This paper was peer-reviewed for scientific content.
Pages 529-534. In: D.E. Stott, R.H. Mohtar and G.C. Steinhardt (eds). 2001. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory.

Locally Led Conservation Activities: Developing a Soil Quality Assessment Tool

A.J. Tugel, S. Seiter, D. Friedman, J. Davis, R.P. Dick, D. McGrath and R R. Weil*

ABSTRACT

Farmers base many management decisions on a variety of personal observations of their crops and soils. However, there was no soil assessment procedure applicable to farms across the country to help farmers record these observations and use them to guide their future management decisions. To address this need, the Soil Quality Institute of the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) and university research and USDA-Cooperative Extension Service (USDA-CES) partners in Oregon and Maryland developed the Soil Quality Card Design Guide. Using the Guide, facilitators followed a 9-step meeting procedure to help farmers identify locally important soil quality indicators, develop descriptive terms for soil quality assessments, and design the format of their soil quality card. Seven cards were developed by local groups of farmers during the period from 1997 to early 1999. The farmer meeting provides an opportunity for USDA-NRCS, USDA-CES, Conservation Districts, producers and others to jointly create soil quality cards for farmers in each unique cropping region of the country. The collaborative process used to create the cards offers locally led conservation opportunities for dialogue and idea sharing, thus blending the scientific knowledge of conservationists and soil scientists with the common-sense experience of producers. Farmers can use soil quality cards to assess changes in soil quality resulting from different management systems and to track changes from year to year. Agricultural professionals, educators, students and others with an interest in soil quality and the impact of management practices on soil can use the cards to enhance communication and learning.

INTRODUCTION

Conservation of soil resources to control erosion, conserve productivity and eliminate soil degradation is a fundamental goal of soil quality and resource management. Even though decisions made by farmers affect the quality of their soil, no simple tool to help farmers observe, record and use observations about their soil resource to guide their future management decisions exists. Farmers in a specific area often face similar soil management problems for similar crops and can benefit from each other's experiences. Locally led conservation involves community stakeholders, including farmers, working together to assess their natural resource conservation needs; set community conservation goals; develop an action plan; obtain resources to carry out the plan; implement the solution; and measure their success (USDA-NRCS, 1998). Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen et al., 1997). Simply stated, soil quality is the capacity of the soil to function. Managing soil to meet farmers' productivity and profitability goals and society's long term environmental and resource health goals requires knowledge of inherent soil capabilities (USDA, 1961) and an evaluation of those soil properties that change in response to management (Larson and Pierce, 1991). Soil quality assessments rate or measure the condition of those soil properties that are affected by land management practices (Doran and Parkin, 1996; Sarrantonio et al., 1996). The subject of this paper, a locally adapted soil quality card, is an example of a qualitative assessment tool. The card includes properties, or indicators of soil quality, that farmers observe to detect changes in their soil. It can be developed by farmers and used by farmers to evaluate the effect of agricultural practices on their own soil quality.

Most producers intuitively or consciously observe the effect of their operations on their fields (Seiter et al., 1996). The Wisconsin Soil Health Scorecard (Romig et al., 1995; Romig et al., 1996), one of the first efforts to provide a qualitative assessment tool, includes 43 indicators of soil quality identified through farmer interviews. From the Wisconsin model, the Soil Quality Institute of the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) developed a vision of creating local soil quality cards, nationwide, according to a specific set of procedures. The vision of these cards included three key elements. First, the cards would be locally adapted to reflect the impact of local cropping systems on the soil properties common to a specific area such as a county or group of counties. Second, local farmers, USDA-NRCS, Conservation Districts and United States Department of Agriculture-Cooperative Extension Service (USDA-CES) would actively participate in the development of the cards to achieve their buy-in and support. Third, the cards would be simple, easy to use do-it-yourself tools.

METHODS

Soil Health Card Team

Between January 1997 and April 1998, the Soil Health Card Team (SHC-Team), including Soil Quality Institute staff, Oregon State University and USDA-CES researchers,

*Corresponding author: atugel@nmsu.edu

University of Maryland researchers and USDA-NRCS state specialists collaborated to develop a procedure for creating local soil health cards. The SHC-Team designed farmer meeting protocols, conducted four farmer meetings in Oregon and three in Maryland and field tested and released cards in Oregon and Maryland. Revised protocols were pilot tested in collaboration with USDA-NRCS, farmers and partners in Montana, North Dakota and New Mexico. The SHC-Team developed a training course for meeting facilitators and prepared the booklet "Soil Quality Card Design Guide: A guide to develop locally adapted conservation tools" (USDA-NRCS, 1999).

