The Soil Management Series

Soil Management

1

The Soil Management Series:

Publications to help you get more from your soil

Whether you grow a few acres of vegetables for local markets, or two thousand acres of corn and soybeans for international markets, you depend on top performance from your soil. The Soil Management series is aimed at improving soil performance. Because each farm is unique, the series will not tell you the “best way” to manage your soil. Only you can decide that. Instead, it will help you make more effective use of recommendations from the university, consultants, and other advisors.

Agronomic recommendations are typically made for broad climatic regions or soil types, but farmers are increasingly interested in fine-tuning and customizing management practices to fit their unique situation and variability across the land. One example of this trend is precision agriculture technology. The goals of a “fine-tuning” approach to land management are to use resources more efficiently, improve profits, and preserve the profitability and health of the land into the future. To fine-tune agronomic practices, farmers need to monitor the variation across the land from year to year, treat different parts of each field differently, and perhaps run personalized experiments to learn what works best on an individual farm.

This series will help by providing the background science needed to monitor soil and to understand how you can modify general recommendations to suit the needs of your farm. Each publication consists of the following sections that feature basic information, practical applications, and places to look for more help:

THE SOIL MANAGER —explains management options for improving your soil.

THE SOIL SCIENTIST —reviews the soil science principles that are important to production agriculture.

YOUR FARM —helps you apply what you are reading to your own farm.

WHAT’S NEXT? —wraps up the chapter by helping you assess your operation and soil.

FURTHER RESOURCES —lists people and publications to consult for more information.

Titles in the Soil Management Series include:

1) Soil Management (BU-7399)
2) Compaction (BU-7400)
3) Manure Management (BU-7401)
4) Organic Matter Management (BU-7402)
5) Soil Biology and Soil Management (BU-7403)

Copies of the individual titles and the complete series (PC-7398) can be ordered from the University of Minnesota Extension Service Distribution Center, 405 Coffey Hall, 1420 Eckles Avenue, St. Paul, MN 55108-6068. To order by e-mail: order@extension.umn.edu
or by credit card: (800) 876-8636.

Soil Management

SOIL: A FARMER’S “SILENT PARTNER”

Soil is the basis of farming. It delivers water and nutrients to crops, physically supports plants, helps control pests, determines where rainfall goes after it hits the earth, and protects the quality of drinking water, air, and wildlife habitat.

The goal of soil management is to protect soil and enhance its performance, so you can farm profitably and preserve environmental quality for decades to come.

In this publication

Why learn more about soil management?

Consider the valuable services your soil provides:

Growing crops. Soil delivers nutrients and water and gives plants structural support. Could your soil cycle nutrients more efficiently so you save on input costs and your crops are healthier? Could your soil store more water so crops do better during dry spells?

Controlling water flow. Soil helps control how water moves over and through the earth’s surface. Does rainfall quickly fill waterways rather than moving slowly through your soil? Could you reduce the amount of organic matter, nutrients, and soil you are losing to erosion?

Filtering water. Healthy soil can filter and decompose organic substances such as manure, agricultural chemicals, and other compounds that can pollute air and water.

Storing carbon. Soil is a storehouse of carbon. As concern grows about increased atmospheric carbon dioxide, farmers may receive financial benefits for increasing the amount of carbon (organic matter) stored in their soil.

You determine how soil performs.

You cannot control slope, texture, climate, and other critical soil factors. But you can control tillage, crop rotations, soil amendments, and other management choices. Through these choices you change the structure, biological activity, and chemical content of soil, and you influence erosion rates, pest populations, nutrient availability, and crop production.

SIX PRACTICES THAT IMPROVE SOIL PERFORMANCE

Improving soil performance requires different actions on each farm. Most soil-friendly farm practices fall into one of six groups. Each of these practices is further explained in other publications in the series.

1. Adding organic matter

Regular additions of organic material may be the most important way to enhance soil quality. Organic matter improves soil structure, enhances water and nutrient holding capacity, protects soil from erosion and compaction, and supports a healthy community of soil organisms. Organic matter includes residue and roots from the previous crop, animal manure, cover crops, or amendments from off the farm.

2. Avoiding excessive tillage and soil compaction

Tillage is valuable for loosening surface soil, preparing the seedbed, and controlling weeds and pests. But tillage can also break up soil structure, speed the decomposition and loss of organic matter, increase the threat of erosion, destroy the habitat of helpful organisms, and cause compaction. Reducing tillage minimizes the loss of organic matter and increases the residue protecting the soil surface. Compaction reduces the amount of air, water, and space available to roots and soil organisms. Compaction is caused by traveling on wet soil or by heavy equipment.

3. Managing pests and nutrients efficiently

In this century, pesticides and chemical fertilizers have revolutionized U.S. agriculture. In addition to their desired effects, they can harm non-target organisms and pollute water and air if they are mismanaged. Nutrients from organic sources also can become pollutants when misapplied or over-applied. Efficient pest and nutrient management means applying only the necessary chemicals, at the right time and place to get the job done; testing and monitoring soil and pests; and adding non-chemical approaches to your management toolbox (such as crop rotations, cover crops, and manure management).

4. Keeping the ground covered

Bare soil is susceptible to wind and water erosion, and to drying and crusting. Groundcover protects soil, provides habitats for larger soil organisms (such as insects and earthworms), and can improve water availability. Farmers often leave crop residue on the surface to cover the ground between growing seasons.

Want to know more?

See Further Resources for contact information

About organic matter

Organic Matter Management (BU-7402 in this series)

Soil Biology (BU-7403 in this series)

About manure

Manure Management (BU-7401 in this series)

About tillage and compaction

Compaction (BU-7400 in this series)

Conservation Technology Information Center (CTIC) publishes information about conservation tillage.

About residue management

Tips for Profitable Crop Residue Management Systems, 1996, University of Minnesota Extension Service publication FS-6049.

About cover crops

Managing Cover Crops Profitably, 2nd Ed., 1998. Describes characteristics of specific cover crops, and provides the information needed to choose a cover crop for your operation.

Living cover crops create new organic matter and help feed soil organisms. Groundcover must be managed to prevent problems with delayed soil warming in spring, diseases, and excessive build-up of phosphorus at the surface.

5. Increasing diversity

Diversity is beneficial for several reasons. Each crop contributes a unique root structure and type of residue to the soil. A diversity of soil organisms helps control pest populations, and a diversity of cultural practices reduces weed and disease pressures. Diversity across the landscape can be increased by using buffer strips, small fields, or contour strip cropping. Diversity over time can be increased by adding crops to the crop rotation or by varying tillage practices. Changing vegetation across the landscape or over time not only increases plant diversity, but also the types of insects, microorganisms, and wildlife that live on your farm.

6. Monitoring soil performance

Nothing can replace the value of "casual" observations of how your land is changing from day to day and year to year. Yet, to fine-tune management practices and promptly determine whether changes in soil or crops are significant, you also need to make systematic observations of the soil.

