Natural Resources Conservation Service

SOIL QUALITY THUNDERBOOK

Revised, March 2004

A Note About Soil Quality and the Thunderbook

What does soil quality mean to you? Soil that is highly productive and profitable now and in the future? Soil that is in harmony with its surroundings? Whether your perspective is economic, aesthetic, or a combination of these views, a key to soil quality is that soil functions within a larger system.

Soil quality, then, is the capacity of a soil to function. Healthy soils are able to:

- Sustain plant and animal diversity and productivity.
- Regulate and partition water and solute flow.
- Filter and buffer potential pollutants.
- Store and cycle nutrients.
- Support buildings and other structures and protect archaeological treasures.

Most people are aware of the importance of air quality and water quality, but only recently are they realizing the significance of soil quality in protecting air and water quality and agricultural productivity. The Natural Resources Conservation Service has 70 years of experience protecting the soil resource and maintaining its ability to function within the landscape. Because soil quality is a result of soil management, it is an integral part of our technical assistance activities. Helping farmers, ranchers, and other land managers to understand and apply soil-building technologies and practices will assure a healthy resource base well into the future.

This thunderbook can help you build a handy reference for soil quality information. Thunderbooks are a traditional agency marketing and educational tool. They have been customized and used by conservationists since the early years of the Service. The intent of thunderbooks at that time was the same as it is today–a place to store and retrieve the materials that you decide are most important and useful to you and your customers. We have supplied tabs and suggested topics for easy organization of the soil quality material you already have and that you will gather. The final section, Resources and References, will start you on your way to accessing sources of soil quality information and educational materials.

We welcome your suggestions about soil quality information, technology, and training needs. Visit the Soil Quality Web site at http://soils.usda.gov/sqi.

SOIL QUALITY THUNDERBOOK

Table of Contents

Soil Quality Institute

Soil Biology Primer

What's it for?

- To introduce readers to the diversity and functions of the organisms that form the living component of soil--the soil food web.
- To help people understand the importance of the soil food web to land management decisions.

Who's it for?

- Farmers and ranchers
- NRCS and Conservation District staff
- Ag professionals
- Educators and students

What's in it for you?

- This color publication consists of eight units that describe the soil food web, its effects on soil health, and the major groups of organisms that form the food web--bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.
- The Primer can be used to support NRCS marketing initiatives, including Earth Day and Backyard Conservation, as well as to provide information for resource considerations for Core Four practices.
- The Primer is an educational tool to stimulate discussions about soil, its biology, health, management, and conservation. The information can also be used in developing training materials on issues related to soil quality, such as pest and nutrient management.
- The Soil Biology Primer is available on the Soil Quality web site at http://soils.usda.gov/sqi, and can be purchased from the Soil and Water Conservation Society.

The NRCS Soil Quality Institute developed the Primer in partnership with the Conservation Technology Information Center, Oregon State University, and Ohio State University.

Soil quality ~ Managing soil for today and tomorrow.

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Soil Quality Institute

Soil Quality Test Kit Guide

What's it for?

- To compare soils under different land management systems.
- To track changes in soil quality over time.
- To demonstrate the effects of practices, such as conservation tillage, on soil quality.
- To create an awareness of the importance of soil quality.

Who's it for?

- NRCS and Conservation District staff
- Farmers and ranchers
- Ag professionals
- Educators

What's in it for you?

- The Guide has two user-friendly parts. The **Instructions Section** describes the relatively simple procedures for 12 diagnostic tests of the physical, chemical, and biological properties of soil. (See back of this page.) It includes worksheets for recording data and calculating results. It also lists types and sources of supplies needed to build a field test kit. The **Interpretations Section** provides information for use in evaluating, primarily for agricultural purposes, the results of each test in the kit.

- Procedures were **field tested** by NRCS state and field staffs in each region, whose comments led to further refinement of test procedures. The Guide was developed by the Soil Quality Institute in partnership with the Agricultural Research Service and the National Soil Survey Center.

- The Guide offers **educational and marketing opportunities** for field days and other special events.

- The Guide is a dynamic document. The NRCS welcomes suggestions for additional tests and interpretive information to incorporate in **future versions** of the Guide.

- Single copies of the Guide are available from the Landcare office. Order by e-mailing landcare@swcs.org or calling 1-888-LANDCARE.

- The Guide can be downloaded from the Soil Quality web site http://soils.usda.gov/sqi

(Over)

Soil Quality Test Kit Guide

Kit Tests

1. Measuring Soil Quality-discusses and gives guidelines for sampling and site characterization.
2. Soil respiration-measured using an aluminum cylinder that is 6 inches in diameter and 5 inches long. The cylinder is capped and accumulated carbon dioxide respired by soil organisms and plant roots is measured. Respiration provides a measure of biological activity, which is related to nutrient cycling and breakdown of pollutants in the soil.
3. Infiltration-measured using the same cylinder as in the soil respiration test. Infiltration is important to reducing runoff and storing water in the soil for plant growth.
4. Bulk Density-measured by inserting a 3-inch-diameter cylinder 3 inches into the soil surface and removing the intact soil. Bulk density is related to root growth, biological activity, and movement of water and air in the soil.
5. Electrical Conductivity (EC) -measured with a pocket EC meter. It provides a measure of salinity (excess salts) in the soil.
6. Soil pH-measured with a pocket pH meter. It relates to nutrient availability and plant growth.
7. Soil Nitrate-measured by dipping nitrate test strips into the solution filtered from a 1:1 ratio soil/water mixture. Soil nitrate levels are important for plant growth and water quality.
8. Aggregate stability-determined by sieving soil in water and measuring the amount of aggregates greater than 0.25 mm in diameter that remain on the sieve. Aggregation is important in decreasing erosion, increasing water and air movement, and preserving organic matter in the soil.
9. Soil slaking-determined by putting soil fragments or aggregates in water and estimating the degree of slaking. Slaking is important to reducing erosion and development of surface crusts.
10. Earthworms-determined by counting the number of earthworms found in a square-foot hole. They are important in nutrient cycling and creating large pores for water and air movement in the soil.
11. Soil Physical Observations and Estimations-shows how to observe soil structure and root patterns and to estimate topsoil depth, penetration resistance, and soil texture in the soil profile. These properties are important to the physical environment for plant growth.
12. Water Quality-estimates salinity and nitrate and nitrite levels in water.

Managing soil for today and tomorrow.

3/04

Soil Quality Institute

Soil Quality Card Design Guide
…a locally led conservation tool.

What's it for?

- To provide **a step-by-step process** for leading farmers in identifying soil quality indicators and in developing a do-it-yourself soil quality rating system--a Soil Quality or Soil Health Card.
- To develop Soil Quality Cards **for farmers by farmers** that are adapted to local conditions and needs.

Who's it for?

- Farmers
- NRCS, Conservation Districts, and RC&D Councils
- Extension specialists
- State conservation agencies

What's in it for you?

- **Part 1: Overview of the Guide** summarizes the concepts and benefits of Soil Quality Cards and farmer meetings. **Part 2: Getting Organized** discusses preparations for conducting the farmer meeting. **Part 3: Putting the Card Together** focuses on the nuts and bolts of the farmer meeting and of field-testing and production of the card. **Part 4: Taking Next Steps** discusses marketing and distribution strategies and integrating the card into established NRCS activities. **Part 5: Tool Box** offers templates, tips, and references for a successful project.
- In the spirit of outreach and locally led conservation, farmer meetings offer opportunities for dialogue and idea sharing, strengthening partnerships and trust, and blending the scientific knowledge of conservationists with the common-sense experience of producers.
- Soil Quality Cards are tools to help farmers inventory and assess resources, evaluate planning alternatives, and monitor practice effectiveness over time. They are also educational tools to initiate discussions about soil quality and soil management.
- The process was field tested through cooperative efforts of the NRCS Soil Quality Institute; University of Maryland; Oregon State University; Cooperative Extension Service; and NRCS staffs and farmers in OR, MD, MT, ND, and NM.
- The Guide and examples of Soil Health Cards can be downloaded from the NRCS Soil Quality web site at http://soils.usda.gov/sqi. The Guide can be ordered from the NRCS Landcare office by e-mailing landcare@swcs.org or calling 1-888-LANDCARE.