Project Principles

The SHC-Team blended basic principles from various approaches, including soft systems inquiry, farmer-scientist participatory learning and locally led conservation, in the development of the procedure for creating soil health cards. Wilson and Moren (1990) describe numerous applications of soft systems inquiry in agriculture and natural resource management. This inquiry approach focuses on the exploration into views and values of various stakeholder groups (Checkland and Scholes, 1990). It enabled the SHC-Team to focus on farmers' perceptions of soil quality and to create a co-learning system in which collaboration leads to both desirable change toward sustainable soil management and a usable product for the farmers (Bawden, 1991). Adhering to these principles also ensured broad and continuous involvement of diverse stakeholders throughout the card design process.

A farmer-scientist participatory approach was used to create a co-learning partnership between farmers and scientists. Meeting events were designed to promote learning through sharing among the farmers, to explore diverse views, values and beliefs, and investigate complex cropping system issues that require interdisciplinary examination (Lev et al., 1993). Participatory group techniques were used during meetings to improve farmers' ability to deal with this complexity and build farmers' ownership of both the meeting process and outcomes (Pretty et al., 1995). Group techniques that address farmers' diverse learning styles (Kolb, 1984) to assure that each participant has the opportunity to contribute to the product were utilized in farmer meetings.

Locally led conservation is based on the principle that local people are best suited to identify and resolve local natural resource issues. This guided the participation and card design activities of farmers, Conservation Districts, specialists and agricultural support professionals in the development of local soil quality cards. Dialogue between partners and farmers involved in the card process was structured to build increased knowledge of soil quality, common language, and an understanding of mutual or similar stakeholder goals and needs.

Creating a Local Card

A card design project (Table 1) in a state or county is led by a local Soil Quality Card Team (Team). Suggested Team members include farm community leaders, Conservation Districts, county or state USDA-NRCS and USDA-CES employees, university researchers and representatives from other farm organizations. The Team determines the number of different cards to be created, secures funding, and makes plans for farmer meetings, field testing, printing, distribution, marketing and future support. One farmer meeting per card is adequate. Team members commonly serve as the facilitators, note takers, recorders, technical specialists, and observers during the farmer meeting, although others assisting the Team may carry out some of these roles.

The farmer meeting is designed as the primary activity for gathering farmer input to create a local card. The goal of the farmer meeting is to learn how farmers determine the impact of field management on soil quality and to capture this information effectively for construction of a local soil quality card. The activities during the meeting encourage interactive learning among farmers and between farmers and the technical specialists or Team. The ideal number of people at a meeting is 10-15 farmers and 1-2 technical specialists plus the 3 or 4 Team members who conduct the meeting. The most important key to success is for the Team and agency members to listen to the farmers, accurately record their comments and avoid dominating conversations. However, specialists can add science-based information to rectify any misleading or incorrect statements to insure that cards are scientifically accurate.

Farmer meeting protocols guide Team members through the nine steps of a 4-hr farmer meeting. Core activities include a "Hands-on activity," "Pin card writing and analysis," "Sticky dots," and a "Card format discussion." A description of objectives, time requirement, staff, materials, procedures and tips for each step are in the Soil Quality Card Design Guide. The "Hands-on activity" is a facilitated discussion about soil samples that are displayed on tables. Farmers share their experience in evaluating the effects of soil management on soil quality while looking at, feeling, and smelling the soils. "Pin card writing" and "Pin card analysis" guide farmers to write on large pin cards the soil quality indicators that they would use in their fields. These pin cards are then posted on the wall and analyzed by the entire group. "Sticky dots" is a technique in which farmers vote by placing self-adhesive color dots on their soil quality pin cards of preference. This activity narrows the list of soil quality indicators for the local card. It also forces clarification of the meaning of each indicator during the discussion that follows the vote. A "Card format

Table 1. The procedure for creating a soil quality card includes a number of steps.