Your Farm #1

How do I keep soil records?

Soil records should allow you to assess your soil, identify problem areas, and track changes in management practices and soil conditions. A record-keeping system could consist of:

- ✔ **Base maps** of your land that help you inventory your soils, and provide a place to record management practices and field conditions.
- ✔ **An inventory** of problem areas you want to address.
- ✔ **Identification** of management practices that you could change to improve the soil, and a plan to implement them.
- ✔ **A list** of information sources and questions you want to pursue.

Want to know more?

About field buffers

Call your local Soil and Water Conservation District office for publications, technical assistance, and possibly financial assistance for establishing vegetated buffers around waterways.

About crop rotations

The following publications are available from the NDSU Extension Service.

Crop Rotations for Profit in North Dakota, 1996. (A-1059);
Crop Rotations for Managing Plant Disease, 1993, (PP-705);

Crop Rotations for Increased Productivity, 1998, (EB-48)

Chapter 2 of the *Organic Field Crop Handbook* describes how to design a crop rotation.

About monitoring

The Monitoring Tool Box provides guidelines for monitoring soil, finances, quality of life, streams, birds, frogs and toads, pests and pasture vegetation.

The NRCS Soil Quality Test Kit is a set of on-farm tests for water infiltration, biological activity, nitrates, aggregate stability and more.

This section gives background information about how soil works. Understanding the basics will help you apply management recommendations found in this and other publications in this series.

Want to know more?

About the origins of soil

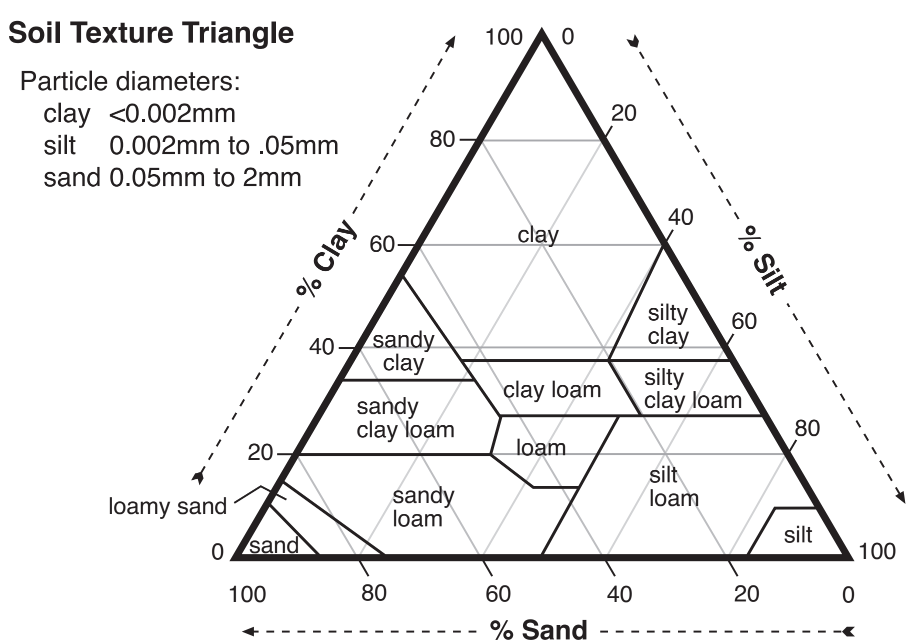
Soils and Landscapes of Minnesota (University of Minnesota Extension Service publication FO-2331) describes how the state's major soils developed. It includes maps of soil parent materials, annual temperatures and precipitation, general relief, and original vegetation. A full color, full-page map divides the state into 16 soil suborders.

WHAT IS SOIL MADE OF?

It takes thousands of years for rock to develop into soil, and hundreds of years for rich organic layers to build up. Soil is made of air, water, mineral particles, organic matter, and organisms. Half of soil is pore space. Generally, pores are about half filled with water and half air, though the proportion varies greatly depending on weather, plant water use, and soil texture. Most of the solid portion of soil is mineral particles. Organic matter may make up only 5% to 10% of the volume of soil (less than 5% of the weight), but it is critical in holding soil particles together, storing nutrients, and feeding soil organisms.

Mineral particles are divided into three groups based on their size: clay, silt, and sand. **Soil texture** depends on the proportion of particles from each of these groups. (See the texture triangle below.) For example, a loam has similar proportions of all three classes of particles. A sandy loam is higher in sand; a clay loam is higher in clay.

Soil structure, or how soil is put together, can be as important as what it is made of. Most soil particles are held together in **aggregates** of many particles. The size and stability of these aggregates determine the size of pores. Soil texture is difficult to change, but farming does impact soil structure.



Your Farm #2

Making a base map.

How well do you know the differences in texture, organic matter, and terrain across your land? Get this information onto paper, so you can use it as a base map. A base map shows the permanent features of your land. Make many copies of your base map, and use them to record changes in soil condition, and to keep management records (see Rodney Rauk's story). By looking at maps of soil types, management practices, and problem areas side-by-side you can identify patterns that give you clues for better soil management.

Start your base map by copying or tracing a Soil Survey map or aerial photos. Today, you might just sketch a portion of your farm with a pencil so you can learn what you want to include in your base map. Some of the features you might include are:

Soil types. Draw boundaries between soil types and label the texture, slope, and any other important characteristics (such as depth). This information is available in the county Soil Survey. Ask at your Soil and Water Conservation District office for help.

Terrain. Mark low spots and hill tops.

Water flow. Draw dotted arrows showing the direction and path of water flow. Note where it comes from before reaching your farm and where it goes after it leaves your farm. Include streams, wetlands, drainage ditches, sinkholes, and waterways that are only wet during a storm.

Wind patterns. Note prevailing wind direction(s).

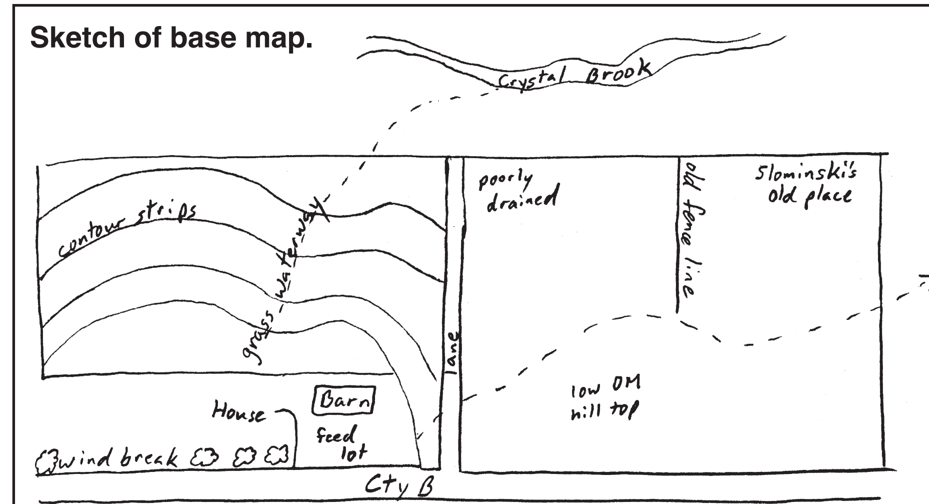
Organic matter. Note areas of high and low amounts of organic matter. High organic matter areas appear darker in an aerial photo.

