SOIL HEALTH STEWARDSHIP

A guide to explore, test and improve your farm's greatest asset

Produced by Farm Journal in Partnership with USDA's Natural Resources Conservation Service

GROUND YOUR BUSINESS ON HEALTHY SOIL

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Whether you grow corn on thousands of acres of black Drummer soil in central Illinois or run a few hundred head of cattle on Mollisols soils in the Great Plains, soil is the fundamental building block of your operation. Have you ever taken a good look at the health of your soils — given each field a checkup of sorts?

Sure, you likely send soil samples to a lab for analysis every so often, but have you ever tested the stability of a clod of soil under rapid wetting conditions or dug a small hole to see what's happening below ground? Have you ever tried a different approach to tillage or grazing to improve the health of your soil? Have you ever planted cover crops?

Investing in soil health requires time, patience and knowledge. It also takes money, so don't forget about federal and state programs for financial and technical assistance.

The good news is healthy soils are more resilient to variable weather and environmental conditions, which is a big win for farmers and their neighbors.

No matter where you stand in your soil health journey, strive to integrate the following four principles:

- Maximize soil cover
- Minimize soil disturbance
- Keep living roots in the soil
- Maximize biodiversity

On the blank lines below, write your personal definition of soil health. With that perspective top of mind, you'll be able to apply learnings from this guide to up your soil health game.

Amy Skoczlas Cole

How do you define soil health for your operation?

This soil health guide is the second in a Conservation Agriculture series.
Download the first guide, Resource Stewardship Planning, at ***AgWeb.com/ACAM***.
Look for a water quality guide in spring 2021.

PHOTO: NRCS, LYNN BETTS

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FOUR PRINCIPLES OF SOIL HEALTH

Conservation planning based in current soil health science is critical to achieve healthy soils. Fields and pastures are systems, which means more than one soil health-targeted conservation practice is usually needed to fully address resource concerns related to improving organic matter quantity or quality, reversing soil organism habitat degradation, alleviating compaction or improving soil aggregate stability. For example, adding a cereal rye cover crop with a two-crop rotation and frequent tillage might provide some weed suppression or help reduce erosion during non-cropped times of the year, but soil aggregate stability will likely still be impaired by regular tillage.

Remember the NRCS soil health principles outlined below to evaluate your systems approach.

PHOTOS: DARRELL SMITH

MINIMIZE SOIL DISTURBANCE

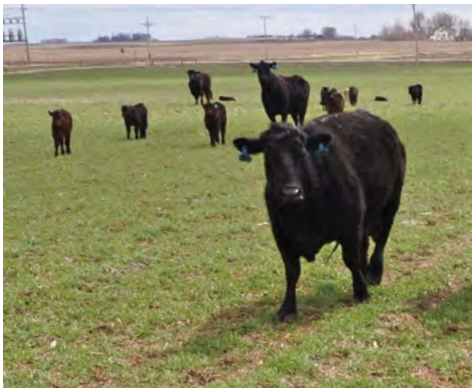
In some cropping systems, physical, chemical or biological soil disturbance is an inevitable consequence of crop production. However, advances in agronomic research and farm equipment and technology have created the potential for most annual cropland acres to be managed with reduced or often no tillage. Disturbance to the soil ecosystem can also result from the inappropriate use of nutrients and pesticides, over irrigation, or over grazing. Reducing disturbance helps to slow carbon losses from the soil, protects soil aggregates from physical destruction and maintains habitat for soil organisms.

MAXIMIZE SOIL COVER

Crop residue and other organic materials such as mulch and compost, when left on the soil surface, provide a protective barrier between the soil and the destructive force of raindrops and wind. In addition, they moderate extremes in soil temperature and reduce evaporative losses from the soil. Soil cover can also be provided by leaves of growing plants. Keeping the soil covered throughout the year helps maintain soil aggregate integrity, protects habitat and provides food for soil organisms.

CONSERVATION PRACTICES TO HELP ACHIEVE THE SOIL HEALTH PRINCIPLES

SOIL HEALTH PRINCIPLE	CONSERVATION PRACTICE								
	Conservation Cover	Conservation Crop Rotation	Cover Crop	Forage & Biomass Planting	Pest Management Conservation System	Mulching	Nutrient Management	Prescribed Grazing	Residue & Tillage Management
Minimize Soil Disturbance	✓			✓	✓		✓	✓	✓
Maximize Soil Cover	✓		✓	✓		✓		✓	✓
Maximize Biodiversity	✓	✓	✓	✓				✓	
Maximize Living Roots	✓	✓	✓	✓				✓	



PHOTOS: NRCS, LYNN BETTS

MAXIMIZE BIODIVERSITY

Diverse crop rotations and integrated crop-livestock systems where feasible are key components of an integrated pest management plan. Primarily through roots, plants affect the kinds and abundance of soil organisms. Different plant species are typically associated with distinct soil microbial communities. In addition, plant root architecture often differs between species with different effects on function. Above ground diversity improves diversity in soil biology, soil organic matter, food and habitat for a diverse soil community, aggregate stability and the likelihood of alleviating compaction.

MAXIMIZE PRESENCE OF ROOTS

The area immediately around plant roots is typically where the highest number and greatest diversity of soil microorganisms are found. Living plant roots exude numerous carbon compounds and slough cells from root surfaces. These organic carbon additions to the ecosystem feed soil organisms and contribute to habitat development. Plant roots are also involved in complex biochemical communication with soil microbes to recruit beneficial organisms and deter pathogenic organisms. Roots can enmesh soil particles to create and preserve soil aggregates. Living plant roots can help alleviate or prevent soil compaction.

THE FUNDAMENTALS OF RESILIENT SOILS

Think about it: Regardless of your management style, use of technology and seed and input choices, it's the soil that underpins how much food and fiber you produce.

"We rely on soils to provide many functions, such as storing water and providing nutrients," says Wayne Honeycutt, director of the Soil Health Institute. "Soil health is basically about how well a soil currently provides those functions compared with what it could provide."

Understanding and evaluating how the biological, physical and chemical properties of soil health work together serves as a springboard for a legacy of stewardship.

"Essentially, all life depends upon the soil."

—Charles E. Kellogg, USDA soil scientist

BIOLOGICAL PROPERTIES

The biological components of soil include the plants, animals, insects, earthworms, nematodes, arthropods, protozoa, fungi and bacteria that live in it. Organic matter, which is made up of decomposed plants and microbial organisms, living microbial tissue and products of plants and microbes, holds nutrients, helps build soil structure and improves water-holding capacity.

Organic matter can be divided into stable, slow and active pools.

Stable organic matter contains stored carbon and consists of materials hundreds to thousands of years old. This pool affects the cation exchange capacity (CEC), and is key in physical processes.