Steps
1. Set-up the Soil Quality Card Team.
2. Train the Card Team.
3. Prepare for farmer meeting.
4. Conduct farmer meeting.
5. Create the card prototype.
6. Field-test the prototype.
7. Finalize and print card.
8. Market and distribute card.
9. Provide card-user support.

Table 2. Indicator rating systems and the number of physical, biological and chemical soil properties and plant based properties selected as soil quality indicators for farmer-developed soil quality cards.

	Type of Indicator†				
State and Card Name	PHY	BIO	CHEM	PLT	Rating System
	---------------------no.------------------				
Illinois					
Northeastern Illinois Soil Quality Card (March 1999)	4	1			Poor, Medium, Preferred 1-3, 4-6 7-9
Maryland					
Maryland Soil Quality Assessment Book (Dec. 1997)	5	1	3	2	Poor, Medium, Good 1-3, 4-6, 7-9
Montana and North Dakota					
Mon-Dak Soil Quality Score Card (Dec. 1998)	5	2		2	Poor, Medium, Good
North Dakota					
Soil Health Guide for Southeastern North Dakota (Nov. 1998)	3	1	2	3	Poor, Fair, Excellent 1-3, 4-6, 7-9
New Mexico					
Soil Quality Assessment (Jan. 1998)	4	1	1	3	- to + 1 to 5
Ohio					
Ohio Soil Health Card (Oct. 1998)	6	3	3	3	Poor, Fair, Good
Oregon					
Willamette Valley Soil Quality Card (June 1998)	5	3		2	Preferred 1, 5, 10
TOTAL	32	12	9	15	

†PHY, physical; BIO, biological; CHEM, chemical; PLT, plants and residue

discussion" is used to determine card layout, scoring system, and other physical features of the prototype Soil Quality Card. The nine steps of the farmer meeting can be modified to meet local needs. Following the farmer meeting, field tests of the prototype card verify that the farmers' language and intent is retained and that the card meets their needs. Farmer responses to questions about content, layout, ease of use, and usefulness of the card are addressed in the preparation of the final cards.

RESULTS AND DISCUSSION

Features of Soil Quality Cards

The seven cards (Table 2) completed at the time this paper was prepared all include a set of indicators, descriptive terms for each indicator defining 3 levels of soil quality, a feature for recording either numerical or adjective ratings, and instructions for use. Some cards provide sections for field management notes and a location sketch. Some of the cards are designed for one time use, while others are a booklet of cards for repeated assessments. Local preference determines the card name of either "Soil Quality Card" or "Soil Health Card." Illinois, North Dakota, and Ohio cards were developed following the protocols in the Guide, but without direct assistance from the original SHC-Team. The Maryland Soil Quality Assessment Book and the Willamette Valley Soil Quality Card are included as examples in the Soil Quality Card Design Guide. A free copy of the Guide can be downloaded from the USDA-NRCS Soil Quality Institute web page http://www.statlab.iastate.edu/survey/SQI/SQassessment.htm (verified 4 Apr. 2001). The website also provides information on how to obtain copies of each card discussed in this paper. New cards are posted upon receipt.

During a meeting, farmers commonly identify more than 20 indicators and select about 10. Including more than 10 indicators complicates the use of the card. Each indicator is identified by a term such as "Water Holding Capacity" or as a question, "Is water available for plant growth?" Indicators suggested by farmers (Table 2) include: physical (structure, tilth, compaction, crusting, porosity, workability, infiltration, drainage, ponding,

Table 3. Selected indicators and descriptive terms for physical, biological and chemical soil properties, and plant and residue properties from soil quality cards developed in the United States.