Permanent structures. Mark the location of terraces, tile lines, buffer strips along waterways, windbreaks, etc. Mark field boundaries, buildings, and livestock yards.

Former structures. Mark locations of former fence lines, buildings, lanes, and livestock yards.

Public areas. Are there parts of your fields visible to others that you want to keep "looking nice"?

Sketch of base map.



In the field:

Making and using base maps

Rodney Rauk raises corn and hogs on silty clay loams near Faribault, Minnesota. He got a photographic slide of his land from his local Farm Service Agency office (FSA, formally ASCS). Rodney projected the slide onto a wall, and traced each section of his land onto a separate 8 ½ by 11 inch sheet of paper. He traced the shape of fields, terraces, and other significant features. Rodney made lots of copies, and uses them as the base map for his record keeping. Each year he records varieties planted, fertilizer rates, weed problems, and other management practices and observations.

Rodney finds it especially valuable to look at the aerial photos of his land that he gets each year from his county Soil and Water Conservation District (SWCD) office. He studies the variation across his and his neighbors' land, and is able to track problem spots from year to year.

HOW DOES SOIL WORK?

Regardless of the kind of farming you do, the rules of soil chemistry, physics, and ecology are the same. Four processes make your soil what it is: formation of soil structure, nutrient cycles, water cycles, and life cycles of soil organisms.

Want to know more?

About compaction

Compaction (BU-7400 in this series) describes more about soil structure and how to control compaction.

1. Soil structure

Soil particles range in size from gritty sand particles as large as 2 mm ($^1/_{16}$ inch) to microscopic clay particles 1000 times smaller. These particles rarely exist separately in the soil. They normally combine into clumps called aggregates or peds. A few particles bind into tiny microaggregates. Microaggregates, in turn, combine to form larger aggregates. Ideally, soil will have a wide range of aggregate sizes and pore sizes. Aggregates in healthy soil will be stable and resist breakage when tilled, hit by rain, or otherwise disturbed.

How soil structure develops

How do aggregates form? Several biological, physical, and chemical processes interact to form aggregates and then stabilize them. Microbes decomposing organic matter create compounds that cement soil particles together. Synthetic polymers (“soil conditioners”) and sugars excreted from roots can have a similar cementing effect. Humus—the stable organic compounds—also binds soil particles together.

Fungal hyphae and fine roots surround and stablize aggregates. This is why surface residue and other organic matter improve soil structure—the residue is food for fungi and bacteria that in turn help form and stabilize soil aggregates.

Larger organisms (such as insects and earthworms), enhance soil structure when they burrow through the soil and deposit fecal pellets that become stable soil aggregates.

Physical and chemical processes are also important to the formation of soil aggregates—especially smaller aggregates. Particles are physically pushed closer together by freezing and thawing, wetting and drying, and roots pushing through the soil.

At the molecular level, electrochemical charges bond clay particles together. In arid areas, this process may be disrupted by large amounts of sodium (Na^+) ions. In tropical and semitropical soils, iron oxides can cement together aggregates.

How do surface crusts form? Rain drops break apart soil aggregates and then fine clay particles clog the spaces between aggregates and form a crust on the soil.

Improving soil structure

Several of our six soil-friendly practices impact soil structure:

Organic matter management. Regular additions feed the organisms that build soil structure.

Tillage practices. Over time, tillage increases the decomposition of soil organic matter and breaks up aggregates—especially when tillage is done in wet soil. Residue left at the surface protects surface aggregates from rain and encourages the growth of fungi that help stabilize aggregates.

Compaction prevention. Compaction pushes aggregates together and eventually breaks them down.

Crop choices. The dense roots of grasses, small grains, and pastures stabilize soil aggregates and improve structure.

Your Farm #3

Where are my soil structure problems?

Mark on your base map or make a list of where the tilth of your soil is not as good as you would like. Where do you have problems with:

- ✔ crusting?
- ✔ compaction or hardpans?
- ✔ soil that is difficult to work?

2. Nutrient cycles

Soil is the storehouse for the nutrients that plants need. It is a dynamic environment in which soil organisms, chemistry, and physics are continually acting to change the form of plant nutrients.

Plant roots draw most of the nutrients they need from the soil solution— the water and dissolved minerals in soil pores. The amount of nutrients in the soil solution at any one time is just a fraction of that needed by plants over the course of the year. The soil solution must be continually replenished from the store of nutrients in minerals and organic matter. Many farmers also contribute nutrients to the soil solution by adding readily available fertilizers once or more each year.

Soil particles and plant residue are made of large quantities of nutrients that are unavailable to plants. Eventually, the soil (mineral) particles weather into sand, silt, clay molecules, or mineral ions. Plant residue eventually decomposes into mineral ions or reforms into humus.

Want to know more?

About nutrient cycling

The following are all University of Minnesota Extension Service publications

Nutrient Cycling Series:

Boron for Minnesota Soils

Copper for Crop Production

Magnesium for Crop Production in MN

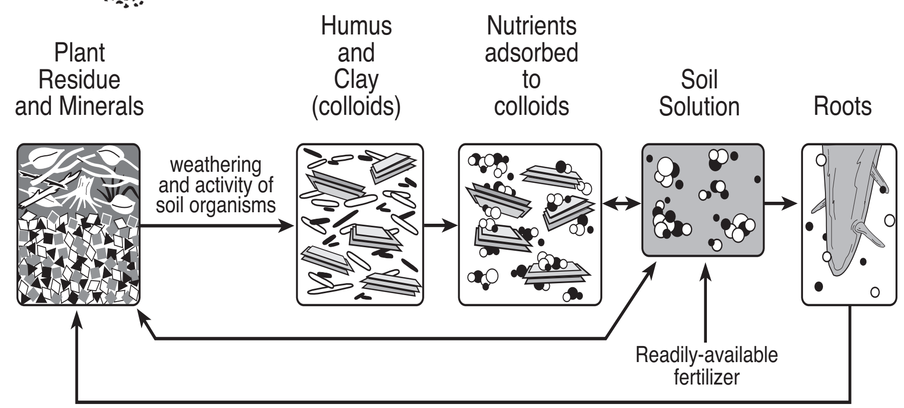
Potassium for Crop Production

Sulfur for Minnesota Soils

Understanding Nitrogen in Soils

Understanding Phosphorus in MN Soils

Zinc for Crop Production



Plant nutrients exist in several forms. Adapted from Brady and Weil, 1996, p. 22.