The turnover time for the slow pool of organic matter spans from years to decades. The slow pool is a source of nitrogen and phosphorous and includes decomposed materials, residues and microbials protected through physical and biochemical processes.

That leaves active organic matter, which is fresh plant and animal residues .

"Active organic matter breaks down fastest and makes nutrients available to plants," says Farm Journal Field Agronomist Ken Ferrie. "The active organic matter value can change fairly rapidly in response to changes in crop rotation and aggressive tillage and cover crop use."

Earthworms improve nutrient availability drainage, soil structure and overall productivity.

PHOTO: DARRELL SMITH

An on-farm test of aggregate stability shows how healthy soil retains its crumb-like structure after being subjected to simulated rainfall. Crumb-like structure allows more and larger macropores between soil particles.

Total organic matter, which you're familiar with on soil tests, is slow to improve, quick to decline and can be lost with aggressive tillage.

"Although it might take many years to make significant improvements in total organic matter content, it's worth the effort in terms of higher yield and lower commercial fertilizer cost," Ferrie says.

Soil organic matter generally increases as farmers implement a soil health management system, agrees David Lamm, lead trainer at the Soil Health Institute.

"Reduced soil disturbance and the addition of cover crops allows for biomass to accumulate above and below ground. The importance of plant roots is often overlooked as a major contributor to organic matter throughout the soil profile," Lamm says.

You can measure organic matter by comparing your soil to a simple color chart. "However, a lab test is better because the results are repeatable in future years," Ferrie says.

Different labs might use different organic matter tests, so it's key to stick with one lab for repeatable results. Sampling depth is also important. Soil within 2" of the surface will show changes in organic matter content faster than soil at 7".

PHYSICAL ASPECTS

The physical components of soil include the rocks and minerals broken up over time into very small particles of sand, silt, and clay. These particles are measured to classify the texture of the soil.

"Texture affects the size of pore spaces, water infiltration rate, available water capacity, permeability and cation exchange capacity," says Thomas Zerebny with Crop-Tech Consulting.

"When soil structure is destroyed, clay and silt particles percolate downward, leaving the sand particles," Ferrie explains. "If you find the percentage of sand particles in the top 6" is increasing, aggregate stability has failed and the healthy crumb-like structure has been lost."

"Think of it like this," Ferrie says, "if a sand particle is a 747 airliner, a silt particle is a Cessna and a clay particle is a hummingbird."

Another physical aspect is soil structure. "Healthy soil has particles bound together in a crumb-like structure," he explains. "Biological properties glue these particles together."

PHOTO: DARRELL SMITH

When collecting soil samples, be sure to follow instructions provided by the lab.

CHEMICAL PROPERTIES

The chemical components of soil include the nutrients, such as nitrogen (N), phosphorus (P), potassium (K); CEC; pH; electrical conductivity; sodium adsorption ratio; and water. The basic soil test you've probably been using for years measures these chemical aspects. A soil health test is similar but more comprehensive.

"The nation that destroys its soil destroys itself."

—President Franklin D. Roosevelt

Besides testing for macronutrients — N, P and K — it's also important to test for micronutrients such as iron, boron, manganese and zinc, Ferrie says. "Overapplying or underapplying macro- or micronutrients might be detrimental to soil health."

CEC is a measure of the soil's ability to hold positively charged ions known as cations. Soils are composed of sand, silt, clay and organic matter. The clay and organic matter particles have a net negative charge, which will attract and hold cations, much like the opposite poles of a magnet attract each other. That attraction prevents the positive nutrients from being carried away. Negatively charged ions, known as anions, will repel other negatively charged soil particles. That means negatively charged nutrients, such as nitrates, sulphates and chlorides, are vulnerable to leaching.

Along with soil type and organic matter content, pH influences CEC; pH is a measure of the active hydrogen ion concentration and an indication of the acidity or alkalinity of soil.

When it comes to pH and determining how much lime to apply, a more sophisticated soil test that reports the traditional water pH reading and the buffer pH reading is necessary.

"The water pH reading [which is the only one reported on many soil tests] measures soil acidity as it affects plants and microbes," Ferrie says. "But you can't use that reading to determine how much lime to apply because the amount needed to neutralize acidity varies by soil types. The reading that tells you how much to apply is buffer pH, which takes into account the soil's buffering ability."

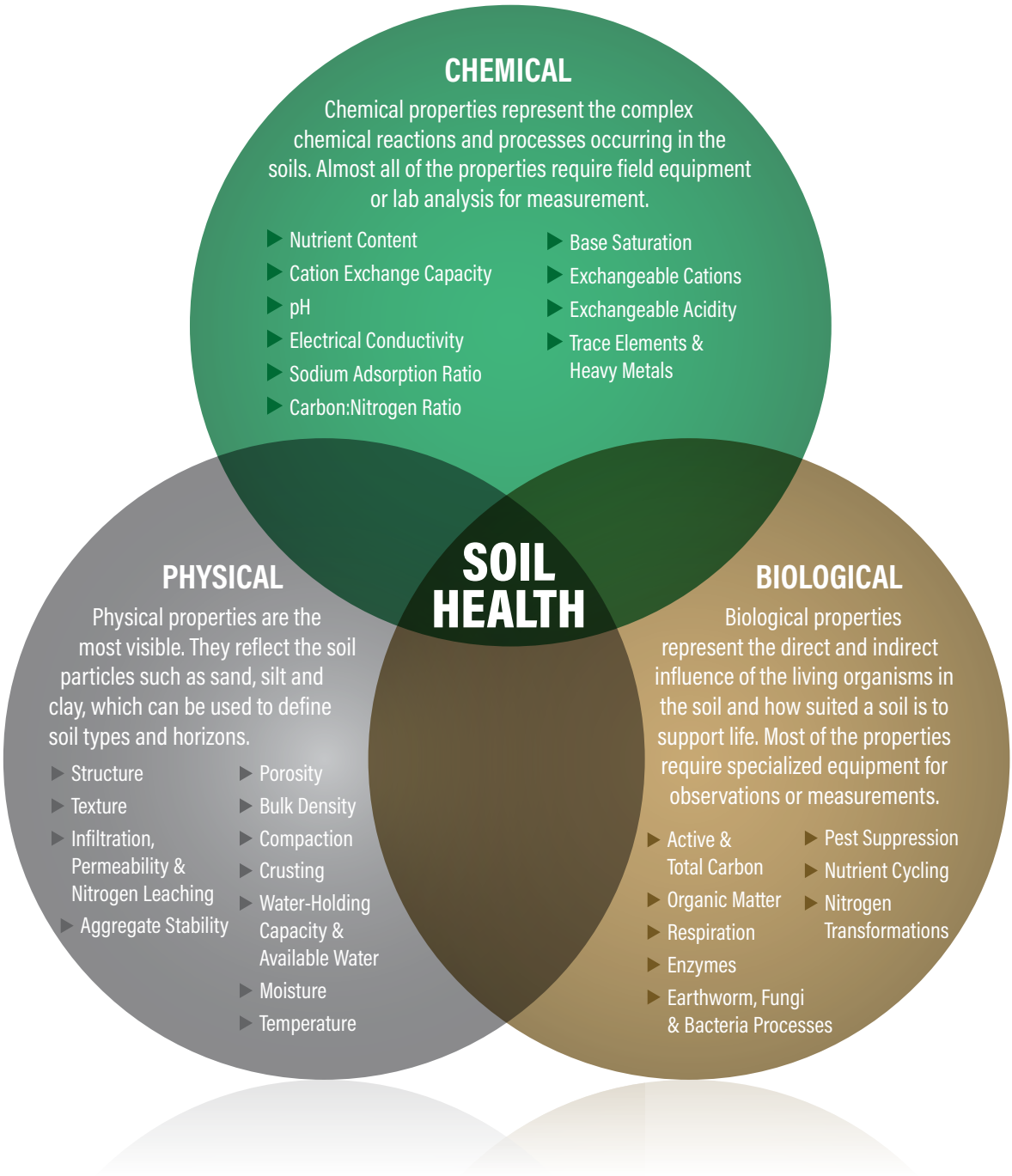
This refers to a soil's capacity to release more acidity from the hydrogen and aluminum ions bound to the soil after the "active acidity" in the soil solution is neutralized.