Indicator	State	Poor	Fair	Good	Property[†]
Physical					
Structure	IL	Hard, slabby, aggregates hard to break	Somewhat blocky	Crumbly, loose, mellow	C, S
Soil Tilth, Mellowness, Friability	MD	Looks dead. Like brick or concrete, cloddy. Either blows apart or hard to pull drill through	Somewhat cloddy, balls up, rough pulling seedbed	Soil crumbles well, can slice through, like cutting butter. Spongy when you walk on it	B, C, S, W
Tilth	MT/ ND	Crusting, large clods, works hard	Some crusting, small clods, medium pull	Mellow, crumbly, works easy	C, CR, W
Structure and Tilth	NM	Cloddy, powdery, and/or tight	Moderate amount of pores; some tightness	Porous, friable, crumbly	C, PO, S
Compacted Layers	OR	Wire flag bends readily, obvious hardpan, turned roots	Some restrictions to penetrating wire flag and root growth	Easy penetration of wire flag beyond tillage layer	B, C, RG
Subsurface Compaction	ND	Hardpan and/or soil occurs in large compressed pieces requiring large shear force, roots absent below 8”	Soil occurs in medium pieces sheared with moderate force, root penetration 12 to 16” deep with some difficulty	Soil occurs in 1” or smaller pieces sheared with small amount of force, roots penetrate without difficulty	B, C, RG, S
Drainage, Infiltration	MD	Water lays for a long time, evaporates more than drains, always very wet ground	Water lays for short period of time, eventually drains	No ponding, no runoff, water moves through soil steadily. Soil not too wet or too dry.	D, PD, R, PR, M
Water Movement	OH	Absorbs water very slowly, lots of runoff & erosion, ponding after moderate rains	Absorbs water, but more slowly, some runoff & erosion, ponding after heavy rains	Rainfall soaks in, very little runoff & erosion, water does not pond	E, I, PD, R
Biological					
Earthworms	MD	0-1 worms in shovelful of top foot of soil. No casts or holes	2-10 in shovelful. Few casts, holes or worms	10+ in top foot of soil. Lots of casts and holes in tilled clods. Birds behind tillage	OG, PO
Living Organisms	NM	Little or no observable soil life	Some moving soil critters	Soil is full of soil organisms	OG
Smell (spring)	MT/ND	Little or no odor	Some odor, mineral odor	Pungent, sweet “earthy” odor	OD
Plant Residue	OR	No residue or not decomposing for long periods	Some plant residue slowly decomposing	Residue in all stages of decomposition	PS
Chemical					
Nutrient Holding Capacity	MD	Soil tests dropping with more fertilizer applied than crops use	Little change or slow down trend	Soil tests trending up in relation to fertilizer applied and crop harvested	N, F
Organic Matter	OH	Organic matter levels are being maintained or increasing, dark, friable, with good structure	Organic matter levels can be improved, some crusting and clods	Organic matter levels are decreasing, light-colored, crusted, cloddy, hard	OM, SC, C, S, CR
pH	MD	Hard to correct for desired crop	Easily correctable	Proper pH for crop	SR
Salt or Alkali	NM	Visible salt/alkali and or dead plants	Stunted growth, signs of leaf burns from salts, especially after rains	No visible salt, alkali, or plant damage	SS, PG
Plants and Residue					
Existing Crop	ND	Poor uneven stand and yields poor, crop color light green to yellow	Wheel tracks visible in stand, some crop lodging, uneven emergence	Healthy looking crop with dark green color and even stand	PG, Y, PE
Seedling Emergence	OH	Rapid and even emergence	Some variability in emergence	Slow and uneven emergence	PE
Root Growth	OR	Poor root growth and structure, brown or mushy roots	Some fine roots, mostly healthy	Vigorous, healthy root system with desirable root color	RG
Crop Residue	MT/ND	Light, <20% cover	Moderate, 20%-40% cover	Heavy, >40% cover	PS

†B, bulk density; C, consistence; CR, crusting; D, drainage; E, erosion; F, fertilizer application; I, infiltration; M, moisture content; N, nutrient level; OD, odor; OG, organisms; OM, organic matter; PD, ponding; PE, plant emergence; PG, plant growth; PO, porosity; PR, permeability; PS, plant residue; R, runoff; RG, root growth; S, structure; SC, soil color; SR, soil reaction; SS, salts; W, workability; Y, crop yield.

runoff, available water holding capacity, erosion, soil color), biological (earthworms, soil organisms, smell, residue decomposition) and chemical (organic matter, nutrients, pH, salinity, alkali) soil properties. Other indicators describe surface residue and plant and root growth. All cards reviewed have physical and biological indicators. The most frequently selected indicators describe physical soil properties, which are often easier to observe than biological and chemical properties. The large number of non-chemical properties demonstrates that farmers observe many things in addition to nutrient status from lab analyses.