> **What's the difference between absorbed and adsorbed?**
>
> An <u>ab</u>sorbed substance is incorporated into the internal structure of a material, such as when a sponge absorbs water. Nutrient ions are <u>ad</u>sorbed or attached to the outer surface of clay or humus particles.

Clay and humus are not absorbed by plants, but they hold nutrients (mineral ions) on their surfaces. The amount of places available on clay and humus to hold nutrients is called the "exchange capacity" of the soil.

Cation exchange capacity is the number of places available—the storage capacity—for positively charged ions, including calcium, magnesium, sodium, and potassium ions (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}). Nutrient ions attached to the exchange sites on clay and humus are released into the soil solution for use by plants and soil organisms such as bacteria and fungi.

As plants draw nutrients out of the soil solution, more may be released into solution from exchange sites on clay and humus. Fertilizers added to the soil solution do not remain unchanged, waiting to be used by plants. Like minerals from other sources, they become attached to exchange sites, are used by micro-organisms, and are transformed.

Roots get nutrients in three ways: 1) the root grows into an area where the soil solution has not been depleted of nutrients; 2) after a root depletes the nutrients near it, nutrients will diffuse into the deficient area; and 3) water flows towards the root and carries nutrients. This means that prolific root growth and adequate water are essential to plant nutrition.

> ***Want to know more?***
>
> **Mycorrhizal fungi** are essential to the growth of many plants. These fungi infect roots, extend their reach into the soil, and expand the plant's access to water and nutrients. Read more about them in *Soil Biology* (BU-7403, in this series).

What is soil fertility?

Where is the most fertile land on your farm? What makes it more productive than other fields? The soil may test high in nutrients, but it probably has additional characteristics that make it your best land. Soil fertility is not just the amount of nutrients, but whether plants can get the nutrients when they need them. In other words, a fertile soil will have:

Good rooting environment. To grow and find nutrients, roots (and mycorrhizal fungi) need well-drained soil with a crumbly, uncompacted structure.

Adequate water. Soil with good "tilth" will have good water infiltration and water-holding capacity.

High organic matter. Organic matter is a source of many nutrients, improves the rooting environment, and helps hold water in the soil.

Active soil community. Soil organisms release and retain nutrients, protect plants from pests, and even enhance plant growth. Their activity depends on food availability, pH, and moisture and temperature levels.

Appropriate pH. When pH changes, many nutrients can become either more or less available to plants, depending on the nutrient. pH also affects microbial activity. For example, *Rhizobia* form nitrogen-fixing nodules poorly in acid soils.

Improving nutrient cycling

Several of our six soil-friendly practices are important to nutrient cycling:

Organic matter management. Organic matter supplies nutrients for plants and feeds the soil organisms responsible for cycling nutrients. It is a "slow release" fertilizer.

Tillage practices. Tillage triggers the decomposition of organic matter and the release of nutrients, and mixes nutrients throughout topsoil. Excessive tillage reduces organic matter and the nutrient-holding capacity of your soil.

Compaction prevention. Preventing compaction improves the ability of roots to grow through soil to reach available nutrients.

Fertilizer management. You have choices about which form and how much of a nutrient to use, and when and how to apply it.

Crop choices. Each crop affects nutrient cycling differently and encourages a different mix of soil organisms. Deep-rooted crops draw up nutrients that other crops cannot reach. Legumes can add nitrogen to the soil.

Your Farm #4

Where are my fertility problems?

Make a list of where your soil is not working as well as you would like. Mark problem areas on a base map. Note where:

- soils test very high or low in nutrients
- soil has low or high pH
- crops tend to have spring deficiencies in phosphorus or sulfur. (This is likely caused by drainage or problems other than a lack of nutrients.)
- crops generally do not thrive.

> ***Want to know more?***
>
> **About fertilizers**
> The University of Minnesota Extension Service publishes *Fertilizer Recommendations for Agronomic Crops in Minnesota, BU-6240,* and *Nutrient Management for Commercial Fruit and Vegetable Crops in Minnesota,* FO-5886. They also have publications for specific crops.

3. Water cycle

If you have watched crops suffer through a drought or have seen yields jump after installing drainage tiles, then you understand that water is a fundamental factor for good crop yields. Like animals, plants need large amounts of water every day. Yet, too much water deprives roots of air and makes soil susceptible to compaction. Water carries soil, nutrients, and other substances, so water management is essential to controlling erosion and pollution.

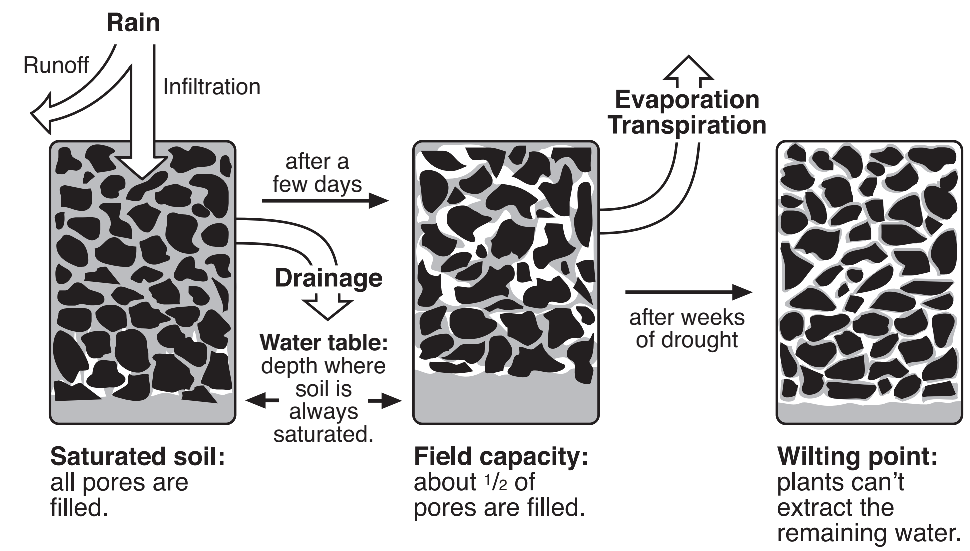
Three major water processes occur in soil: water gets into the soil (infiltration), is held by the soil, and drains out of the soil. How these processes occur depends on soil type and management.

Infiltration is the rate at which water gets through the surface and into the soil. With higher infiltration, more water will be available to plants and less will run off the surface, erode soil, and wash away nutrients. Crop residue, living plants, or a rough soil surface will slow down the flow of water so more can infiltrate. A soil crust reduces infiltration and can be minimized by leaving surface residue, improving organic matter levels, and enhancing biological activity.

Available water holding capacity is the amount of water soil can hold for plant use. After water gets into the soil, the surface tension of water holds it in soil pores against the pull of gravity. Because of surface tension, small pores in fine-textured soils such as silt and clay loams hold more water than the large pores in sandy soils. Organic matter also holds large quantities of water. The maximum amount of water that a soil can hold against the pull of gravity is called the field capacity. Generally when a soil is at field capacity, half the pores are filled with water.