As a farmer, your goal is to manage chemical, physical and biological aspects.

"For example, it's possible to have high fertility levels due to sound fertilizer management but poor biology and physical health," Ferrie explains. "For healthy soil, you must manage all three components and the processes that create an ecosystem."

FOCUS ON THE SWEET SPOT FOR SOIL HEALTH

Soil encompasses biological, chemical and physical properties. While the components can be viewed separately, it is the interaction among the three that creates and sustains healthy soil — and ultimately productivity and profitability for present and future generations.



CROPLAND EVALUATION

A deliberate look at every field you farm can tell you a lot about the No. 1 resource that affects your present and future productivity and profitability: your soil. Take the time to answer each of the following questions on a field-by-field basis to serve as a baseline as you prepare to dive deeper.

Field location/name and soil type(s), if known.

Describe the typical crop rotation.

Describe any tillage practices, including frequency, type of tool and depth.

Is the field irrigated? If so, explain irrigation method and application rate.

Is manure applied to the field? If so, explain source and application method and rate.

Are cover crops part of the management plan? If so, what species and when, how and at what rate are they planted? How are they terminated? If not, what barriers prevent cover crop use?

Do livestock graze cash crop residue or cover crops, if planted? If so, for how long?

Are there places where soil is exposed? If so, what percent of the field has bare soil not covered with cash crops, cover crops or residue?

Does the field include any areas of concern, such as low spots where water ponds, areas of compaction, erosion or other areas that don't support optimal crop growth?

Does the soil smell earthy and fresh, metallic or have little odor at all?

Describe the color of the soil.

Describe the texture of the soil.

Do you see any living organisms, such as earthworms, spiders or ground beetles?

Are roots uninhibited in terms of growth, or do you see roots moving horizontally across the soil rather than straight down?

Summarize any past soil test results and describe management adjustments you made to address issues.

PASTURE EVALUATION

A deliberate look at every pasture you graze can tell you a lot about the No. 1 resource that affects your present and future productivity and profitability: your soil. Take the time to answer each of the following questions on a pasture-by-pasture basis to serve as a baseline as you prepare to dive deeper.

Field location/name and soil type(s), if known.

List all species/classes of livestock grazed as well as frequency and typical duration.

Are managed or prescribed grazing practices used? If so, explain your typical approach, including when/how you decide to move the herd.

In animals per acre or live weight per acre, what is the typical stocking rate (continuous grazing of large pastures) and/or stocking density (short duration grazing of paddocks within a larger pasture)?

List the major grass and forb species and percent composition of each species.

Is the pasture baled for hay?

Describe any pasture improvement practices such as reseeding, irrigation, fertilization, lime, ash, compost and biochar applications.

Describe any low quality or invasive plant species you would like to address.

Are there places where soil is exposed? If so, what percent of the pasture has bare soil not covered by plant material, either living or dead?

Does the field include any areas of concern, such as low spots where water ponds, areas of compaction, erosion or other areas that don't support optimal forage growth?

Is hay ever baled off this pasture? If so, how often?

Does the soil smell earthy and fresh, metallic or have little odor at all?

Describe the color of the soil.

Describe the texture of the soil.

Do you see any living organisms, such as earthworms, spiders or fungi?

Are roots uninhibited in terms of growth, or do you see roots moving horizontally across the soil rather than straight down?

Summarize any past soil test results and describe management adjustments you made to address issues.

OBSERVE, ASSESS AND THEN ADDRESS

Make an effort to routinely evaluate, whether that's through a lab test, field measurement or observation, the indicators that help you keep soil health in check.

"Do a regular soil test every two to three years for phosphorus, potassium and organic matter," says soil scientist Larry Oldham of Mississippi State University Extension. "If you are using no-till, test the top 2" for pH and lime requirements, and monitor nutrient stratification from nutrient applications, in addition to the normal 6" sample for phosphorus, potassium and lime requirements."

The best soil health path is the one traveled step by step and field by field. Don't hesitate to ask for advice along the way.

SOIL COVER

OBSERVE: A layer of residue protects soil from the elements, reduces erosion and runoff, and helps maintain water-holding capacity. If the majority of soil is uncovered, you could lose topsoil — the most valuable layer with most of the nutrients plants need to thrive. The goal is to have an active root system or a blanket of protection as many days as possible to keep soil and nutrients put.

HOW TO ASSESS: Iowa State University Extension shares these methods to measure crop residue:

- **Line transect.** Count the number of times a marked line intersects with a piece of residue. Stretch a 50' to 100' tape measure at a 45° angle to the crop rows between two stakes. Looking from above the tape, count the number of times where a "foot" mark intersects with crop residue. Use only the left or right side of the foot mark on the tape to avoid over counting residue. The count directly converts into the percentage of residue remaining in that sample area. (Example: 38 occurrences of intersection equals 38% crop residue remaining).

- **Meter stick.** Throw a yardstick with metric markings into the air. Once the yardstick lands on the soil, evaluate at each centimeter mark the crop residue occurring along one edge of the yardstick. Total these measurements. (Example: if residue occurs at 35 centimeter marks, the residue remaining is 35%.)