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This is an example of a Soil Quality Card designed by farmers in the Willamette Valley of Oregon.

Willamette Valley

Soil Quality Card

Date: ______________ Crop: ______________

Field location: ______________ Year of planting: ______________

Soil moisture: ❑ Good for planting ❑ Too dry for planting ❑ Too wet for planting

Indicator	1	2	3	4	5	6	7	8	9	10 (→ Preferred)	Observations	Rating the indicator: 1	5	10
1. Does the soil have good structure and tilth?												Cloddy, powdery, massive, or flaky	Some visible crumb structure	Friable, crumbly
2. Is the soil free of compacted layers?												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
3. Is the soil worked easily?												Many passes and horsepower needed	Medium amount of power and passes needed	Tills easily; requires little power to pull tillage implements
4. Is the soil full of living organisms?												Little or no observable soil life	Some (moving) soil critters	Soil is full of a variety of soil organisms
5. Are earthworms abundant in the soil?												No earthworms	Few earthworms, earthworm holes, or casts	Many earthworms, earthworm holes, and casts
6. Is plant residue present and decomposing?												No residue or not decomposing for long periods	Some plant residue slowly decomposing	Residue in all stages of decomposition; earthy, sweet smell
7. Do crops/weeds appear healthy and vigorous?												Stunted growth, discoloring, uneven stand	Some uneven, stunted growth; slight discoloration	Healthy, vigorously and uniformly growing plants
8. Do plant roots grow well?												Poor root growth and structure; brown or mushy roots	Some fine roots; mostly healthy	Vigorous, healthy root system with desirable root color
9. Does water infiltrate quickly?												Water on surface for long periods after light rain	Water drains slowly; some ponding	No ponding after heavy rain or irrigation
10. Is water available for plant growth?												Droughty soil, requires frequent irrigation	Moderate degree of water availability	The right amount of water available at the right time
Other														

GLOSSARIES

GLOSSARY OF SOIL QUALITY TERMS

Including soil properties, soil quality indicators, and assessment terminology.

See also: the *Glossary of Soil Science Terms*. 1997. Published by the Soil Science Society of America, Madison WI. Order by calling the SSSA at 608-273-8080. Available online at: http://www.soils.org/

aggregate stability:
The ability of soil aggregates to resist degradation. An aggregate is many soil particles held together in a small mass. In a "well-aggregated soil" the aggregates and pores between them hold up well to forces such as rain, wind, and compaction. (Compare to ***slake test***.)

amoozemeter:
A tool that uses a constant head of water to measure the rate of water movement in a saturated soil, and thus estimates saturated hydraulic conductivity.

anthropogenic:
Generated by humans. Used to indicate soil conditions, ***disturbances,*** or stresses that are created by people.

assessing soil quality:
Estimating the ***functional capacity*** of soil by comparing a soil to a standard such as an ecological site description, a similar soil under native vegetation, a reference soil condition, or quality criteria. The objective of the assessment dictates the standard to be used. (Compare to ***monitoring***.)

attributes of soil change:
Quantifiable properties used to describe the nature of soil change, including drivers, types, rates, reversibility, and pathways of change.

baseline:
The initial soil condition before monitoring soil quality over time. Subsequent measurements on the same soil are compared to the baseline measurement.

benchmark soil:
A benchmark soil is one of large extent, holds a key position in the soil classification system, or is of special significance to farming, engineering, forestry, livestock production, or other uses. The purpose of benchmark soils is to focus data collection and research efforts on soils that have the greatest potential for expansion of data and interpretations.

bulk density (D_b or BD) :
The density of soil, i.e., the weight of soil divided by its volume. The BD of agricultural soils normally ranges from 1.0 to 1.6 g/cm3.

cation exchange capacity (CEC) :
The capacity of soil to hold nutrients for plant use. Specifically, CEC is the amount of negative charges available on clay and humus to hold positively charged ions. Effective cation exchange capacity (ECEC) is reported for acid soils (pH<5). Expressed as centimoles of charge per kilogram of soil ($cmol_c$/kg).

cotton strip assay:
Measures the amount of biological activity as determined by the degree of degradation of a standardized strip of cotton buried in the soil.

disturbance:
An event or its change in intensity or frequency which alters the structure or ***functional status*** of an ecosystem. Examples of disturbances that can affect soil include drought, fire, harvest, tillage, compaction, overgrazing, or addition of pesticides.

dynamic soil properties:
Soil properties that change over the ***human time scale*** in response to ***anthropogenic*** (management, land use) and non-anthropogenic (natural disturbances and cycles) factors.

Many are important for characterizing ***soil functions*** and ecological processes and for predicting soil behavior on human time scales. (Compare to ***use-dependent soil properties***.)

electrical conductivity (EC) :
How well the soil conducts an electrical charge. EC is a measure of salinity, generally expressed as decisiemens per meter at 25ºC (dS/m).

fatty acid analysis:
Examination of the fatty acid methyl esters (FAMEs) in the soil using gas chromatography. Fatty acids are within the cell walls of soil organisms, so the types of fatty acids found in soil are an indicator of the structure and diversity of the soil community.

function:
A service, role, or task that meets objectives for sustaining life and fulfilling humanity's needs and is performed by soil or an ecosystem. (Compare to ***soil function***.)

functional capacity:
The quantified or estimated measure of physical and biophysical mechanisms or processes selected to represent the soil's ability to carry out the ***function***.

human time scale:
That portion of the pedogenic time scale that covers periods of centuries, decades, or less.

hydraulic conductivity (Ksat):
A quantitative measure of how easily water flows through soil. (Compare to ***infiltration*** and ***permeability***.).

indicator of soil quality:
A quantitative or qualitative measure used to estimate ***soil functional capacity***. Indicators should be adequately sensitive to change, accurately reflect the processes or biophysical mechanisms relevant to the function of interest,, and be cost effective and relatively easy and practical to measure. Soil quality indicators are often categorized into biological, chemical, and physical indicators.

> **biological soil quality indicators:**
> Measures of living organisms or their activity used as indicators of soil quality. Measuring soil organisms can be done in three general ways: 1) counting soil organisms or measuring ***microbial biomass***, 2) measuring their activity (e.g. ***soil basal respiration***, cotton strip assay, or ***potentially mineralizable nitrogen***), or 3) measuring diversity, such as diversity of functions (e.g., biolog plates) or diversity of chemical structure (e.g. cell components, ***fatty acids***, or DNA). Each approach provides different information.
>
> **chemical soil quality indicators:**
> These include tests of ***organic matter***, pH, ***electrical conductivity***, heavy metals, ***cation exchange capacity***, and others.
>
> **physical soil quality indicators:**
> Physical characteristics that vary with management include ***bulk density, aggregate stability, infiltration, hydraulic conductivity,*** and ***penetration resistance***.

infiltration rate:
The rate at which water enters soil. (Compare to ***hydraulic conductivity.***)

inventory:
The systematic acquisition of resource information needed for planning and management.

microbial biomass:
The total amount of organisms in the soil, excluding macrofauna and plant roots. Microbial biomass is typically determined through ***substrate-induced respiration***, or fumigation-extraction methods.