Plants cannot use all of the water in soil. As water evaporates and is drawn out of soil by plants, the water content gradually declines until plants can no longer extract the small amount of remaining water held tightly to soil particles. This remaining amount of soil water is called the wilting point. Clays have a high wilting point. They hold water more tightly than coarser-textured soils and so less of the water is available to plants. Thus, although silt loams hold a bit less water (have a lower field capacity) than clay loams, more of it is available to plants. Salts prevent roots from absorbing water and thus increase the wilting point.

Drainage or percolation is excess water that soil cannot hold that moves out of the rooting zone so roots and organisms can get air. After a heavy rain, the soil will be saturated (all the soil pores are filled with water). Many roots and soil organisms will die if the excess water does not quickly percolate out and allow air into the pores again.



Changes in Soil Water. Field capacity minus wilting point is the amount of water available to plants.

Improving the availability of water

Several of our six soil-friendly practices increase field capacity and improve infiltration:

Organic matter management. Organic matter significantly increases the water-holding capacity of soil in two ways. It absorbs and holds large amounts of water, and it improves the structure of the soil—increasing the total volume and size of pores that can hold water and preventing soil crusting.

Tillage practices. Leaving residue on the surface slows runoff and prevents crusting. Residue encourages populations of earthworms and other burrowing organisms and water infiltrates rapidly into their burrows.

Compaction prevention. Compaction reduces water holding capacity by reducing the number and size of soil pores.

Erosion control. Erosion reduces the depth of your soil and its water-holding capacity.

Your Farm #5

Where are my water problems?

Review this section on water cycling and list (or mark on your base map) where your soil is not working as well as you would like. Where do you have problems with:

- slow drainage and ponding after a rain?
- poor infiltration and high runoff?
- crops susceptible to drought?

A YEAR IN THE LIFE OF YOUR SOIL

(Dates are approximate for Minnesota and vary each year.)

	Spring (Late April through early June)	**Summer** (June through August)	**Fall** (Late August through September)
STRUCTURE & TEMP.	Saturated soils have a weak structure and are prone to compaction. Spring soil is highly susceptible to wind and water erosion, because soil is often bare and soil structure is weak. By late spring, bacterial and fungal activity will help stabilize soil aggregates, and plant growth will begin to protect the soil surface.	Even healthy soil is difficult to penetrate when it gets very dry.	Risk of soil compaction increases again as soil moisture levels rise and heavy harvest equipment enters the fields.
NUTRIENTS	Bacteria and fungi are becoming active, but not necessarily enough to provide nutrients to young plants. Side-dressing of nutrients may be useful.	If a young (high N) forage is plowed down, soil organisms quickly release N and other nutrients to the next crop. A low-N amendment, such as straw, may trigger N deficiency in a crop, as soil organisms use soil nitrate to decompose the high carbon amendment.	Fall is a good time to test soil—leaving all winter to use test results for planning the next cropping season. Cool season cover crops can take advantage of nutrients (and water and sunlight) not being used by the main-season crop, and can prevent nitrogen losses.
WATER	Compacted soils drain slowly. The loose, rough surface of newly tilled soil readily allows rain water to infiltrate into the soil—unless a crust forms.	High temperatures in July and August cause high water loss through evaporation and transpiration from plants. Soil water stores are at their lowest.	Soil water levels begin to recharge as temperatures drop and evaporation and transpiration slow.
ORGANISMS	Warming temperatures, air from tillage, and food from a plowed-down crop trigger a high level of activity. Organisms give off heat, carbon dioxide, and nutrients as they consume residue.	Any change in environment—new food, hot spell, heavy rain—will change microbial activity. In late summer, organisms from bacteria to earthworms are less active and reproduce less because of the lack of water.	Microbial activity increases in response to greater soil moisture and new food in the form of roots and residue from harvested crops.
PLANTS	Tillage triggers weeds to sprout. As crop roots begin to grow, they continually contribute organic matter to the soil. They exude organic compounds and slough off dying cells.	Root growth slows as plants produce flowers and other reproductive growth. By this time, roots may have extended deep into subsoil in search of water and nutrients. Warm season plants such as corn and some grasses flourish in the heat (if they have enough water).	Over the course of the year, 40% of the photosynthetic energy captured by a plant is used by the roots, and enters the soil system. Most of this carbon is released from the roots as CO_2.

A Year in the Life of Your Soil (continued)

	Freezing (October through mid-November)	**Winter** (Mid Nov. through February)	**Thawing** (March and April)
STRUCTURE & TEMP.	Both surface residue and the irregular surface left by rough fall tillage protect the soil from winter wind erosion and spring water erosion.	A January thaw affects the structure of the top inch or so of soil.	Bare soils warm more quickly than residue-covered soils.
NUTRIENTS	In late fall nitrate leaching increases as plant uptake and microbial activity decline.	Few changes occur in nutrients during the winter. Freezing temperatures prevent biological and chemical activity, or water movement.	Microbes and plants are not active and using nitrate, so soil nitrate is prone to leaching in early spring. Cool temperatures prevent denitrification losses.
WATER	If an early heavy snow insulates the soil, the ground may not freeze deeply.	Surface soil may freeze and thaw several times each winter, but subsoil only freezes once. Any water from thawed snow or surface-applied manure cannot soak in and will run off.	Soil ice does not thaw evenly. Cracks and openings in the ice begin to allow water to flow down into subsoil and recharge water supplies.
ORGANISMS	If it is warm, fall plowing triggers a final flush of microbial activity and organic matter decay.	There is little or no biological activity, except from a few species adapted to living in snow and cold soil.	A few organisms are becoming active. Root nodules on some perennial legumes have survived the winter and begin to fix nitrogen. When the soil fully thaws, some arthropods and earthworms move toward the surface from deep in the soil where they have been dormant.
PLANTS	As perennials "harden off" they send energy down to the roots for storage. If perennials such as alfalfa are protected by a continuous snow cover, they may stay green and perform some photosynthesis well into winter.	The soil environment is steeply stratified: Little or no root activity occurs near the frozen surface, while deep down, temperatures may be in the 40°s. Even when all above-ground growth is dead, deep perennial roots are alive and growing. They get energy from stores in the thicker roots.	Root activity (growth and uptake of water and nutrients) gradually increases as soil warms, but does not become very active until soil temperatures pass 50 degrees. Perennials such as alfalfa take energy from the roots to start growth of a new crown.

4. Life cycles of soil organisms

Soil organisms were mentioned in connection with all three of the previous soil processes. Their life cycles are an integral part of the formation of soil structure and nutrient cycles, and their activity is highly dependent on the water status of soil. Temperature, food supply, and pH are other factors that determine what lives in your soil and when they are active. The table on the previous pages, "A Year in the Life of Your Soil," shows how the annual cycles of organisms link to other soil processes.