- **Photo comparison.** Compare your fields' residue cover to these photos that show a known percentage of crop residue.

BEST PRACTICES TO ADDRESS: Reduced-till, no-till, cover crops, mulching, forage and biomass planting, prescribed grazing

Watch a time lapse photography project of fields across the U.S. to help understand how crop residues break down and the decomposition cycle.

SURFACE CRUSTING

OBSERVE: Surface crusting happens when surface aggregates are destroyed by water and disperse into smaller particles that fill pores and harden when dried. Surface crusting, which is related to soil texture, organic matter and sodium content, is more common on fine-textured soils. Surface crusting impacts plant emergence and uniformity of stand and reduces water infiltration.

HOW TO ASSESS:

- **Visual observation.** From the surface the soil will appear smooth and small polygonal plates will be prevalent. Use a spade to carefully scoop up a sample of crusted soil. Look for the horizontal layering of the clay particles from the side.
- **Penetrometer or wire flag.** A soil penetrometer measures penetration resistance of a soil crust. If you don't want to invest in a penetrometer, an 18" wire flag and a tape measure can achieve the same purpose.

BEST PRACTICES TO ADDRESS: Reduced-till, no-till cover crops, mulching, forage and biomass planting, prescribed grazing.

PONDING

OBSERVE: Ponding occurs in flat areas when water input is greater than water output, and the water can only be removed by percolation, transpiration or evaporation. Compaction can cause ponding, as can poor aggregation and the loss of surface pores.

"Water ponding on the surface creates an anaerobic situation in the soil that affects microbial activity and soil chemistry," explains soil scientist Larry Oldham of Mississippi State University Extension. "If a flood persists, there will be compaction issues."

HOW TO ASSESS:

- **Penetrometer or wire flag.** If you noticed ponding on your fields, first check for compaction, which can be done using a soil penetrometer. If you don't want to invest in a penetrometer, an 18" wire flag and a tape measure can measure the depth of compaction.
- **Infiltration test.** Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly might lead to ponding on level fields. A simple water infiltration test involves driving a 6" ring into the soil, pouring in a known volume of water and recording how long it takes to soak in the ground. Other supplies include plastic bottle, distilled water and a stopwatch/timer.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops.

An infiltration test involves driving a 6" ring into the soil, pouring in a known volume of water and recording how long it takes to soak in the ground.

COMPACTION

OBSERVE: Another physical property of soil is penetration resistance. You can think of it as compaction or soil strength. When soil is free of compaction and dense layers, it is easier for crop roots to penetrate. It's also easier for water to move upward, via capillary action.

Soil that crumbles without much force indicates water can percolate and easily reach roots. If soil does not easily crumble, it might indicate your soil is compacted. When soil is tightly packed it reduces pore space between soil particles, water infiltration and drainage rates. Roots expend more energy to penetrate soil until compaction reaches the point roots can no longer push through.

HOW TO ASSESS:

- **Penetrometer or wire flag.** Soil hardness, or compaction, can be measured with a soil penetrometer. If you don't want to invest in a penetrometer, an 18" wire flag and a tape measure can be used to measure the depth of compaction.

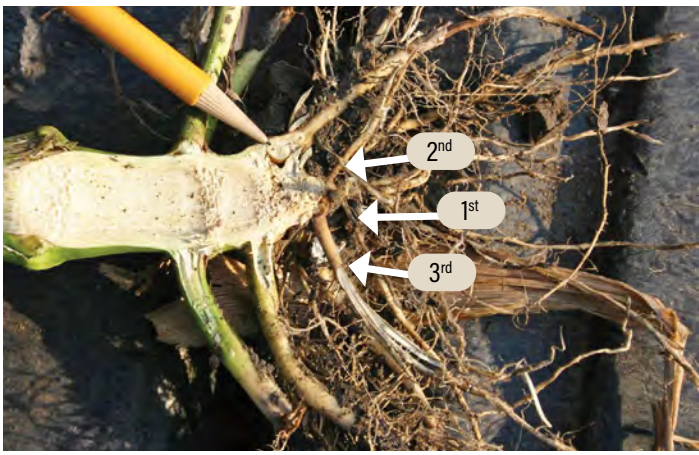
  "Measurements must be taken when the soil moisture is at field capacity because dry soil might show resistance without being compacted," says Ken Ferrie, Farm Journal Field Agronomist. "Look for resistance above 150 psi because that's the amount of hardness roots start to have difficulty penetrating."

- **Infiltration test.** Penetration resistance and water infiltration rate are related, but not always correlated. Slow infiltration might have little to do with soil compaction. However, it doesn't hurt to conduct an infiltration test to see what you learn. A simple water infiltration test involves driving a 6" ring into the soil, pouring in a known volume of water and recording how long it takes to soak in the ground. Other supplies include 500-mL plastic bottle or graduated cylinder, distilled water and a stopwatch/timer.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops.

PHOTOS: DARRELL SMITH AND CROP-TECH CONSULTING

A penetrometer measures soil resistance to penetration in pounds per square inch. Look for resistance above 150 psi.



Dig some corn root balls during the growing season. If the crown roots are growing horizontally, compaction could be the culprit.

AGGREGATE STABILITY

OBSERVE: Aggregate stability, a physical aspect of soil, is important for water infiltration and storage, gas exchange, plant growth and soil organism habitat. "Different sized aggregates create macropores, which hold water that can be extracted and used by plants and allow for excess water drainage and air exchange," says Farm Journal Field Agronomist Ken Ferrie. "Smaller pores, called micropores, also hold water, but it is bound tightly to soil particles and unavailable to plants."

"For practical purposes, the water-holding capacity determines how heavy a population you can plant — something you must understand to use variable-rate technology," he summarizes.

HOW TO ASSESS:

Aggregate stability can be determined by a lab, or you can verify with in-field tests.

- **Slake test.** The slake test measures the stability of soil when exposed to rapid wetting. This test is qualitative and should be measured using air-dried soil fragments or aggregates.

  "If soil is poorly aggregated, the onrush of water as you immerse the cylinder will blow the structure apart," Ferrie says. "Small silt and clay particles fall through the screen [top left photo, right cylinder]. The more the aggregate holds together, the healthier the soil and the more resistant it is to crusting."

  A sink strainer and clear Solo cups or plastic containers can also do the trick. Crush up soil to the size of peas and place in the strainer. Immerse the strainer in a cup of water. Once the soil is saturated, flip it out of the strainer onto a flat surface to compare.

  You can also purchase a Cornell University Sprinkle Infiltrometer (top right photo) to measure field infiltration and wet aggregate stability. Using the infiltrometer, you can apply a given amount of "rainfall" and measure how much soil slakes at that intensity and therefore falls through the screen. You can also measure water infiltration rates and resulting runoff with an accessory ring equipped with a hose (middle photo).