minimum data set (MDS) :
The smallest set of soil properties that can be used to characterize or measure soil quality. The MDS will vary based on the intended land use, soil type, and climate. The first MDS was suggested by Larson and Pierce and included the following:

nutrient availability	total organic C
particle size, texture	labile organic C
plant-available water capacity	soil structure
soil strength	maximum rooting depth
pH	electrical conductivity

monitoring soil quality:
Tracking trends in quantitative ***indicators*** or the ***functional capacity*** of the soil in order to determine the success of management practices or the need for additional management changes. Monitoring involves the orderly collection, analysis, and interpretation of data from the same locations over time. (compare to ***assessing***.)

organic matter:
Any material that is part of or originated from living organisms. Includes soil organic matter, plant residue, mulch, compost, and other materials.

soil organic matter (SOM) :
The total organic matter in the soil. It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues (the active fraction), and the well-decomposed and highly stable organic material. Surface litter is generally not included as part of soil organic matter.

active fraction:
The highly dynamic or labile portion of soil organic matter that is readily available to soil organisms. May also include the living biomass. **Particulate organic matter** (POM) and **light fraction** (LF) are measurable indicators of the active fraction. POM particles are larger than other SOM and can be separated from soil by sieving. LF particles are lighter than other SOM and can be separated from soil by centrifugation.

stabilized organic matter:
The pool of soil organic matter that is resistant to biological degradation because it is either physically or chemically inaccessible to microbial activity. These compounds are created through a combination of biological activity and chemical reactions in the soil. **Humus** is usually a synonym for stabilized organic matter, but is sometimes used to refer to all soil organic matter.

pedotransfer function (PTF) :
A mathematical relationship between two or more soil properties that shows a reasonably high level of statistical confidence. PTF's are used to predict difficult-to-measure soil properties from readily obtained properties of the same soil.

penetration resistance or penetrability:
The ease with which a probe can be pushed into the soil.

permeability:
The qualitative estimate of the ease with which fluids, gases, or plant roots pass through soil.

pitfall trap:
A small container (trap) buried so the rim is at the level of the soil surface. It is used to catch soil arthropods that move across the ground surface.

porosity:
The volume of pores in a soil sample divided by the bulk volume of the sample. Air-filled porosity is the fraction of the bulk volume of soil that is filled with air at any given time or under a given condition, such as a specified soil-water content.

potentially mineralizable nitrogen (PMN) :
A test measuring the amount of soil organic nitrogen converted to plant available forms under specific conditions of temperature, moisture, aeration, and time. It is a measure of biological activity and indicates the amount of N that is relatively rapidly available.

primary ecological processes:
Ecological processes including the water cycle (the capture, storage and redistribution of precipitation), energy flow (conversion of sunlight to plant and animal matter), and the nutrient cycle (the cycle of nutrients such as nitrogen and phosphorus through the physical and biotic components of the environment).

processes:
Physical, chemical and biological mechanisms that follow fundamental scientific laws. Examples include pedogenic processes, geomorphic processes, and ecological processes.

reference soil condition:
The condition of the soil to which ***functional capacity*** is compared. . Soil quality is usually assessed by comparing a soil to a reference condition. The reference condition may be data from a comparable ***benchmark soil***, baseline measurements taken previously on the same soil, or measurements from a similar soil under undisturbed vegetation, or under similar management.

scoring function:
A standardization procedure used to convert measured values or subjective ratings to unitless values usually between 0 and 1. This allows all soil property measurements to be integrated into one value or index for soil quality. The four general types of scoring functions used in soil quality assessments are:

- more is better (higher measurements mean higher soil quality, e.g. SOM)
- less is better (lower measurements mean higher soil quality, e.g. salinity)
- optimum range (a moderate range of values is desirable, e.g. pH)
- undesirable range (a specific range of values is undesirable)

slake test:
A measure of disintegration of soil aggregates when exposed to rapid wetting.

soil change:
Temporal variation in soil at various time scales at a specific location.

soil function:
Any service, role, or task that soil performs, especially: 1) sustaining biological activity, diversity, and productivity; 2) regulating and partitioning water and solute flow; 3) filtering, buffering, degrading, and detoxifying potential pollutants; 4) storing and cycling nutrients; and 5) providing support for buildings and other structures and to protect archaeological treasures. (Compare to ***function***, ***functional capacity***.)

soil quality or **soil health:**
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. In short, the capacity of the soil to function. There are two aspects of the definition: inherent soil quality and dynamic soil quality. (Compare to ***functional capacity***.)

> **dynamic soil quality:**
> That aspect of soil quality relating to soil properties that change as a result of soil use and management or over the ***human time scale***.

inherent soil quality:
That aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation, in the absence of human impacts.

soil resilience:
The capacity of a soil to recover its ***functional capacity*** after a ***disturbance***.

soil resistance:
The capacity of the soil to maintain its ***functional capacity*** through a ***disturbance***.

soil respiration:
The amount of carbon dioxide given off by living organisms and roots in the soil.

basal respiration:
The level of carbon dioxide given off by a soil sample. Basal respiration is a measure of the total biological activity of microorganisms, macroorganisms, and roots.

substrate-induced respiration:
A measure of the carbon dioxide given off by a soil sample after adding sugar or other food. It is used to estimate microbial biomass in the sample.

soil structure:
The arrangement of soil particles into aggregates which form structural units. Size, shape, and distinctness are used to describe soil structure. Farmers often describe soil structure with words such as crumbly or cloddy.

tilth:
The overall physical character of soil with regard to its suitability for crop production.

use-dependant or management-dependent properties:
Soil properties that show change and respond to use and management of the soil, such as soil organic matter levels and ***aggregate stability***. This is a narrower term than ***dynamic soil properties*** which encompasses all changes on the ***human time scale*** including those induced by natural disturbances or cycles.

use-invariant properties:
Soil properties that show little change over time and are not affected by use and management of the soil, such as mineralogy and particle size distribution.

water holding capacity:
The amount of water that can be held in soil against the pull of gravity.

available water capacity (AWC) :
Loosely, the amount of water available for plants to use. Specifically, the volume of water released from soil between the time the soil is at field capacity (the maximum water held in soil against the pull of gravity) until the time it is at the wilting point (the amount of water held too tightly in soil for commonly grown crops to extract). Loamy soils and soils high in organic matter have the highest AWC.

GLOSSARY OF SOIL ECOLOGY TERMS

Including soil organisms, biological processes, and ecology terminology

See also: *Soil Microbiology Terms*, compiled by David Sylvia. http://dmsylvia.ifas.ufl.edu/glossary.htm

actinomycetes:
A large group of bacteria that grow in long filaments that are too small to see without magnification. Actinomycetes generate the smell of "healthy soil," and are important in decomposing cellulose, chitin, and other hard-to-decompose compounds, especially at higher pH levels. Many produce antibiotics.

aerobic:
With oxygen. Aerobic organisms, including animals and most soil organisms, require environments with oxygen. See ***anaerobic***.

algae:
Non-vascular photosynthetic plant-like organisms, some of which live in or on the soil. They are informally divided into groups by their dominant pigments (i.e., green, blue-green, etc.)

anaerobic:
Without oxygen. Anaerobic organisms, including some soil bacteria, need oxygen-free environments such as saturated soils. Facultative anaerobes can function as either aerobes or anaerobes depending on environmental conditions. See ***aerobic***.