The food web of organisms living underground is at least as diverse and complex as the ecosystem of plants and animals living above ground. Practically all the energy for the food web comes from the sun. Plants and other photosynthesizers convert the sun's energy and carbon dioxide into the carbon compounds used by other organisms. Plant-eaters create compounds that other organisms need. As bacteria, fungi, earthworms, microscopic insects, and other organisms consume and transform carbon compounds, they release carbon dioxide back into the atmosphere and make nutrients available to plants. Farmers depend on these life cycles for their livelihood.

Improving the soil ecosystem

Several of our six soil-friendly practices can improve your soil's ecosystem:

Organic matter management. Soil organisms need a regular supply of organic matter for food.

Increase diversity. It is generally beneficial to increase the diversity of organisms in the soil. Diversity is increased by using different management practices, including long crop rotations, changing tillage practices from year to year, supplying several types of organic matter, or creating buffer strips or other vegetation that adds variety to the landscape.

Want to know more?

About the activity of soil organisms

Soil Biology (BU-7403 in this series)

About types of organic matter

Organic Matter Management (BU-7402 in this series)

Your Farm #6

Where are my biology problem areas?

Are desired plants and animals thriving, or do weeds and pests dominate in some areas? On your base map or on a list, note the locations of:

- weed problems,
- disease or pest infestations,
- slow residue decomposition, or other signs of poor biological activity.

MAKING A SOIL MANAGEMENT PLAN

Now that you have reviewed how soil works, and how it is working on your farm, it may be time to begin clarifying which soil management changes would be beneficial on your farm. Whole farm planning includes four steps which can be modified for use in developing a soil management plan:

1. Setting goals

What do you want to get from your soil? On page one is a list of services or functions that soil performs. Look at these for ideas as you write your soil management goals. Think about them in relation to the overall goals you have for your farm.

2. Inventory and assessment

Inventorying and assessing soil

What kind of soil do you have? What problems are of greatest concern? To begin answering these questions, look at the problem areas you identified in "Your Farm #3, 4, 5, and 6." Also consider areas where erosion or loss of organic matter is a problem, where crop performance is consistently poor, or where crops are highly susceptible to less-than-ideal weather conditions. You will probably find that many of the areas on each list will overlap.

Which areas are costing you the most money, causing the most environmental damage, or threatening the long-term productivity of your farm? After you narrow down your major soil management concerns, make a detailed description of the problem areas: How severe is the problem? What are its boundaries? What is the condition of the soil? You can come back to this description periodically to track improvements.

Inventorying and assessing practices

What are the effects of your current management practices? Listing your current soil management practices will help you examine their effects and will give you a baseline for tracking changes.

You might develop this list by going through the six soil-friendly practices for improving soil health, and describing your current practices in each category. For example, for the first item (adding organic matter), you might write:

✔ Soybean roots and residue are added every other year.
✔ Corn roots and residue are added every other year.
✔ Only corn stubble is left on field X, when we harvest silage.
✔ Liquid manure is applied to field A and B every year.

Leave room for comments and move on to the next category.

Want to know more?

About planning

Whole Farm Planning: Combining Family, Profit and Environment (University of Minnesota Extension Service publication FO-6985) explains the basics of whole farm planning and describes several programs and approaches to planning.

In the field

Convenient record keeping

Wayne Hess keeps two records of the management and condition of his fields. One is in a calendar; the other on a map. Wayne keeps a week-by-week appointment calendar in his tractor. This makes it convenient for him to write down field operations as he does them, such as planting dates and chemical and fertilizer application rates. He jots down observations of weed or pest problems when he sees them.

When he gets his map from the FSA office, Wayne adds notes about field conditions and activities. For example, he will write down the location of chemical applications, and sketch in the position of weed problems or rocks that need picking.

3. Creating an action plan

What are your management alternatives? What information do you need to decide how each alternative could address your problems and goals? Review the six soil-friendly practices and ask which ones might address your problem areas. Examine the other publications in this series for more ideas.

Label a sheet of paper as your "preliminary management plan" and jot down possible management changes to consider and learn more about.

4. Monitoring progress

What changes do you expect to see in your soil, water, and crops? Are they occurring? If your soil/crop ecosystem works well, it provides essential services: high crop yields, quality crops, water control, and pollution control. If the system is not working well, the land is less productive, pollution is more likely, and the soil shows signs of degradation, such as erosion, salinization, or compaction. The purpose of monitoring and record keeping is to find the link between soil quality and the management practices you use.

The table on page 17 lists items you might include in your soil management record-keeping system. When deciding what to measure and monitor, think about what information would convince you either that your soil is improving or that your practices are not having the desired effect. Keep in mind that some soil properties might not change significantly until a few years after changing a practice.

To monitor changes in soil quality, you can measure 1) how you are treating the soil (management practices, such as residue cover or length of crop rotation), 2) the condition of the soil (e.g., nutrient levels or compaction), or 3) how the soil is performing (e.g., yield, water quality, or erosion). All three provide different clues about how to modify management practices.

Information on how to monitor each of these is available in other publications in this series and from soil and crop advisors such as Extension educators, NRCS conservationists, private consultants, and dealers.

On-farm trials

One part of monitoring may be on-farm trials. Before changing a practice on the entire acreage, many farmers test a small area to see if it is beneficial, how the technique needs to be modified, and what new problems are created. Take time before testing a new practice to make sure the trial will give you the information you need. On-farm trials are only informative if they make a valid comparison between the old and new practice. Ask your local Extension educator for help setting up a trial, and check the list of on-farm trial information in the Further Resources section at the end of this publication.

In the field

Funding for on-farm trials

Howard Kittleson ridge tills corn and soybeans south of Owatonna, Minnesota. Before he put his money into site-specific farming technology, Howard wanted to know whether variable rate applications would pay off in reduced input costs. He devised a low-cost implement to adjust the delivery rate of urea, potash, and phophate based on soil tests done on a 2.5 acre grid sampling. Howard got a grant to test his methods from the Energy and Sustainable Agriculture Program (ESAP) from the Minnesota Department of Agriculture. The results of his experiment (and other ESAP-funded projects) are in *Greenbook '98*. Call MDA for a free copy at 651-296-7673.

Another source of financial help is the Agricultural Conservation Innovation Center. ACIC provides risk insurance to farmers who are trying conservation practices. If you apply certain practices to part of your farm, the insurance protects you from a yield loss on that land. For more information, contact ACIC at 843-740-1325, or e-mail: megan.terebus@agconserv.com.