- **Air-dry clods.** Another way to assess structure is to air-dry clods from the same soil type but different management systems. Dunk the clods in a jar of water. In a healthy, crumb-like structure (bottom right photo), the soil holds together. With poor structure (bottom left photo), the soil falls apart when immersed in water.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops, prescribed grazing.

SOIL STRUCTURE

OBSERVE: If soil has good structure for its type, it will have large, medium and small macropores, all bonded together in a crumb-like structure that resembles cottage cheese. "Improving structure means creating more macropores," says Ken Ferrie, Farm Journal Field Agronomist.

Macropores are most important for aeration since plant roots and organisms need oxygen. Mesopores (medium) hold the majority of plant-available water. Micropores are small pores inside the crumb structure of soil, but they hold very little usable water or oxygen. Biopores are channels in the soil where roots decomposed or worms/other organisms once were. All pores provide habitat to diverse soil organisms.

"As soils health improves, the structure improves downward through the profile. The deeper we improve the structure, the healthier and more resilient our crop will become," Ferrie says. "The process takes a long time and serious commitment to following the four principles of soil health."

HOW TO ASSESS: Dig a small hole, about 1' deep, then slice a spadeful of soil from the wall of the hole and observe. Look for changes in color to indicate different horizons, and look at structure in each horizon. See if the soil is crumbly or cloddy.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops.

SOIL COLOR

OBSERVE: In general, darker soils indicate higher levels of organic matter versus lighter ones. Organic matter is a driver of biologically active soil and contributes to the soil's capacity to serve as a reservoir of nutrients, reduce compaction and surface crusting and increase water filtration.

HOW TO ASSESS:

- **Color chart.** You can measure the amount of organic matter in soil by comparing it to a simple color chart — but Ferrie recommends a lab analysis for repeatable results. Use the same lab each time and be mindful of sampling depth, he adds.
- **Visual assessment.** When assessing soil color, compare the same soil type from two areas that have been managed differently. For example, compare the color of the soil in a field you actively farm to the same soil in an undisturbed area, such as a fence row or field edge.

PRACTICES TO ADDRESS CONCERNS: Crop rotation, reduced-till, no-till, cover crops.

SOIL TEXTURE

OBSERVE: Soil texture influences pore size, water infiltration rate, available water capacity, permeability, cation exchange capacity and how much organic carbon a soil can hold on to, explains Thomas Zerebny with Crop-Tech Consulting. You can't change soil texture through management, but management does affect structure and aggregation, which modify the effects of texture on pores and water dynamics.

Soils are classified according to the proportions of each of the three sizes of particles they contain. The highest proportion is listed first, as in "silty clay loam."

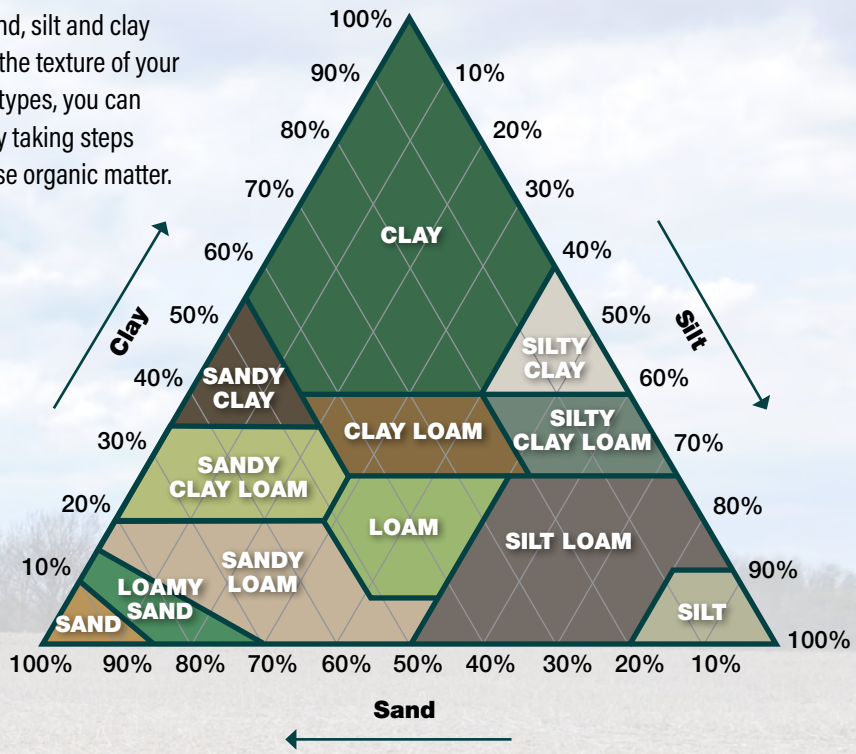
HOW TO ASSESS:

- **Web Soil Survey.** Operated by USDA-NRCS, Web Soil Survey is a simple way to access and use soil maps and data to determine soil texture.

- **SoilWeb.** In partnership with the University of California–Davis, USDA-NRCS created the SoilWeb app, which you can download for free from Google Play and Apple. The app uses GPS technology to pull up data on the soil, including texture, where you stand.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops, prescribed grazing, nutrient management, integrated pest management.

The percentage of sand, silt and clay particles determines the texture of your soil. Within most soil types, you can improve soil health by taking steps to protect and increase organic matter.



BIOLOGICAL ACTIVITY

DESCRIPTION: Biologically active soils are healthy soils. The presence of fungi, earthworms and other beneficial soil organisms indicates soil is healthy and able to support a robust, beneficial ecosystem — as well as productive crop growth.

HOW TO ASSESS:

- **Soil Biological Respiration and Nitrification (BRAN) test.** The BRAN test measures carbon dioxide respiration by soil microbes, which is fueled by the active carbon portion of the organic matter in the soil. It estimates the quantity of nitrogen released per year and the degree of biological activity in the soil. Many labs measure soil respiration rates, which correlates with potentially mineralizable nitrogen. The higher the rate, the higher the mineralizable nitrogen.

- **Mineralizable nitrogen.** Mineralized nitrogen is nitrogen in the ammonium form, which plants and microbes can use. It might be provided by soil organic matter during the growing season. "If you know the soil's potential to mineralize nitrogen, temperature and moisture conditions, it will indicate how much ammonium nitrogen will become available," says Farm Journal Field Agronomist Ken Ferrie. "That will help you decide whether to make a late-season nitrogen application."