AM (arbuscular mycorrhizae):
The group of endomycorrhizal fungi important in non-woody plants, including many agricultural crops. Sometimes called vesicular-arbuscular mycorrhizae (VAM).

arthropods:
Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, springtails, arachnids (spiders), and others.

bacteria:
Microscopic, single-celled organisms. They include the photosynthetic cyanobacteria (formerly called blue-green algae), and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).

bacterial-dominated food web:
A soil food web in which the ratio of fungal biomass to bacterial biomass is less than one.

biological soil crust:
Also called microbiotic, microphytic, cryptobiotic or cryptogamic crusts. A living community of bacteria, microfungi, cyanobacteria, green algae, mosses, liverworts, and lichens that grow on or just below the soil surface. Biological crusts can heavily influence the morphology of the soil surface, stabilize soil, fix carbon and nitrogen, and can either increase or decrease infiltration. The percent cover and the components of the crust can vary across short distances. Identification of biological crust organisms is simplified through the use of three broad morphological groups: The cyanobacteria group includes ***cyanobacteria*** and green algae. The moss group includes short and tall ***mosses***, but not club moss mats, such as those in northern latitudes, or spike moss. The lichen group includes crustose, gelatinous, squamulose, foliose, and fruiticose ***lichen***, as well as liverworts.

comminuters:
Organisms that shred organic material into smaller pieces.

compost tea:
An infusion made by leaching water through compost, sometimes with nutrients added, such as molasses and kelp, to encourage certain organisms. Soluble organic matter and the organisms in the compost are rinsed out of the solid phase and left suspended in the water. This "liquid compost" is easier to apply than solid compost.

cyanobacteria:
Filamentous or single-celled bacteria that fix carbon and nitrogen (formerly called blue-green algae). Only the filamentous species can be seen without a microscope. Cyanobacterial crusts with low biomass are generally the color of the soil and those with high biomass and diversity are dark (brown to black),

decomposition:
The biochemical breakdown of organic matter into organic compounds and nutrients, and ultimately into its original components.

denitrification:
A process performed by a few species of anaerobic soil bacteria in which nitrite or nitrate is converted to nitrogen gas (N_2) or nitrous oxide (N_2O). Both N_2 and N_2O are volatile and lost to the atmosphere.

detritivores:
Organisms that eat detritus, that is, dead plants and animals.

diversity:
Biological diversity can refer to the number of species in an area, the number of types of species (e.g. microbial functional groups, or plant structural types), the degree of genetic variability within a species, or the distribution of species within an area.

ectomycorrhizal fungi:
A type of mycorrhizal fungi that grows between root cells and forms a sheath around roots, but does not actually invade cells. They are important to many woody plants.

emergent properties:
Properties of a whole system that are not apparent from examining properties of the components of the system.

endomycorrhizal fungi:
A type of mycorrhizal fungi that invades the cells of plant roots.

exudates:
Soluble sugars, amino acids and other compounds secreted by roots.

food web, soil:
The interconnected community of organisms living all or part of their lives in the soil.

functional redundancy
The presence of several species that serve similar functions (e.g. nitrification).

fungal-dominated food web:
A soil food web in which the ratio of fungal biomass to bacterial biomass is greater than one.

fungi:
Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi such as yeast are single-celled.

fungivores :
Organisms that eat fungi.

generalist:
A species that will eat or prey on a wide variety of food resources. (See ***specialist***)

grazers:
Organisms such as protozoa and nematodes that eat bacteria and fungi.

habitat:
The environment where an animal, plant, or microbe lives and grows.

hyphae:
Long chains of cells formed by fungi usually occurring between aggregates rather than within micropores. (Compare to ***mycelium***.)

immobilization:
The conversion by soil organisms of inorganic nutrients such as ammonium or nitrate into organic compounds that are part of their cells. This makes the nutrients temporarily immobile in the soil and unavailable to plants. (See mineralization.)

keystone species:
A species which, if removed from an ecosystem, causes a dramatic change in the system, and which has been proposed as an indicator of the functional capacity of the system.

lichen:
A composite of fungi and algae or cyanobacteria. The fungi capture and cultivate photosynthetic organisms which together provide themselves needed water and nutrients. Lichen species occur in many colors including black, brown, dark olive green, red, yellow and white.

lignin:
A hard-to-degrade compound that is part of the structure of older or woody plants. The carbon rings in lignin can be degraded by a few fungi.

liverworts:
Small non-vascular plants.

metabolic quotient (qCO_2):
The ratio of microbial activity to microbial biomass.

microbe or **microorganism:**
An imprecise term referring to any organism too small to see with the naked eye. Generally, "microbes" refers to bacteria, fungi, and sometimes protozoa.

mineralization:
The conversion of organic compounds into inorganic, plant-available compounds such as ammonium. This is accomplished by soil organisms as they consume organic matter and excrete wastes. (See ***immobilization***.)

moss:
Photosynthetic plants with small leaves that unfurl when moistened (thus the moss appears to swell). When dry, mosses are dark and dull-colored; when moistened, the color changes markedly to a bright, light green to brown. This makes them easy to distinguish from lichens.

mutualists:
Two species that have evolved together into a mutually beneficial relationship. For example, mycorrhizal fungi get carbon compounds from plant roots and help deliver water and nutrients to the root.

mycelium:
A bundle of fungal ***hyphae*** that form the vegetative body of many fungal organisms.

mycorrhizal associations:
A symbiotic association of certain fungi with roots. The fungi receive energy and nutrients from the plant. The plant receives improved access to water and some nutrients. Except for brassicas (mustard, broccoli, canola) and chenopods (beets, lamb's-quarters, chard, spinach), most plants form mycorrhizal associations.

nematodes:
Tiny, usually microscopic, unsegmented worms. Some are parasites of animals or plants. Most live free in the soil.

nitrification:
A process accomplished by a few groups of aerobic organisms in which ammonia is converted to nitrite and then nitrate.

population:
All the individuals of a species in a given area.

protozoa:
Single-celled organisms with animal-like cells, including amoeba, ciliates, and flaggelates.

rhizine:
Root-like structure of lichen and other organisms.

rhizoid:
Root-like structure of mosses and ferns used to attach to a substrate.

rhizosphere:
The narrow region around roots where most soil biological activity occurs. Soil organisms take advantage of the sloughed and dead root cells and the root exudates found in this region.

saprophytic fungi:
Fungi that decompose dead organic matter.

sheath:
Tubular structure formed around a chain of cells or around a bundle of filaments. The fine, polysaccharide sheaths formed by some filamentous cyanobacteria help bind soil particles together and can be seen dangling from soil surface fragments. Ectomycorrhizal fungi form a sheath of hyphae around plant roots.

soil ecology:
The study of interrelations among soil organisms and between organisms and the soil environment.

specialist:
A species that consumes only one or a few types of food sources or forms associations with a narrow range of hosts. For example, certain collembola (tiny insects called springtails) specialize in eating specific species of fungi. (See ***generalist***)

trophic levels:
Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking of the food web. In fact, some organisms eat members of several trophic levels.

Soil Quality Web Sites

<u>NRCS Soil Quality</u>
http://soils.usda.gov/sqi
Includes publications and further links.

<u>Conservation Technology Information Center</u>
http://www.ctic.purdue.edu, 317-494-9555
Information and data about conservation tillage and residue management.

<u>University of California-Davis Sustainable Agriculture Research and Education Program</u>
http://www.sarep.ucdavis.edu/soil/websites.htm
A list of internet links to soil quality and soil management information.

The following resource collections can be ordered from: SAREP, University of California, One Shields Ave., Davis,CA 95616. Tel. 530-752-7556.

Cover Crops: Resources for Education and Extension. 1997. David Chaney and Ann D. Mayse (Editors). UC Division of Agriculture and Natural Resources, Sustainable Agriculture Research and Education Program, Davis, CA.

