority be placed on exploring options to use modeled values—rather than measured values—as inputs to SMAF (see Potter et al. 2006, for example) and on options to simplify or reduce the number of measured indicators that are required to complete the assessment.

Another important opportunity is to increase the number and accuracy of scoring curves available to interpret measured indicators. Participants indicated the following scoring curves would, if they were available, particularly strengthen the application of SMAF:

- Particulate organic matter carbon.
- Labile or active carbon.
- Enzymes as indicators of biological activity.
- Available potassium.

Participants recommended building a common, public database to help develop and calibrate scoring curves and to ensure the inflection point on scoring curves reflects inherent soil properties.

A significant opportunity also exists to work with commercial soil testing laboratories to incorporate soil quality interpretations into their programs and to collect and measure data that would enable interpretation of additional indicators.

The utility of SMAF as a soil assessment tool could also be quickly improved by enriching the interpretive text that accompanies each indicator report.

SCI and SMAF in the Ideal System

SCI and SMAF are complementary tools with different strengths and weaknesses. Both tools, either individually or in combination, fall short of the ideal system outlined by participants in the expert consultation. SCI and SMAF can take us closer to the ideal system immediately given their current strengths. If improved as recommended above, the two tools can make an even more important contribution to building the ideal system.

SCI and SMAF in Soil Assessment and Monitoring

Both SCI and SMAF can and should play important roles in assessing and monitoring changes in soil resources in the United States. The SCI is already being used in conjunction with the USDA NRCS National Resources Inventory to conduct national and regional assessments of trends in soil carbon as part of the USDA Conservation Effects Assessment Project (CEAP). The SCI in national and regional assessments can estimate how current management is affecting soil carbon and allow reporting the proportion and location of acres on which management is likely degrading, sustaining, or building soil carbon. Comparing SCI results in different time periods can identify change in the amount and distribution of acres on which soil carbon is decreasing, increasing, or staying the same. As such, the SCI can and should be used to complement national and regional assessment of the risk of erosion to provide a more comprehensive picture of soil resources in the United States.

SMAF has obvious potential applications to soil assessment and monitoring at national and regional scales. SMAF has the potential advantage of making possible assessments on multiple dynamic soil properties and the soil functions they represent. As noted above, using SMAF in soil assessment and monitoring activities requires repeated measurements of the soil properties selected as indicators of soil function. Enabling use of modeled rather than measured values for soil properties would increase the ability of SMAF to contribute to regional and national assessments of soil resources. The indicator interpretation step of SMAF was successfully modified to interpret modeled data for carbon in the National Nutrient Loss and Soil Carbon Database Report for CEAP. SMAF is currently being tested as a soil quality monitoring tool in CEAP watershed studies. The results of those tests should be carefully considered in developing plans for wider use of SMAF in assessing and monitoring change in soil resources at regional and national scales.

SCI and SMAF in Soil Management and Conservation Planning

Both SCI and SMAF can and should also play important roles in enhancing soil management at the field and farm operation scale by enabling producers and their advisors to consider factors in addition to soil erosion that should be part of a more comprehensive conservation plan.

The SCI is a predictive tool and therefore already is and should continue to be used in the most critical step in conservation planning—evaluating the relative performance of alternative conservation practices and systems available to producers. The SCI, if linked through a common interface with other tools such as phosphorus indices, would expand the number of endpoints affected by soil management that could be evaluated as part of the planning process.

SMAF has not been developed as a predictive tool to date, which will limit its use in conservation planning. Participants concluded the feasibility and desirability of trying to turn SMAF into a predictive tool remains an open question. Participants did agree, however, that SMAF has the potential to serve as a soil benchmarking tool that could inform soil conservation planning by identifying other important factors that should be considered during the planning process. The effect of different conservation practices and systems on those factors could be evaluated using other tools and/or professional judgment.

SCI values already are and should continue to be used to augment T when evaluating whether current management is adequate to protect and enhance soil resources. An SCI improved as recommended above could make greater contributions to improving the management of soil resources in the United States. SMAF promises a more comprehensive set of standards to augment T in soil management. Much additional work, however, will be required to develop scoring functions and thresholds to realize that promise.

SCI and SMAF in Conservation Program Management

SCI and SMAF can and should make contributions to managing and directing conservation programs. Participants in the expert consultation, however, urged caution in how the tools should be applied to program management.

SCI and SMAF could and should be used to evaluate the performance of conservation practices and systems in regard to their effect on soil resources. Such evaluations could and should inform the ranking systems used to evaluate the potential performance of offers to participate in conservation programs. In addition, such evaluations could and should help identify the most effective and low-cost practices and systems that should be made eligible for financial assistance through conservation programs. Finally, SCI and SMAF could and should be used to inform the development of quality criteria for soil resource management that augments T.

Participants urged caution when attempting to use SCI or SMAF to set hard, quantitative standards for eligibility to participate in conservation programs or to scale payments based on estimated or measured changes in dynamic soil properties. Estimated or measured changes in the scores produced by SCI or SMAF are highly dependent on baseline conditions, soil type, and climate. SCI or SMAF results must be adjusted to common baseline conditions, soil types, and climates to enable equitable comparisons of performance among producers seeking to participate in conservation programs.