What to Monitor

Management practices	Soil characteristics	Soil performance
Organic matter additions Tillage practices Pesticide and fertilizer applications Residue coverage (%) Length of time soil is bare each year Crop rotation Landscape diversity	Compaction Crusting Salinization pH Nutrient (soil test) levels Cation exchange capacity (CEC) Contamination with heavy metals or other pollutants Soil structure (aggregation) Water infiltration Water holding capacity Drainage Total organic matter Active organic matter Biological activity Earthworms Soil respiration Residue decomposition rates	Productivity e.g.: yield/acre yield/fertilizer inputs yield/pesticide use yield/total $ inputs yield/precip or irrigation Insect, disease, & weed pressure (monitor pattern and severity) Crop quality Variability in yield Erosion rates Water quality e.g.: nitrate phosphorus sediments

Your Farm #7

Pulling it together.

By now you should have:

- a base map
- a list of soil problems to address
- an assessment of current practices
- a preliminary management plan
- a list of questions to pursue

These five items are the start of your soil management plan. Use this information to decide which publication in this series to read next. Keep your plan handy as you read the other publications, and revise it as you go.

Want to know more?

About on-farm trials

A Farmer's Guide to On-Farm Research
On-Farm Testing: A Grower's Guide
The Greenbook
The Paired Comparison: A Good Design for Farmer-Managed Trials
The Practical Farmer

PEOPLE

Begin with experts in your area, such as the county Extension office and the local Soil and Water Conservation District office. They know the local soils and cropping problems. Then try these state and national organizations.

Appropriate Technology Transfer for Rural Areas (ATTRA)
ATTRA is a private, non-profit organization funded by an annual USDA grant. They provide free information on alternative practices and crops, and "sustainable" practices. Visit their web site at www.attra.org or call 1-800-346-9140.

Conservation Technology Information Center (CTIC)
CTIC publishes information for farmers and conservationists interested in crop residue management, conservation tillage, watershed management, water quality, wetlands, nutrient management, and pest management. For a list of publications, call 317-494-9555. Or click on "Farm Resources Management" on their web site at www.ctic.purdue.edu/CTIC.html.

Minnesota Department of Agriculture (MDA)
The MDA offers demonstration grants, loans for adopting sustainable practices, whole farm planning workshops and a variety of field days. Visit their web site at www.mda.state.mn.us, or call 651-296-7673.

Minnesota Institute for Sustainable Agriculture (MISA)
MISA brings together the agricultural and University communities in an effort to develop and promote sustainable agriculture. They can link farmers and researchers and respond to individual requests for information. Visit their web site at: www.misa.umn.edu or call 612-625-8235.

PUBLICATIONS

Agricultural Education Materials Service (AEMS). Iowa State University.
AEMS sells many curriculum materials, including some related to soil. Call 515-294-6924, or visit their web site at: www.ag.iastate.edu/departments/aged/outreach/aemscc.htm

Building Soils for Better Crops. 1993. Fred Magdoff. University of Nebraska Press. (1-800-755-1105)
A guide to improving soil quality by building organic matter. A second edition is expected soon. If you cannot find the first edition at your library, photocopies may be available by writing to John Nelson, Northeast SARE, Hills Building, University of Vermont, Burlington, VT 05405.

Crop Rotation Series. North Dakota State University Extension Service. Call 701-237-7882, or e-mail slane@ndsuext.nodak.edu
Crop Rotations for Profit in North Dakota, 1996, A-1059
Crop Rotations for Managing Plant Disease, 1993, PP-705
Crop Rotations for Increased Productivity, 1998, EB-48

Earthworm Empire: The Living Soil. 1996. Eldon C. Weber. Kendall/Hunt Publishing Company.
This book is for teachers who want to link agriculture to science, history, language arts, and mathematics. Order from the Soil and Water Conservation Society, 515-289-2331 ext. 19; http://www.swcs.org/ or call Eldon Weber at 515-294-0893.

A Farmer's Guide to On-Farm Research. 1990. Rhonda Janke, Dick Thompson, Ken McNamara, and Craig Cramer. Rodale Institute.
A practical handbook available for about $5. Contact Rebecca Haring, 610-683-1439, rharin@rodaleinst.org. Or contact: Thompson On-Farm Research, 2035-190th St., Boone, IA 50036-7423, (515) 432-1560.

The Greenbook. Annual. Energy and Sustainable Agriculture Program (ESAP), Minnesota Department of Agriculture.
This publication describes on-farm trials and demonstrations funded by ESAP and conducted by Minnesota farmers. Further resources are provided. For a free copy, or for information about applying for an ESAP grant, call 651-296-7673.

Managing Cover Crops Profitably, 2nd Ed. 1998. Sustainable Agriculture Research and Education Program. This is the most comprehensive book on the topic. Describes characteristics of specific cover crops, and provides the information needed to choose a cover crop for your operation. Available from Sustainable Agriculture Publications, Hills Building, Room 10, University of Vermont, Burlington, VT 05405-0082.

Monitoring Tool Box. 1998. Land Stewardship Project. This book, along with the video *Close to the Ground,* is for farmers interested in easy techniques for monitoring the impact of management decisions on their land, finances, and family. Order the complete book and video, or individual sections, such as the soil monitoring information. To order, call the Land Stewardship Project at 507-523-3366.

The Nature and Properties of Soils, 11th Ed. 1996. N. C. Brady and R. R. Weil. Prentice Hall, Upper Saddle River, NJ. This, and the earlier editions, are excellent college textbooks explaining how soil works. Look in your local library or order from a bookstore.

Nutrient Cycling Series. University of Minnesota Extension Service. To order copies call 1-800-876-8636 or visit our web site at http://www.extension.umn.edu. Many of these can be viewed on-line.
Boron for Minnesota Soils, 1993, FO-0723
Copper for Crop Production, 1996, FS-6790
Magnesium for Crop Production in MN, 1978, FO-0725
Potassium for Crop Production, 1996, FO-6794
Sulfur for Minnesota Soils, 1979, FO-0794
Understanding Nitrogen in Soils, 1989, FO-3770
Understanding Phosphorus in MN Soils, 1979, FO-0792
Zinc for Crop Production, 1997, F0-0720

On-Farm Testing: A Grower's Guide. 1992. Baird Miller, Ed Adams, Paul Peterson, and Russ Karow. Washington State University.
An introductory guide to doing replicated strips. Call the Washington State University Cooperative Extension Bulletin Office, 509-335-2857. Or visit their web site at drycrops.wsu.edu/crop_management/OFT/oftman.html.

Organic Field Crop Handbook, 1992. Canadian Organic Growers Inc.
Available from Faye Jones, Education Outreach Coordinator, Wisconsin OCIA, N7834 Co. Rd. B, Spring Valley WI 54767.

The Paired Comparison: A Good Design for Farmer-Managed Trials. 1992. Rick Exner and Richard Thompson.
Contact Rick at dnexner@iastate.edu, or Thompson On-Farm Research, 2035-190th St., Boone, IA 50036-7423, (515) 432-1560.

The Practical Farmer
This is the membership newsletter for Practical Farmers of Iowa. It reports results of replicated experiments run on the farms of PFI members and includes articles on various aspects of farming. Call 515-294-1923.