Soil Quality: Resources for Education and Extension. 1999. David Chaney and Ann D. Mayse (Editors). UC Division of Agriculture and Natural Resources, Sustainable Agriculture Research and Education Program, Davis, CA. Available February 1999.

<u>National Association of Conservation Districts</u>
http://www.nacdnet.org/

<u>Soil and Water Conservation Society</u>
http://www.swcs.org/

<u>Sustainable Agriculture Network</u>
http://www.sare.org/san/

Includes publications, and information about demonstration and education grants available from the Sustainable Agriculture Research and Education (SARE) Program.

Soil Quality Institute

Products and Projects

April 2004

NRCS Soil Quality web site: http://soils.usda.gov/sqi

About the NRCS Soil Quality Institute

Mission

Cooperate with partners in the development, acquisition, and dissemination of soil quality information and technology to help people conserve and sustain our natural resources and the environment.

Functions

- Leadership in soil quality.
- Technology development for soil assessment and management.
- Technology transfer and training.
- Building partnerships.
- Customer service delivery.
- Marketing for stewardship.

Strategies

- Integrate soil quality considerations with NRCS programs and technical guidance materials.
- Cooperate with training organizations to increase our training capacity.
- Provide information to multipliers to expand the transfer of technology and information.
- Promote a national consciousness of the importance of managing resources for long-term health and productivity.
- Cultivate new and existing partnerships for effective and efficient relations.

Focus on the Future

Trends of intensified crop production to meet world food demands, pressure on nonrenewable resources, and global climate changes provide a long-term focus on managing for soil quality. In the short-term, soil quality considerations are essential for on-farm decisions about practices such as conservation tillage and pest and nutrient management. They are also important to other issues, including water and air quality, rangeland health, carbon sequestration, and agency performance. SQI projects, products, and services are designed to address such issues and to assist customers in making informed decisions.

Current Staff

- William Puckett, Director
- Arlene Tugel, Soil Scientist
- Lee Norfleet, Soil Scientist
- Mike Hubbs, Agronomist
- Ann Lewandowski, Geographer
- Susan Andrews, Ecologist

Former staff

- Maurice Mausbach (director)
- Cathy Seybold
- Debra Dirlam
- Craig Ditzler (director)
- John Brejda (temporary)
- Betty Joubert (temporary)
- Tom Reedy (temporary)
- Susan Sampson-Liebig (temporary)

For more information about the Soil Quality Institute's strategies and visions, see the "Business Plan" and the "Workforce Planning Report."

Publications

General Soil Quality

Soil Quality Information Sheets

One-page introductions to soil quality topics for NRCS staff, partners, and customers. From the National Soil Survey Center, SQI, and the ARS National Soil Tilth Laboratory. Titles include the following. (1996-2001)

Original Cropland Series:

- Soil Quality – Introduction
- Indicators for Soil Quality Evaluation:
    - Organic Matter
    - Soil Crusts
    - pH
    - Infiltration
    - Aggregate Stability
- Soil Quality Resource Concerns:
    - Soil Erosion
    - Compaction
    - Salinization
    - Pesticides
    - Soil Biodiversity
    - Hydrophobicity
    - Sediment Deposition on Cropland
    - Available Water Capacity

Rangeland Soil Quality Series:

- Introduction
- Indicators for Assessment and Monitoring
- Compaction
- Infiltration
- Organic Matter
- Soil Biota
- Water Erosion
- Wind Erosion
- Aggregate Stability
- Physical and Biological Soil Crusts

Pastureland Soil Quality Series:

- Introduction
- Indicators for Assessment and Monitoring

> ➢ *Available on web site. Order copies from the Landcare office: landcare@swcs.org or 1-888-LANDCARE.*

Rangeland Soil Quality Information Sheets Poster

Use to describe and promote the Rangeland Soil Quality Information Sheets. (2001)

> ➢ *Available on web site.*

Soil Quality Institute Business Plan

Defines the working strategy of the Institute by explaining the background and desired outcomes for six major initiatives: Technology transfer and training, Customer deliver, Technology development for soil assessment, Technology development for soil management, Building partnerships, and Marketing for stewardship.

> ➢ *Available on web site.*

Soil Quality Institute Pamphlet

Defines soil quality, describes the work of the Soil Quality Institute, and lists contact information. (Aug02)

> ➢ *Available on web site. Order from the Landcare office at landcare@swcs.org or 1-888-LANDCARE.*

Soil Quality Institute Workforce Planning Report

Presents medium and long-term visions for soil quality work within the NRCS.

"The Soil Quality Concept" Booklet

Contains reprints of eight key journal articles describing the concepts of soil quality. (Oct96)

> ➢ *Order hard copies from margaret.hitz@nssc.nrcs.usda.gov. Web site lists citations to the eight articles.*

Glossary of Soil Quality Terms

- *Available on web site.*

Soil Quality Thunderbook

Use this packet to help organize soil quality information. Includes a cover and spine to slip into the cover of a three-ring binder, labeled divider tabs, a soil quality glossary, a bibliography, and suggestions for sources of soil quality information. (updated Mar04)

- *Available on web site.*

Soil Quality Assessment

Guidelines for Soil Quality Assessment in Conservation Planning

Provides guidelines primarily for assessing soil quality in the context of the 9-step conservation planning process, but it is also useful in informal soil quality assessments, or as an educational resource. Illustrates the practical use of tools and information developed by SQI, and links soil quality assessment to specific practices that help solve soil quality problems. (Jan01)

- *Available on web site.*

Soil Quality Test Kit Guide

Adapted from the ARS Soil Health Kit and designed for use by NRCS field staff, SWCDs, and ag consultants. Measurements included are pH, electrical conductivity, soil nitrate-N, bulk density, respiration, infiltration, aggregate stability, soil slaking, earthworms, water quality, and soil physical observations and estimations. The Guide includes instructions for building a kit, conducting the tests, and evaluating test results. **Spanish version** is also available. The **Test Kit Worksheet** is an Excel file set up to do all necessary calculations. (Aug98)

- *Available on web site. Order copies from the Landcare office: landcare@swcs.org or 1-888-LANDCARE.*

Soil Quality Card Design Guide

The Guide gives instructions for conducting farmer focus sessions to develop local Soil Quality/Health Cards. A Card is a qualitative field assessment tool developed by farmers for farmers to monitor soil quality from year to year or to compare practices. Conservationists can use it in locally led conservation, education, and information activities. The SQI developed the procedures and the Guide in collaboration with Oregon State University, OSU Cooperative Extension Service, Univ. of Maryland, and NRCS staff in OR, MD, MT, ND, and NM. (May99)

- *Available on web site. Order copies from the Landcare office: landcare@swcs.org or 1-888-LANDCARE.*

Soil Quality Card Examples

Developed by farmers and conservationists around the country.

- *Available on web site.*

State and Transition Models and Dynamic Soil Properties Databases.

Text from the proceedings of the National Cooperative Soil Survey Conference in Ft. Collins in June 2001. The paper describes how state and transition models have been applied in rangelands of the western United States and how the model can provide a framework for an information system that includes dynamic soil properties.

- *Available on web site.*

Soil Management

Managing Soil Organic Matter: The Key to Air and Water Quality.

A 4-page technical note suitable for broad distribution. (Aug03)

- *Available on web site. Order hard copies from the Landcare office at landcare@swcs.org or 1-888-LANDCARE.*

Soil Conditioning Index User's Guide

An explanation of how to use and interpret an Excel-based model to predict the effect of a crop management system on soil organic matter trends. The Soil Conditioning Index is now incorporated into RUSLE2. (Oct02)

- *Excel file and Users' Guide available on web site.*

Crop Residue Removal for Biofuel Production

A literature review examining the effect of crop residue removal on water quality and soil quality. (Mar03)

- *Available on web site.*

Soil Quality-Agronomy Technical Notes

This series describes the effects of conservation practices on soil quality. Intended for NRCS field staff use.