  Nitrogen availability changes daily in humid regions based on rainfall and temperature, so snapshot tests for nitrogen-use efficiency, such as the Illinois Soil Nitrogen Test, the Cornell University Potentially Mineralizable Nitrogen Test or a stalk nitrate test after harvest, can provide insights. It's a good idea to pull a preplant nitrogen test or pre-sidedress nitrogen test to reduce overapplication.

  Newer dynamic nitrogen modeling approaches are becoming increasingly available to recommend sidedress amounts based on daily weather conditions and specific management factors.

- **PLFA and EL-FAME test.** Phospholipid fatty acids (PLFA) are an essential structural component of all microbial cellular membranes. A PLFA analysis of soil is offered by some commercial labs. However, a newer method, the ester-linked fatty acid methyl ester profile (EL-FAME), provides essentially the same information and is less expensive per sample to conduct.

- **Handheld carbon dioxide meter.** Put soil in a sealed container, insert the wand of a carbon dioxide meter and measure the amount of carbon dioxide respired over a period of time.

- Solvita Soil CO_2 Burst Test Kit. Dry, weigh and moisten samples of soil and seal them in a plastic jar. Read a color-sensitive tab to determine the amount of carbon dioxide given off.

- **Earthworm measurements**. Earthworms are most active in the spring and fall. Conduct a quick assessment of the earthworm population in a field using tap water, a shovel, a large jar and a mustard solution.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops, mulching, prescribed grazing, nutrient management, integrated pest management.

PLANT ROOTS

OBSERVE: Roots that have grown uninhibited appear white in color and have fine roots growing off of the main root. Roots with a bend or are J-shaped indicate the root hit a restrictive layer and could not penetrate the soil further. This could mean your soil is compacted, which limits percolation of water through the soil and the potential productivity of your crop.

HOW TO ASSESS: Dig a hole about 1' deep. Look at the plant roots in the hole and a spade slice of soil. Dig down along a plant stem to get a better look at the roots. The roots should be well branched with lots of fine root hairs. Look for roots with a bend/J-shaped, balled up roots or roots growing sideways. A lack of fine root hairs indicates oxygen deprivation in the root zone. Lateral root growth indicates a hardpan or compacted layer.

BEST PRACTICES TO ADDRESS: Crop rotation, reduced-till, no-till, cover crops, forage and biomass planting, prescribed grazing.

ADDITIONAL LAB ANALYSES

Lab methods are not intended to be used on an annual basis but rather to obtain baseline measurements that can inform soil health management and then evaluate every few years. Available tests vary by lab, but the following are often options:

Chemical:

- ☐ Nitrogen
- ☐ Phosphorus
- ☐ Potassium
- ☐ pH
- ☐ Micronutrients
- ☐ Water pH
- ☐ Buffer pH
- ☐ Cation exchange capacity
- ☐ Electrical conductivity

Physical:

- ☐ Aggregate stability
- ☐ Texture
- ☐ Water capacity
- ☐ Surface and sub-surface hardness
- ☐ Bulk density

Biological:

- ☐ Total organic matter (carbon)
- ☐ Active organic matter (active carbon)
- ☐ Mineralizable nitrogen
- ☐ Root health assessment
- ☐ Respiration
- ☐ Soil protein content
- ☐ Microbe analysis

BEST PRACTICES TO IMPROVE SOIL HEALTH

PHOTO: LINDSEY POUND

When you better understand the various aspects of soil health, you can start improving it using a host of best practices.

"A good place to begin might be balancing fertility and pH levels and removing compacted layers," says Ken Ferrie, Farm Journal Field Agronomist. "Improve infiltration if you and any landlords can afford the investment."

After that, it's best to tailor additional practices to specific fields or farms.

Whether you're just getting started or advanced in your soil health practices, avoid looking for magic bullets, says soil scientist Larry Oldham of Mississippi State University Extension.

"Crop rotations, residue management, cover crops and reduced tillage are still effective," Oldham points out. "When it comes to the effectiveness of something, new soil tests, cover crop mixtures, etc., always ask for evidence."

Bear in mind the role of an even scarcer resource that impacts all management decisions — time.

"Changes are unlikely to be evident over short time frames; soils are complex systems and do not change suddenly," Oldham explains.

Invest with a long view, and you're more likely to recognize the value of your efforts.

"Some day our kids and grandkids will farm these fields," Ferrie says. "Our goal is to leave a healthy, profitable and sustainable farm — that's what we have to keep in mind as we invest our time, money and effort today."

Assess Soil Health Best Practices for Your Operation

As you review this section, keep an open mind and challenge yourself to answer the questions for each of the best practices that might have a place on your farm — or even in one field. Stay curious and keep notes.

BEST PRACTICE: CROP ROTATION

Crop rotation is the practice of sequential planting of different crops in the same field year after year. Potential benefits of this practice include improved crop yield, soil nutrients and soil structure; reduced soil erosion; and lower incidence and intensity of pests and diseases. If implemented properly, the financial benefits are usually recognized in reduced fertilizer and pesticide inputs.

"Alternating monocot (grasses such as corn) and dicot (soybeans, cotton) rooting systems within cropping systems has been shown to improve soil hydrological properties and soil organic carbon," says Larry Oldham of Mississippi State University Extension.

There are two general types of crop rotation plans — the simple rotation of two or three crops such as corn and soy or the complex rotation of dozens of crops such as corn, wheat, oats and other small grains. Rotation of at least three distinct crops over five years is optimal.

When studying various crop rotations, consider the nitrogen requirement for the crops. For example, corn is a nitrogen-demanding crop. As corn grows, it extracts nitrogen from the soil that will need to be replenished after harvest. Planting soybeans, a nitrogen-fixing crop, adds nitrogen back into the soil by converting atmospheric nitrogen to a form usable by the plant.

The key with crop rotations is acknowledging different plants have different nutritional needs and are susceptible to specific pathogens and pests.

By rotating crops, you return nutrients to the soil, playing to the natural, inherent strengths of the crops and reducing the amount of purchased inputs needed to grow a productive crop.

Does your crop rotation for a particular field include three different crops over a five-year period? If not, what crop(s) could you add to the rotation?

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Could you benefit from reducing input costs? Does pest pressure seem to be getting out of hand?

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For additional information, visit:

- Dakota Lakes Research Farm Crop Rotation Tool
- Conservation Crop Rotation on Norwood Farms
- Conservation Groups Studying Extended Crop Rotations

BEST PRACTICE: REDUCED TILLAGE

"Too much tillage can destroy soil," says Ken Ferrie, Farm Journal Field Agronomist. "The more abrasive the tillage tool, such as a large offset disk, as opposed to a chisel plow, the more you will damage soil structure and destroy residue."

Reducing tillage means fewer passes through the field and decreasing the intensity of the passes, which can slow the loss of organic matter, increase energy savings and reduce compaction and the need for inputs.