The problems can be particularly acute when attempting to scale payments to estimated or measured changes in SCI and SMAF results. Even heroic effort by a producer may result in little change in SCI and SMAF results under some baseline conditions, soil types, or climates. Alternatively, very little effort by a producer may result in large improvements in SCI or SMAF results under different baseline conditions, soil types, and climates. Making payments based on an increment of change in a SCI or SMAF score will result in payments flowing to those producers whose baseline conditions, soil types, and climates make it easy to produce large changes in SCI and SMAF scores—a good result in terms of efficiency. Such a payment schedule, however, may have little relation to the cost the producer incurs in sustaining soils that are already in good condition or in producing the improvement in soil resources, which will raise questions about the fairness and credibility of the resulting payment schedule. Participants in the expert consultation suggested a good compromise between efficiency and equity is to use SCI and/or SMAF to identify those proposed conservation practices and systems that will most improve soil resources at the lowest cost and give those proposals priority for enrollment in the appropriate conservation programs. Actual payments, however, would be based on a payment schedule that is related to the cost of applying the selected practices and systems. Participants were encouraged to learn that NRCS was developing SWET as a more appropriate tool for determining eligibility for conservation programs.

The current operational and logistical advantages of the SCI that were mentioned earlier suggest the SCI will likely continue to be the tool used to help manage and direct conservation programs, hopefully as recommended in this report. Therefore, it is imperative that USDA take action to improve the SCI as recommended above, particularly to facilitate additional validation and sensitivity analysis of the tool. The utility of SMAF in directing conservation programs would be greatly improved if, as mentioned above, ways were found to use modeled rather than measured data on selected soil indicators. SMAF's main benefit may lie in national assessment of modeled conservation effect until and unless SMAF is adopted by mainstream soil testing laboratories.

Coordinated Strategy Needed

Our expert consultation made it clear that SCI and SMAF are complementary tools that differ in their strengths and weaknesses. As outlined above, using SCI and SMAF, as currently developed, can bring us closer to the comprehensive soil assessment and management system we need. We are, however, still falling short of the ideal system outlined by participants in the expert consultation.

USDA must develop a plan to improve both SCI and SMAF in a coordinated fashion that plays to unique strengths of each tool. Such a coordinated plan should focus on those investments in improving SCI or SMAF that will have the most immediate impact on our ability to assess and plan for conservation of soil resources. Such a plan must look for opportunities to reduce the cost of data collection and to link SCI and/or SMAF with other tools that can contribute to a comprehensive approach to conservation planning and soil management. A suite of existing or developing tools, each with its own unique strengths, linked through a common interface with geographic information system capability may well be the most efficient approach to building an ideal system.

USDA should develop a coordinated a plan in collaboration with current and potential partners in academia, federal, state, and local agencies, and nonprofit and for-profit entities. Such collaboration will accelerate acceptance and use of the tools and help refine the tools for use in diverse settings and for diverse purposes. A coordinated plan will make the best use of people and money to advance toward the capabilities of an ideal system.

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APPENDIX

Consultation Agenda

Tuesday Afternoon Session: Get on the Same Page

The purpose of this session:
- Familiarize ourselves with the three primary soil quality tools currently in use or under development.
- Identify the key issues we need to address in the consultation.
- Revise agenda accordingly as needed.

1:00 p.m. Welcome and Introductions
1:15 p.m. Background Presentations—Questions and discussion after each presentation
Craig Cox—Consultation Purpose and Policy Setting
Lee Norfleet—Soil Conditioning Index
2:30 p.m. Break
3:00 p.m. Background Presentations—Questions and discussion after each presentation
Doug Karlen—Soil Management Assessment Framework
Susan Andrews—Soil Quality Tool
4:15 p.m. Identify Key Issues and Review Agenda
5:30 p.m. Adjourn
6:30 p.m. Dinner (Lied Lodge Dining Room)

Wednesday Morning Session: What Do We Want from Our Tools?

The purpose of this session:
- Clarify what specific purposes and deliverables we want from a suite of soil quality standards and tools.
- Clarify the characteristics and capabilities such standards and tools must meet to achieve the stated purposes and produce the stated deliverables.

8:30 a.m. Purposes, deliverables, characteristics, and capabilities:
- Soil quality assessment and monitoring.
- Predicting impact of management on soil quality.
- Soil conservation and management planning.
- Conservation program soil quality payment and eligibility criteria.
- Others?

12:00 p.m. Lunch

Wednesday Afternoon Session: Where Are We Today?

The purpose of this session:
- Assess the strengths and weaknesses of current tools.
- Identify actions that can and should be done in the short-term to improve capabilities.
- Identify actions needed to reach long-term goals.

1:30 p.m. Discussion of strengths, weaknesses, and opportunities for action
3:00 p.m. Break
3:30 p.m. Discussion of strengths, weaknesses, and opportunities for action
4:30 p.m. Recap of discussion findings and conclusions
5:30 p.m. Adjourn

Thursday Morning Session: Conclusions and Recommendations

The purpose of this session is to review, critique, and revise preliminary conclusions and recommendations. Craig Cox will work Wednesday evening to produce a rough draft of conclusions and recommendations as a starting point for the session.

8:30 a.m. Critique and revise rough draft of conclusions and recommendations
11:30 a.m. Next Steps
12:00 p.m. Adjourn

Consultation Participants

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Craig Cox, Soil and Water Conservation Society
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