The descriptive terms (Table 3) used on the card are indigenous farmer terms and concepts that provide common language for farmers and technical specialists working together on soil quality. Farmers often link related features, or soil properties, in one indictor (Table 3). A single indicator such as "Drainage, Infiltration" on the Maryland card may be based on the farmers' observations of whether or not water stays on or in the soil, how water enters and flows through the soil, and how wet or dry the soil is. For the farmer, these properties are inseparable for management and plant growth considerations, and thus, are combined in one indicator even though these properties are characterized separately in the study of soil science. The integration of numerous soil properties by farmers in their indicators and descriptive terms warrants additional study to elucidate soil property relationships from a systems perspective.

Large numbers of descriptive terms for similar soil features were listed. Although not studied, the differing term usage in various parts of the country might be attributed to differences in soil texture, soil classification, common tillage and farming practices, or the crops grown, as well as cultural language differences. On the Oregon card, 3 levels of ratings for soil structure and tilth are "cloddy, powdery, massive, or flaky," "some visible crumb structure," and " friable, crumbly." This example allows the inclusion of a variety of descriptions and economizes on words. An alternative approach uses modifiers such as "very cloddy," "slightly cloddy," and "few clods."

A score that combines the results of all the indicators into one number was proposed to farmers at various meetings. However, farmers saw limited value in a single score and preferred ratings (Table 2) for individual indicators that would enable them to evaluate specific features that needed improvement. Farmers usually prefer space for field management notes. Many cards include a description of the best time to assess each indicator, such as "before planting, active crop growth, pre-tillage, post-harvest, good soil moisture, after heavy rainfall, early spring, summer, fall, late fall, winter, and anytime." These categories can vary depending on the indicator, soil, crop and climate of the region.

Use and Reliability of the Cards

Tools required usually include a shovel and a thin metal rod or wire flag to examine and probe the soil to a depth of 15 to 20 cm. Regular annual assessments allow farmers to monitor changes in soil quality over time. The farmer may also use the card on a comparative basis to evaluate the effects of different management practices, such as conservation tillage and conventional tillage, on similar soils. Problem spots can also be analyzed with the card. The farmer may rate a particular field by assigning an adjective such as "good," "fair," or "poor," according to the perceptions of those farmers who created the card, and thus estimate the quality of his/her soil, as well as its potential for improvement. Assessments are most reliable when completed by the same person, at the same time of the year, at the same location, and under similar moisture levels. The assessments are qualitative and thus do not represent any absolute measure. Replicating the assessment provides results that are more accurate. Cards are not designed for rigorous data collection that requires total objectivity, precision and accuracy. The assessment by one farmer is not meant to be compared to those of other farmers; and ratings on two different soils should not be compared to each other. If no other criteria are available, the initial assessment for each field or location within a field becomes the baseline condition that serves as a reference point for future annual assessments and records by the individual farmer.

BENEFITS AND OUTCOMES

By making soil quality assessments and tracking changes in soil quality over time, farmers gain information about their soil and management impacts to guide future management decisions. The card can help farmers identify soil resource problems for locally led conservation planning and evaluate the results of plan actions. In addition, the card aids communication between farmers and agricultural professionals of USDA-NRCS, USDA-CES, universities and agribusiness. Conservationists and extension personnel can use the card to introduce the concept of soil quality to farmers, discuss soil condition and its connection to management practices, learn about soil quality issues important to farmers, identify research topics, and demonstrate soil features important to soil quality. Illinois used the card to increase awareness and then provided additional educational activities such as workshops on soil quality and the soil quality kit (USDA-NRCS and USDA-ARS, 1998).

Card Team partners can use the card to encourage farmers' voluntary conservation efforts, and foster a systems approach to conservation in which all stakeholders are encouraged to participate and gain ownership. The card offers USDA-NRCS employees the opportunity to approach farmers in a non-program context to discuss conservation. Agency participation and listening at farmer meetings as well as acceptance of farmer language can improve farmers' trust in government. Participation in farmer meetings provides an opportunity for farmers and all stakeholders to become more knowledgeable of soil quality and other related resource concerns. Additionally, the farmer meeting enhances collaboration and communication among stakeholders and thus supports locally led conservation. Although not yet tested, the farmer meeting protocols could be used to address other resource issues such as water quality, watershed health and rangeland health.