Current titles:

1. Cover and Green Manure Crop Benefits to Soil Quality (Apr96)
2. Conservation Crop Rotation Effects on Soil Quality (Aug96)
3. Effects of Residue Management, No-till on Soil Quality (Oct96)
4. Effect of Soil Quality on Nutrient Efficiency (Aug97)
5. Herbicides (2001)
6. Legumes and Soil Quality (Mar98)
7. Effects of Erosion on Soil Productivity and Soil Quality (Aug98)
8. Liming to Improve Soil Quality in Acid Soils (May99)
9. Managing Conservation Tillage (May99)
10. Sunn Hemp: A Cover Crop for Southern and Tropical Farming Systems (May99)
11. Agricultural Management Effects on Earthworm Populations (Jun01)
12. Long-Term Ag. Management Effects on Soil Carbon (Aug01)
13. The Knife Roller (Crimper): An Alternative Kill Method for Cover Crops (Sep02)
14. Improving Soil Quality on the Southern Coastal Plain: One Farmer's Experience (Oct02)
15. Soil Quality and Vegetable Production: One Farmer's Experience (Oct02)
16. Interpreting the Soil Conditioning Index: A Tool for Measuring Soil Organic Matter Trends (Apr03)
17. Soil Compaction: Detection, Prevention and Alleviation (Aug 2003)

- *Available on web site.*

Soil Quality-Urban Technical Notes

1. Erosion and Sedimentation on Construction Sites (Mar00)
2. Urban Soil Compaction (Mar00)
3. Heavy Metal Soil Contamination (Sep00)

- *Available on web site.*

"Phosphorus in Agriculture" Pamphlet

Describes the importance of phosphorus in plant growth and the environmental impacts and management of agricultural phosphorus (Jan98).

- *Available on web site.*

The Minnesota Soil Management Series

Developed in cooperation with the Minnesota Institute for Sustainable Agriculture and University of Minnesota Extension. (2000)

- *View on-line or order from the University of Minnesota at www.extension.umn.edu/distribution/cropsystems/DC7398.html*

"Soil Quality Considerations in the Conversion of CRP Land to Crop Production" Presentation

A presentation made at the CRP-96 Conference, "Preparing for Future CRP Land Use in the Central and Southern Great Plains", Amarillo, TX (Oct96).

- *Available on web site.*

Soil Biology

"Soil Biology Primer" Publication

An introduction to the living soil system for NRCS field staff, partners, and customers. This full color booklet describes the importance of soil organisms and the soil food web to soil productivity and water and air quality. It addresses how soil organisms are affected by management practices. The Primer is a collaborative effort of the SQI, the Conservation Technology Information Center, Oregon State University, the Ohio State University, and other scientists. (Aug99)

- *Text available on web site. Purchase from the Soil and Water Conservation Society at www.swcs.org, or 1-800-THE-SOIL.*

Soil Biology Primer slide set

A PowerPoint file including many of the pictures from the Soil Biology Primer.

- *Available on web site.*

Soil Biology Classroom Activities

A set of three soil biology activities for use in K-12 classrooms. (Feb01)

- *Available on web site.*

"Introduction to Microbiotic Crusts"

Discusses microbiotic crusts, including what they are, where they occur, what their role is, and how they are affected by disturbance. This 13-page, color pamphlet was developed by the SQI in cooperation with the Grazing Lands Technology Institute. (Jul97)

- *Available on web site. Order copies from the Landcare office at landcare@swcs.org or 1-888-LANDCARE.*

Soil Biology Information Resources

For land managers, resource professionals, and educators. A list of web sites, Extension publications, booklets, articles, videos, classroom materials, and other soil biology resources. Some college-level materials are included, but the emphasis is on non-technical resources. (Nov02)

- *Available on web site.*

2001 NRCS Soil Planner: Soil Biology

Each month of the 2001 NRCS Soil Planner featured a different group of soil organisms or an important soil biological process.

- *Out of print.*

Soil Biology and Land Management

This 20-page technical document describes how land management decisions affect the belowground component of the food web. It explains four general land management practices that promote healthy soil biological function, and discusses management issues specific to particular land uses. This information is not a set of prescriptive guidelines, but is designed to increase awareness and prompt field trials. The primary audience is NRCS field staff and partners; but it is also suitable for a broad audience including land managers. It was developed by the NRCS Soil Quality Institute along with the National Soil Survey Center. (Jan04)

- *Available on web site.*

Outreach and Education

Soil Quality Card Design Guide

The Soil Quality Card Design Guide gives instructions for conducting farmer focus sessions to develop local Soil Quality/Health Cards. A Card is a qualitative field assessment tool developed by farmers for farmers. It is a do-it-yourself rating guide for farmers to monitor soil quality from year to year or to compare practices. Conservationists can use it in locally led conservation, education, and information activities. The SQI developed the procedures and the Guide in collaboration with Oregon State University, OSU Cooperative Extension Service, University of Maryland, and NRCS staff in OR, MD, MT, ND, and NM.

- *Available on web site. Order copies from the Landcare office: landcare@swcs.org or 1-888-LANDCARE.*

Soil Quality Clipart

A set of free clipart images representing soil, soil functions, farmers using a soil quality/health card, and the soil quality symbol.

- *Available on web site.*

Soil Quality Exhibit Posters

64” by 43” posters for use at exhibits to promote soil quality and associated soil management practices. Available in cropland, rangeland, and pastureland versions.

- *Electronic files suitable for printing available on web site.*

SQIforum: A Soil Quality E-mail List

This e-mail listserve facilitates communication among NRCS employees and partner conservationists. Subscribers may post messages related to the research and application of soil quality technology. To subscribe to the list, send an e-mail message to: listproc@nrcs.usda.gov. In the body of the message write: subscribe SQIforum [your first and last name]

Organic Agriculture and Resource Conservation

A web page providing information about organic agriculture for field staff who work with organic producers. http://soils.usda.gov/sqi/soil_quality/land_management/organic.html

Training Courses

Farmer Workshops for Locally Developed Conservation Tools (Soil Quality Cards)

Prepares NRCS staff and partners to conduct farmer/conservationist participatory workshops and to develop local soil quality/health cards. The basic principles of farmer participatory action and learning are presented. Participants practice a step-wise approach to lead farmers in identifying soil quality indicators, developing a rating system, and designing a local soil quality/health card. Take-home strategies to market and develop local soil health cards are developed. (Available on request to the SQI.)

Soil Quality: Assessment and Applications for Field Staff

The Soil Quality Institute and National Employee Development Center (NEDC) developed a soil quality course designed to provide NRCS staff and partners with an overall understanding of soil quality. Participants will be able to recognize soil quality concerns, communicate those concerns to land managers and users, and provide alternatives to remedy those concerns in a manner that meets requirements of the agency and the land manager. The course is offered as train-the-trainer sessions. For more information, contact Mike Hubbs, 334-844-4741 Ext. 176, mike.hubbs@ftw.nrcs.usda.gov.

Other Projects

Soil Management Assessment Framework (SMAF)

The Soil Quality Institute provided partial funding for an ARS postdoctoral research associate to work on the development of a soil quality index. Peer-reviewed papers from this postdoc and prior dissertation research on the same topic include Andrews and Carroll (2001), Andrews, et al. (2002a and b), Karlen and Andrews (2000), Karlen et al. (2001), and Wander et al. (2002).