Jodi DeJong-Hughes, a University of Minnesota Extension researcher, believes it doesn't have to be no-till or nothing — every farmer can reduce their tillage.

"Reduce the number of passes, reduce how aggressive the machine is or reduce the depth it goes into the soil," she says.

There are several types of reduced tillage, including mulch-, ridge-, strip- and vertical-till. Reduced tillage should leave at least two thirds of the surface covered with residue after planting.

The biggest hindrance for a lot of people is not soil, according to DeJong-Hughes. It's tradition. Especially for people who might have tried to reduce tillage a long time ago to no avail, it's easy to be discouraged from trying again. However, in the past decade a lot has changed, including equipment, seed genetics, seed treatments and weed, disease and insect resistance.

What am I trying to accomplish using tillage?

What planter or equipment changes will be necessary?

What residue, fertilizer, weed, disease and insect management changes will be necessary?

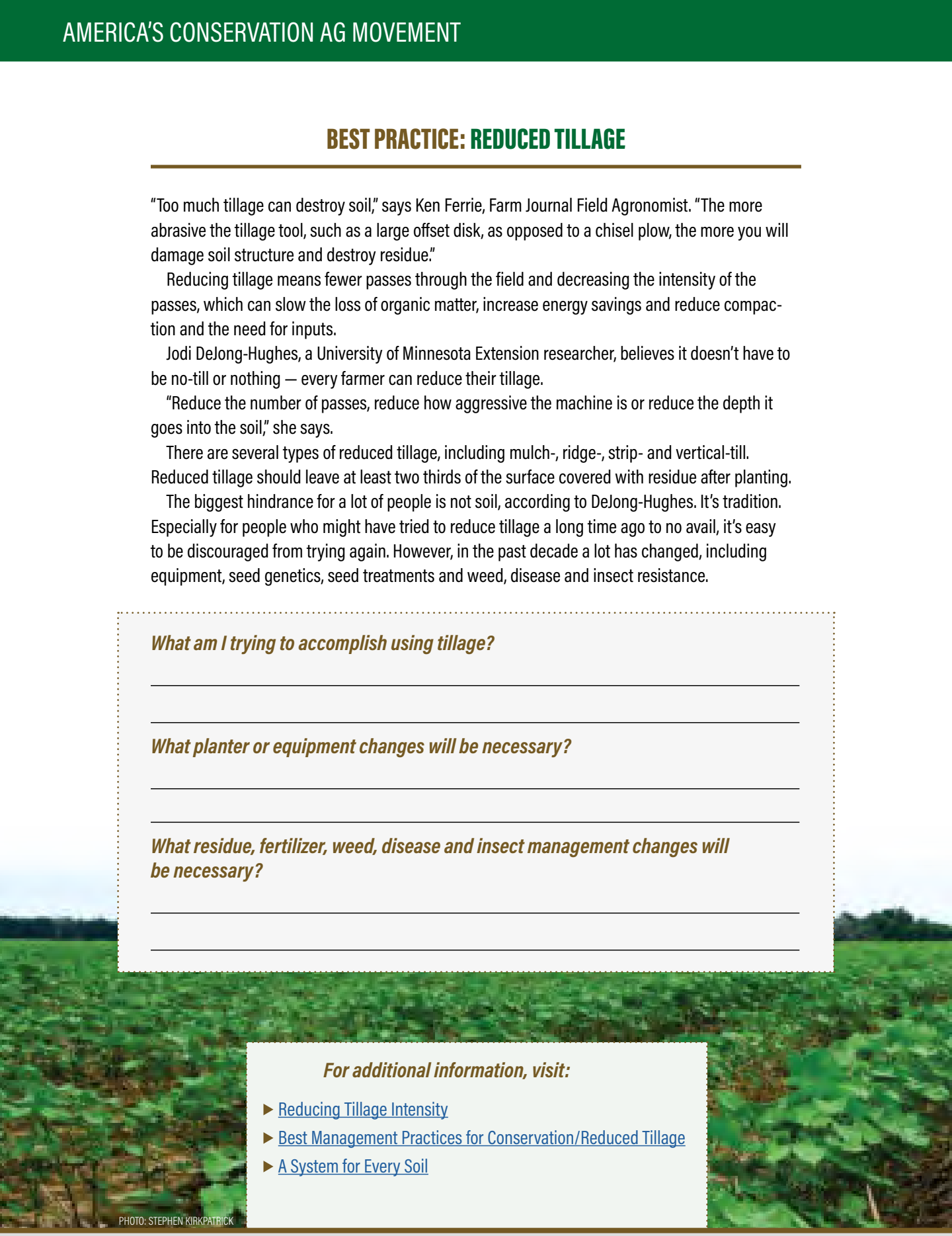

PHOTO: STEPHEN KIRKPATRICK

For additional information, visit:

- Reducing Tillage Intensity
- Best Management Practices for Conservation/Reduced Tillage
- A System for Every Soil

BEST PRACTICE: NO-TILL

According to a 2017 USDA-NRCS report, switching from continuous conventional-till to seasonal no-till saves a little more than 3.2 gal. of fuel per acre, but the benefits of no-till extend beyond fuel savings. Fields that have been no-tilled for multiple years generally have a higher water-holding capacity than conventionally tilled fields. No-till adoption also reduces soil erosion, increases soil biological activity and increases soil organic matter.

"No-till takes some time to get used to and the fields can be hard to look at the first couple of years," says Debbie Borg, a farmer from Allen, Neb., who adopted no-till practices more than 35 years ago. "The improvements don't happen in one year. It's a marathon, and sometimes there's a little pain, but once you get over it there are many benefits."

Farm Journal Field Agronomist Ken Ferrie recommends spending up to three years to prepare soil for no-till planting. "The first step is to dig in your field and examine soil structure and root growth to identify dense layers," he says. "Dense layers can be removed by using cover crops with roots that penetrate compacted layers and stabilize new pores, equipment or a combination of both."

Do you plan to include cover crops in your management practices?

How might no-till impact your fertility program, such as fertilizer placement?

On which of your fields would it make the most sense to try no-till for the first time?

For additional information, visit:

- Saving Money, Time and Soil: The Economics of No-Till Farming
- No-Till Practices on Hitchens Farm
- The Dirty Dozen No-Till Misconceptions

BEST PRACTICE: COVER CROPS

Cover crops, in conjunction with no-till, have the highest potential to improve soil health, says Ken Ferrie, Farm Journal Field Agronomist.

"Cover crops can provide diversity for soil microbes; improve soil aggregation, water infiltration and storage; suppress weeds; reduce soil erosion; and recycle crop nutrients so they won't escape and pollute water sources," he says. "But just like adding new cash crops to your rotation, cover crops require knowledge and good management to be successful — so do your homework first."