Soil Quality Test Kit
A collection of tests that can be completed on-farm, including tests for water infiltration, biological activity, nitrates, aggregate stability, and more. Available at the NRCS Soil Quality Institute web site (www.statlab.iastate.edu/survey/SQI) or from your Soil and Water Conservation District office.

Soil Science Simplified, 3rd Edition. 1997. Milo I. Harpstead, Thomas J. Sauer, and William F. Bennett. Iowa State University Press, Ames, Iowa.

Soils and Landscapes of Minnesota. 1984. University of Minnesota Extension Service FO-2331.
To order copies call 1-800-876-8636 or visit our web site at http://www.extension.umn.edu.

The Soul of Soil. 3rd Edition. 1995. G. Gershuny and J. Smillie. agAccess.
This book is an overview of how soil works, practical ideas for monitoring soil, and a summary of effects of different management practices. It is aimed at the "organic" farmer, but applicable to other methods. Available from agAccess at 1-800-540-0170.

Start with the Soil. 1993. G. Gershuny. Rodale Press. A guide to organic soil improvement. Available by contacting Rodale at 1-800-914-9363.

Whole Farm Planning: Combining Family, Profit, and Environment. 1998. University of Minnesota Extension Service BU-6985.
To order copies call 1-800-876-8636 or visit our web site at http://www.extension.umn.edu.

Maps

Aerial photos
The local Farm Service Agency (look in the phone book under U.S. Government, Agriculture Department.) will provide a photocopy of their most current base maps (usually from about 1991). They may also provide a copy of the slide they take every year for compliance verification.

Soil Surveys
A copy of the county Soil Survey is generally free to county residents. Contact the local Soil and Water Conservation District (look in the phone book under U.S. Government, Agriculture Department, Natural Resources Conservation Service). These maps show the boundaries of different soil types across your farm, descriptions of the soils, and can be copied and used as base maps for planning soil management.

ACKNOWLEDGMENTS

Author
Ann Lewandowski, Soil Quality Institute, Natural Resources Conservation Service, United States Department of Agriculture

Advisors
Deborah Allan, professor, Department of Soil, Water, and Climate, University of Minnesota
Phill Arnold, Farmer, Long Prairie
Jay Dorsey, (former) research associate, Department of Soil, Water, and Climate, University of Minnesota
Thomas Hansmeyer, graduate student, Department of Soil, Water, and Climate, University of Minnesota
David Huggins, (former) professor, Department of Soil, Water, and Climate, University of Minnesota
Maggie Jones, consultant, Blue Earth Agronomics
Tim King, Farmer, Long Prairie
Bob Olson, Washington County Extension, University of Minnesota Extension Service
Jean Peterson, farmer, Delano
Carl Rosen, Department of Soil, Water, and Climate, University of Minnesota
Mark Zumwinkle, Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture

Series Editor
Debra Elias Morse, Minnesota Institute for Sustainable Agriculture

Production
Kathleen Cleberg, copy editor, Press 1 Production
Roxanne Madison, product manager, Communication and Educational Technology Services, University of Minnesota Extension Service
John Molstad, Studio 31 Graphics, Inc., designer

Reviewers
Deborah Allan, Department of Soil, Water, and Climate, University of Minnesota
Jim Anderson, Department of Soil, Water, and Climate, University of Minnesota
Barb Bakken, farmer, Alden
Carmen Fernholz, farmer, Madison
Dennis Gibson, farmer, Montevideo
Ken Matzdorf, Natural Resources Conservation Service, United States Department of Agriculture
Steve Potter, farmer, Sauk Centre
Linda Schroeder, Schroeder Communications
Russ Severson, West Polk County Extension, University of Minnesota Extension Service

Funding for this project approved by the Minnesota Legislature, 1995 Minnesota Laws, Ch. 220 Sec. 7, Subd. 2.

Additional funding provided by the Soil Quality Institute, Natural Resources Conservation Service, United States Department of Agriculture

The Sustainable Agriculture Information Exchange

This publication is part of a series developed through the Sustainable Agriculture Information Exchange, a clearinghouse of sustainable agriculture information and materials in Minnesota. These informational materials are accessible to the public by phone (toll-free), fax, e-mail, or World Wide Web.

The Information Exchange works to bridge the gap between the need for timely, practical information about sustainable agriculture and existing resources and information; to identify gaps in research and education and direct funding and support to address them; and to promote education and discussion of issues relevant to the sustainability of agriculture.

To ensure that all of the Information Exchange's publications are applicable and user friendly, they are developed by teams and reviewed by individuals who will use the material, including farmers, researchers, Extension educators, other agricultural professionals, and members of the agricultural community. Information Exchange activities are guided by an advisory committee that includes farmers, researchers, and other agricultural community interests and are carried out in cooperation with the Minnesota Department of Agriculture-Energy and Sustainable Agriculture Program and the University of Minnesota Extension Service.

The Information Exchange is part of the Minnesota Institute for Sustainable Agriculture (MISA), a partnership between the University of Minnesota–College of Agricultural, Food, and Environmental Sciences and the Sustainers' Coalition, a group of individuals and community-based non-profit organizations.

Other publications in this series include:

- **Discovering Profits in Unlikely Places: Agroforestry Opportunities for Added Income** (University of Minnesota Extension Service Distribution Center BU-7407)
- **Organic Certification of Crop Production in Minnesota** (University of Minnesota Extension Service Distribution Center BU-7202)
- **Whole Farm Planning: Combining Family, Profit, and Environment** (University of Minnesota Extension Service Distribution Center BU-6985)

New topics in the series are continually in development, including alternative hog production systems, business planning, collaborative marketing organizations, management of solid hog manure, and resources for new farmers.

For more information on this series, the Information Exchange, MISA, or to request individualized information on questions related to sustainable agriculture, please contact us.

Minnesota Institute for Sustainable Agriculture
411 Borlaug Hall
1991 Buford Circle
St. Paul, MN 55108-1013
612/625-8235 or toll-free 800/909-MISA (6472)
fax 612/625-1268
misamail@tc.umn.edu
http://www.misa.umn.edu

MISA
Minnesota Institute for Sustainable Agriculture

USDA NRCS
Natural Resources Conservation Service

IN PARTNERSHIP ...

College of Agricultural, Food, and Environmental Sciences
UNIVERSITY OF MINNESOTA

UNIVERSITY OF MINNESOTA
Extension
SERVICE

Find more University of Minnesota Extension Service educational information at www.extension.umn.edu on the World Wide Web.

Additional copies of this item can be ordered from the University of Minnesota Extension Service Distribution Center, 405 Coffey Hall, 1420 Eckles Avenue, St. Paul, MN 55108-6068, e-mail: order@extension.umn.edu or credit card orders at (800) 876-8636.

Produced by Communication and Educational Technology Services, University of Minnesota Extension Service.

BU-7399-S
PC-7398-S
2000