The postdoctoral research resulted in a tool for interpreting soil indicator data in terms of soil function, which was adopted by USDA-ARS as a research tool for their Soils National Program 2002. The tool is also in use by other researchers around the world with technical assistance from SQI. Notable projects are in Australia, Germany, and India. Through ARS funding, SQI is currently working with a contract computer programming firm to create a CD version of SMAF. Other available materials include PowerPoint presentations, spreadsheet versions of the tool in MS Excel, and written introductory materials for working with the tool. For more information contact Susan Andrews, SQI, (515) 294-9762; andrews@nstl.gov or Doug Karlen, ARS, (515) 294-3336; karlen@nstl.gov.

Farming Systems Comparison Procedure for Soil Quality

The Farming Systems Comparison Procedure is a decision-making tool for conservation planning that compares farming systems and ranks them for their ability to enhance or maintain soil quality and meet economic goals. This tool applies a systems approach to analyze multiple agronomic, economic, and ecological factors. A prototype in MS-Excel format was developed for Ohio.

The FSCP uses a multiple-attribute, hierarchical decision support system (DSS) that combines a) a prioritization of goals for resource and economic health; b) an impact ranking of factors that effect the condition of the soil (i.e., effect the capacity of the soil to function); and c) the numerical scores of the effect of land management practices on soil quality, the environment and economics. The DSS allows the decision maker or agricultural professional to change priority orders and re-compute the resulting rank of one farming system compared to another.

A draft technical note, executive summary, extensive literature review, and other documentation are available.

Soil Quality Reference Soils Map

The Soil Quality Institute and Auburn University collaborated to establish a set of 27 soils for use as a standard reference set for soil quality research. The soils were selected on the basis of acreage, land use, economics, and environmental importance. This limited set of soils can be used to help focus research and data collection efforts for maximum relevance and application.

Available products include a list and map of these soils, maps of the commodity crops grown, and databases of information about these soils including the NSSL characterization data, NRI data, EPIC model database, and several sets of data from state university (NCSS) labs. For some soils, data were sparse and in most cases land use and management practices are unknown; however, first approximations of the ranges and means for several properties such as organic carbon, bulk density, and texture were established. For more information, contact Lee Norfleet.

Dynamic soil properties

Soil survey enhancements are needed to meet user needs for information about how soils change in response to use, management and natural disturbances. The Soil Quality Institute is cooperating in the development of agency plans for the collection and interpretation of information on dynamic soil properties, use-dependent soil properties and soil change relationships. Field testing of new procedures for dynamic soil properties data collection was conducted in 2003 and 2004 at Big Bend National Park. This was the first data collection trial by a soil survey crew on rangelands. The draft procedures were developed by the Soil Quality Institute and the Jornada Experimental Range of the USDA-Agricultural Research Service. Feedback from this field trial will enhance the development of new technologies for use on all soil surveys.

See the following National Soil Survey Center, National Cooperative Soil Survey, and SQI white paper references: Hipple et al, 2003; Tugel 2003a and b; Tugel and Herrick, 2003; Tugel et al., 2002; Tugel and Brown, 2001.

County Economic, Agriculture, and Environmental Health Index

Patterned after an indexing method developed by Gomez et al., 1996. The objective of this study was to explore using existing national databases such as NRI and NASS statistics to evaluate counties on an MLRA basis with standards or thresholds unique to the agricultural community and natural resources in each MLRA. A pilot test of this procedure was performed. The partners in this study were the Natural Resources Inventory and Analysis Institute and the Soil Quality Institute with assistance from NRCS scientists in Temple, Texas. For additional information, contact Lee Norfleet, SQI, (334) 844-4741, ext. 176, norfleet@eng.auburn.edu; or David Buland, NRIAI, (254) 770-6522; Email buland@brcsun0.tamu.edu.

The Soil Quality Pilot NRI Study

Tested the potential for assessing soil quality regionally by sampling soils at points within the NRI framework and measuring soil properties that indicate soil quality.

Results are detailed in a series of articles by Brejda et al. (2000a, 2000b, 2000c, 2001).

Testing of a Labile Carbon Measurement Method

The method of Weil et al. (2003) for estimating labile carbon is a relatively simple and promising method that could be adopted by soil test labs for use in routine soil analyses. It has potential as an early warning indicator of long-term changes in soil carbon levels. Results are well correlated with analyses that are considered to be indicators of labile C fractions, such as microbial biomass or POM C. The method has not yet been adequately tested in arid regions. The test has been promoted as an in-field method. However, the reagents have relatively short shelf lives and require precise and accurate measurements to prepare. The primary reagent is a strong oxidizer that requires safety equipment for proper handling. Using the hand-held colorimeter requires additional dilutions of standard solutions to allow the development of a standard curve before each use, which again requires accuracy not easily obtained by untrained personnel in the field. Protocol modifications may by possible to address these issues but, as currently described, this method has several barriers to adoption for in-field use by NRCS field staff. Development and testing of this method was partially funded by the SQI.

The Soil Quality Web Site

Development of this independent web site was funded by a grant from the USDA - Sustainable Agriculture Research and Education - Professional Development Program (USDA SARE PDP), in cooperation with the University of Illinois, USDA Agricultural Research Service National Soil Tilth Laboratory, USDA Natural Resource Conservation Service Soil Quality Institute, and Iowa State University. The draft version is at: http://csltest.ait.iastate.edu/SoilQualityWebsite/home.htm. The site is a clearinghouse for information on soil quality assessment, effects of management practices, and resources for educators and researchers.

Crop Residue Removal for Bioenergy Production

Industry-driven interest in the use of corn stover and wheat straw harvest for bioenergy production led to much discussion between USDA and DOE. Several groups have produced research reviews or reports, including an SQI white paper (NRCS Soil Quality Institute, 2003). SQI involvement includes technical advising to on-going and proposed research projects, technical merit review of USDA-DOE grant proposals, and research collaboration toward development of a decision tool that addresses the soil quality effects of crop residue removal. For more information contact: Susan Andrews, (515) 294-9762; andrews@nstl.gov.

Soil Quality Test Kit Guide Revisions

Revisions are planned for the Soil Quality Test Kit Guide before it is reprinted. For more information contact: Susan Andrews, (515) 294-9762; andrews@nstl.gov.

Research Publications

Includes peer-reviewed and other technical publications written by SQI staff,
as well as results from SQI-supported projects.

Andrews, S.S. and C.R. Carroll. 2001. Designing a decision tool for sustainable agroecosystem management: Soil quality assessment of a poultry litter management case study. Ecological Applications 11 (6): 1573-1585.

Andrews, S.S., D.L. Karlen, and J.P. Mitchell. 2002a. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems and Environment 90 (1): 25-45.

Andrews, S.S., J.P. Mitchell, R. Mancinelli, D.L. Karlen, T.K. Hartz, W.R. Horwath, G.S. Pettygrove, K.M. Scow and D.S. Munk, 2002b. On-farm assessment of soil quality in California's Central Valley. Agronomy Journal 94: 12-22.

Andrews, S.S., C.B. Flora, J.P. Mitchell, and D.L. Karlen. 2003. Growers' perceptions and acceptance of soil quality indices. Geoderma 114: 187-213.

Andrews, S.S., D.L. Karlen, and C.A. Cambardella. 2004. The soil management assessment framework: A quantitative soil quality evaluation method with case studies. Soil Science Society of America Journal. In Review.

Brejda, John J. 1997. Soil changes following 18 years of protection from grazing in Arizona chaparral. The Southwestern Naturalist 42 (4): p. 478-487.

Brejda, J.J., D.L. Karlen, J.L. Smith, and D.L. Allan. 2000a. Identification of regional soil quality factors and indicators: II. Northern Mississippi loess hills and Palouse prairie. Soil Sci. Soc. Am. J. 64:2125-2135.