The measure-of-success of the effectiveness of the soil quality cards as a conservation tool should be improvements in soil conservation, and not the frequency of card use by individual farmers. Future evaluations of card use should address the following questions: 1) Has farmers' awareness of soil quality changed? 2) Do farmers have an improved understanding of management effects on soil quality? 3) Have farmers' field practices changed as a result of their assessment? and 4) Because of improved farmer and stakeholder understanding, what's next to meet their needs? The answers to these questions will reveal the impact of the soil quality card on soil conservation. Since 1999, the date of preparation of this paper, voluntary development of soil quality cards by farmers in an additional six states and by gardeners in one state are testimony to the interest in soil quality as a component of conservation.

ACKNOWLEDGMENTS

The authors thank M. L. Norfleet, M. D. Hubbs, J. Saunders, M. Sucik, M. Rosales, B. Joubert (USDA-NRCS) and J. Burket and A. Moldenke (Oregon State University) for their assistance in this project. We thank D. Morales for editorial assistance on the Soil Quality Card Design Guide. We also acknowledge participants at farmer meetings including farmers and staff of USDA-NRCS and USDA-CES from Oregon, Maryland, Montana, North Dakota and New Mexico.

REFERENCES

Bawden, R.J. 1991. Systems thinking and practice in agriculture. J. Dairy Sci. 74:2362-2373.

Checkland, P. and J. Scholes. 1990. Soft systems methodology in action. J. Wiley & Sons, West Sussex, England.

Doran, J.W. and T.B. Parkin. 1996. Quantitative indicators of soil quality: A minimum data set. p. 25-37. *In* J.W. Doran and A.J. Jones. (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. SSSA, Madison, WI.

Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.R. Harris and G.E. Schuman. 1997. Soil quality: A concept, definition, and framework for evaluation. Soil Sci. Soc. Amer. J. 61:4-10.

Kolb, D. 1984. Experiential learning: Experience as the source of learning and development. Prentice Hall Inc., New Jersey.

Larson, W.E. and F.J. Pierce. 1991. Conservation and enhancement of soil quality. p. 175-203. *In* Evaluation for sustainable land management in the developing world, Vol. 2: Technical paper. Bangkok, Thailand. International Board for Research and Management. IBSRAM Proceedings No. 12(2).

Lev, L.D., D. McGrath, H. Murray and R.D. William. 1993. Organizing and conducting farmer-scientist focus sessions. J. Nat. Res. Life Sci. Edu. 22(2):148-152.

Pretty, J., I. Guijt, I. Scoones and J. Thomson. 1995. Participatory learning and action: A trainer's guide. International Institute for Environment and Development, London.

Romig, D.E., M.J. Garlynd, R.F. Harris and K. McSweeney. 1995. How farmers assess soil health and soil quality. J. Soil Water Conserv. 50:225-232.

Romig, D.E., M.J. Garlynd and R.F. Harris. 1996. Farmer-based assessment of soil quality: A soil health scorecard. p. 39-60. *In* J.W. Doran and A.J. Jones. (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. SSSA, Madison, WI.

Sarrantonio, M., J.W. Doran, J.J. Halvorson and M.A. Liebig. 1996. On-farm assessment of soil quality and health. p. 83-105. *In* J.W. Doran and A.J. Jones. (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. SSSA, Madison, WI.

Seiter, S., C. Knott and R.D. William. 1996. Farmers design integrated crop-tree systems. p. 34-41. *In* Proc. Intl. Symp. Sustainable Farming Systems, 14^{th}, Colombo Sri Lanka. vol. 10. Colombo, Sri Lanka

United States Department of Agriculture. 1961. Land capability classification system. U.S. Dep. Agric. Handb. 210

USDA-Natural Resources Conservation Service. 1998. Conservation Programs Manual, General Manual, 440-V-CPM, PART 500. Washington, DC.

USDA-Natural Resources Conservation Service. 1999. Soil quality card design guide: A guide to develop locally adapted conservation tools. Available online at http://www.statlab.iastate.edu/survey/SQI/SQassessment.htm (verified 4 April 2001).

USDA-Natural Resources Conservation Service and USDA-Agricultural Research Service. 1998. Soil quality test kit guide. Available online at http://www.statlab.iastate.edu/survey/SQI/SQassessment.htm (verified 4 Apr. 2001).

Wilson, K. and G.B. Moren. 1990. Systems approaches for improvement in agriculture and resource management. MacMillan, New York.