Brejda, J.J., T.B. Moorman, D.L. Karlen, and T.H. Dao. 2000b. Identification of regional soil quality factors and indicators: I. Central and southern high plains. Soil Sci. Soc. Am. J. 64:2115-2124.

Brejda, J.J., T.B. Moorman, J.L. Smith, D.L. Karlen, D.L. Allan, and T.H. Dao. 2000c. Distribution and variability of surface soil properties at a regional scale. Soil Sci. Soc. Am. J. 64:974-982.

Brejda, J.J., M.J. Mausbach, J.J. Goebel, D.L. Allan, T.H. Dao, D.L. Karlen, T.B. Moorman, and J.L. Smith. 2001. Estimating surface soil organic carbon content at a regional scale using the National Resource Inventory. Soil Sci. Soc. Am. J. 65:842-849.

Cambardella, C.A., T. B. Moorman, S. S. Andrews, and D.L. Karlen. 2004. Watershed-scale assessment of soil quality in the Loess Hills of Southwestern Iowa. Soil and Tillage Research (In press).

Carter, M.R., S.S. Andrews, L.E. Drinkwater. 2004. Systems Approaches for Improving Soil Quality. p. 261-281. In: Managing Soil Quality – Challenges in Modern Agriculture. P. Schjonning, T.B. Christensen, S. Emholt, eds. CAB International.

Ditzler, C.A and A.J. Tugel. 2002. Soil Quality Field Tools: Experiences of USDA-NRCS Soil Quality Institute. Agron. J. 94:33-38.

Herrick, J.E., J.R. Brown, A.J. Tugel, P.L. Shaver and K.M. Havstad. 2002. Application of Soil Quality to Monitoring and Management: Paradigms from Rangeland Ecology. *Agronomy Journal* 94:3-11.

Karlen, D.L. and S.S. Andrews. 2000. The soil quality concept: A tool for evaluating sustainability. Proceedings of Soil Stresses, Quality, and Care Conference. Nordic Association of Agricultural Research. Ås, Norway, April 10, 2000. Danish Institute of Agricultural Sciences.

Karlen, D.L., S.S. Andrews, and J.W. Doran. 2001. Soil Quality: Current concepts and applications. Advances in Agronomy Vol. 74 pp. 1-39.

Karlen, D.L., C.A. Ditzler, and S.S. Andrews. 2003. Soil quality: why and how? Geoderma 114: 145-156.

Karlen, D.L., S.S. Andrews, and B.J. Wienhold. 2004. Soil Quality, Fertility, and Health – Historical Context, Status and Perspectives. p. 17-33. In: Managing Soil Quality – Challenges in Modern Agriculture. P. Schjonning, T.B. Christensen, S. Emholt, eds. CAB International.

Karlen, D.L., S.S. Andrews, J.W. Doran, and B.J. Wienhold. 2003. Soil quality: Humankind's foundation for survival. Journal of Soil and Water Conservation 58(4):171-179.

Mausbach, M.J. and C.A. Seybold. 1998. Assessment of soil quality. P. 33-43. In: R. Lal (ed.) Soil Quality and Agricultural Sustainability. Ann Arbor Press, Chelsea, MI.

Discusses the assessment of soil quality at various scales, ranging from field to national. The article reviews the definition of soil quality with a discussion of indicators, reference values, and assessments.

Norfleet, M.L., C.A. Ditzler, W.E. Puckett, R.B. Grossman and J.N. Shaw. 2003. Soil Quality and its Relationship to Pedology. Soil Science 168 (3): 149-155.

Seybold, C.A., J.E. Herrick, and J.J. Brejda. 1999. Soil resilience: A fundamental component of soil quality. Soil Science 164:224-234.

This journal article addresses the concept of soil resilience and its relationship to soil quality. It provides a review of the literature on the assessment and quantification of resilience. The paper was prepared for the Natl. Coop. Soil Survey Conf. in Baton Rouge, LA (June 1997).

Seybold, C.A., M.J. Mausbach, D.L. Karlen, and H.H. Rogers. 1998. Quantification of soil quality. P. 387-404. In: R. Lal, J.M. Kimble, R.F. Follet, and B.A. Steward (eds.) Soil processes and the carbon cycle. Advances in Soil Science. Chapter 27. CRC Press, Boca Raton, Florida.

Discusses approaches to quantifying soil quality and recommends a framework for measuring and assessing soil quality. The chapter reviews definitions, indicators, indices of soil quality; minimum data sets; and effects of scale.

Seybold, C.A., R.P. Dick, and F.J. Pierce. 2001. USDA soil quality test kit: Approaches for comparative assessments. Soil Survey Horizons 42(2):43-52.

This journal publication uses real case studies to describe three approaches for assessing soil quality using the Soil Quality Test Kit. The background and history of the development of the test kit are also discussed.

Seybold, C.A. and J.E. Herrick. 2001. Aggregate stability kit for soil quality assessments. Catena 44(1):37-45.

A description of the aggregate stability test that is included in the soil quality test kit guide. The kit method is compared to the commonly used laboratory aggregate stability method using a range of soils varying in texture. Detailed information is provided for on constructing an aggregate stability kit which can run 8 samples at a time.

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Descriptive and Analytical Characterization of Soil Quality/Health
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Terrestrial Carbon Pools in Grasslands and Agricultural Soils: Preliminary Data from the Corn Belt
Carbon and Nitrogen Mineralization as Influenced by Long-Term Soil and Crop Residue Management Systems in Australia
Biologically Active Pools of Carbon and Nitrogen in Tallgrass Prairie Soil
A Method to Determine Long-Term Carbon and Nutrient Mineralization in Soils
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Physical Tests for Monitoring Soil Quality
Soil Water Parameters and Soil Quality
Soil Organic Carbon and Nitrogen
Measurement and Use of pH and Electrical Conductivity for Soil Quality Analysis
Assessing Soil Nitrogen, Phosphorus, and Potassium for Crop Nutrition and Environmental Risk
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Soil Microbial Biomass, Activity and Nutrient Cycling as Indicators of Soil Health
Soil Enzyme Activities as Integrative Indicators of Soil Health
Soil Microflora as Bioindicators of Soil Health
Potential Use of Plant Root Pathogens as Bioindicators of Soil Health
Soil Microfauna as Bioindicators of Soil Health
Community Structure of Soil Arthropods as a Bioindicator of Soil Health
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Observing and Evaluating Your Soil
Soil Management Practices
The Marketplace and Organic Certification

Regional and Local Resources

Some of the most valuable soil quality publications are specific to your region. On this page, record contact information for people and organizations that provide regional publications and technical help.

NRCS state soil quality technical specialists:

Regional technical team or consortia:

State conservation agencies:

USDA-ARS Research Locations (Find contact information at:http://www.ars.usda.gov/pandp/places.htm):

Cooperative Extension Specialists and Experiment Stations: (Find contact information at the Cooperative State Research, Education, and Extension Service (CSREES) http://www.reeusda.gov/) Search for Extension publications nationwide at: E-Answers: http://www.e-answers.org/ http://www.e-answersonline.org/

Other:

The Soil Quality Symbol

The symbol for soil quality embodies the circle of life (earth), the natural resources, their dependence on soil, and the human dependence on the health of it all. Two corn stalks represent agriculture and people working together to produce food and a bountiful, healthy life. The tree symbolizes all natural resources, including forests, rangelands, wildlands, and home garden. The shaded background within the circle is the soil, the warm, sustaining resource that is the foundation of all life. A circle of harmony and protection embraces these resources and the open sky (a raindrop) from which rain replenishes living things. Light from the sun's rays warms and energizes all.

To download this symbol, visit the NRCS Soil Quality web site at

http://soils.usda.gov/sqi