On your first attempt, Ferrie suggests planting a cover crop that's easy to manage, and start with a few acres. "Don't expect to see benefits the first year, but they could be there. It usually takes three years to see definite results from cover crops," he adds.

What do you want to accomplish with a cover crop?

Which cover crop will you plant? ***(Don't forget to consider the potential impact of your herbicide program and the cash crop to follow.)***

How will you plant the cover crop (drill, airplane, etc.) and when?

When and how will you terminate the cover crop?

Will you need to restructure your nitrogen and fertilizer program to handle a carbon penalty resulting from cover crop residue?

For additional information, visit:

- Midwest Cover Crops Council
- Cover Crop Practices on Roberts Farms
- Real-World Soil Health Builders

PHOTO: LINDSEY POUND

BEST PRACTICE: NUTRIENT MANAGEMENT

Nutrient management should be part of a soil health plan to improve organic matter levels, aggregate stability and soil structure, infiltration, drainage and aeration, soil biological activity and water use efficiency. As tillage is reduced, biological communities and activity change. Adapting the 4Rs of nutrient stewardship to complement the change in biological nutrient delivery, and better physical soil functioning, is key to sustaining yield during the transition from full width tillage.

One of the first steps to manage nutrients in your fields is to understand how they are lost. For example, most nutrients are lost with water leaching down through the soil profile, through tile lines or via the air through denitrification.

"Water moves faster through coarse soils, such as sand and sandy loam, than it does through heavier soil, such as clay loam," explains Ken Ferrie, Farm Journal Field Agronomist. "The faster it flows, the easier it is to flush out the nutrients."

Surface runoff and soil erosion account for the highest level of phosphorus loss because phosphorus leaves fields attached to soil particles, he adds.

Ferrie suggests starting with these steps to put nutrient management practices into motion:

1. Determine what type of tillage, if any, is best when and where to avoid creating erosion.
2. Base all fertilizer applications, whether commercial fertilizer or manure, on a sound soil test.
3. Assess the risk of nutrient loss for every soil type you farm.
4. Timing your nitrogen application is just as important as the equipment you use.
5. Apply less lime more often and use the correct nitrogen stabilizer. Understand your nitrogen source, too.

Which of the above five steps might deserve more attention on specific fields?

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_____

How might you use variable-rate technology to manage nutrients?

_____

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For additional information, visit:

- 4Rs in the Field – Strom Family Farms
- Soil Health Paves Road to Profit
- A New Era of Nutrient Management

BEST PRACTICE: INTEGRATED PEST MANAGEMENT

A good practice to incorporate into a soil health management system is integrated pest management (IPM). The term refers to a holistic system of preventing, avoiding, monitoring and suppressing pests. Pesticides can kill or reduce the vigor of macro and microorganisms in the soil. IPM can reduce pesticide use, which in turn can improve the health of organisms and ultimately soil health.

How are pests and soils connected? Simply put, good soil health — defined in part by conservation crop rotation and healthy organic matter — supports healthy plants.

"Soil testing gives growers the knowledge they need to amend soils correctly, so that crops will grow under optimal conditions," explains Rachel Maccini, pesticide safety education program coordinator, University of New Hampshire. "Strong, healthy plants resist disease and insect attack."

A good habitat for beneficial organisms is also important to keep predator/prey relationships in balance. Avoid preventative or insurance approaches to pest management when practical as they can have unintended detrimental consequences to beneficial organisms important to keeping pests in check.

A variety of practices can help you manage pests on top of a foundation of healthy soil, according to the Integrated Pest Management Institute of North America. For example:

- Trap pests to monitor pest trends and plan around increasing pest pressure.
- Use weather forecasts to gauge when outbreaks might occur, allowing you to plan treatments of pesticides or other products and ensuring you only spray when needed.
- Assess the potential economic impact of pests and avoid treatments until you arrive at this threshold. "Until that threshold is reached, the cost of yield and quality loss will be less than the cost for control," the institute notes.
- Keep records of your traps, weather conditions and treatment strategy to inform future management choices.

To what degree am I using this best practice today?

What additional information do I need about this practice to evaluate its application and potential benefits on my farm?

For additional information, visit:

- NRCS Integrated Pest Management Overview
- What is Integrated Pest Management
- Integrated Pest Management and Soil Health

PHOTO: USDA

BEST PRACTICE: FORAGE AND BIOMASS PLANTING

Whether you seed grass and legumes for pasture and hay for livestock or for production of biomass to be used in renewable energy production it helps reduce erosion. The living root promotes water infiltration. As the plants die, they provide further organic matter that decomposes in the soil.

To get the most out of forage and biomass planting, be sure to:

- Follow recommendations from a trusted adviser on planting rates, methods and dates.
- Explore which plants fit best based on management, environment and yield considerations.
- Defer grazing until plants are well established, and avoid initial grazing when fields are wet.
- Assess whether these plantings are compatible with other species in the field.
- Plant when soil moisture is just right and at the right depth for uniform seed-to-soil contact.
- Try a pre-inoculated seed or use a Rhizobia strain suited for the field before you plant legumes.

"Be prepared to feed or stockpile graze a little longer into spring so you have adequate growth before turning out livestock. That means perennial pastures with at least 8" of growth," explains Allen Williams, an Alabama cattleman and founding partner of Understanding Ag. "If you must graze too early, then do what I call a 'flash' or 'tickle' graze where you rapidly move the livestock through the pastures. Don't let them consume more than 30% of the total forage biomass. This stimulates soil biology and jump-starts forage growth."

Can my soil types and climate/weather support these plants?

Will the plants be beneficial to any livestock once well established?

If I plant perennials, can I ensure enough plant tissue will remain postharvest to continue to grow through photosynthesis?

For additional information, visit:

- Forage and Biomass Planting on Sites Farms
- Conservation Choices: Forage and Biomass Planting
- A Simple Method to Estimate Plant Biomass for Grazing

BEST PRACTICE: PRESCRIBED GRAZING

If some of your pastures have low biomass, a high number of weed species and limited grazing days, prescribed grazing can help address those challenges. The practice can also increase ground cover and root growth, which increases soil organic matter. The process involves dividing a bigger pasture into manageable pastures. You then move cattle or other livestock through each paddock based on the availability of specific forages and the nutritional needs of animals.

"A well-managed rotational grazing system will see an increase in desirable grass and pasture yield, prolonged grazing days and a reduction in hay feeding cost," explains Tong Wang, South Dakota State University Extension advanced production specialist. "Other benefits include decrease in runoff and erosion, faster drought recovery and increase in stocking rate capacity."

To get the most out of this practice, you'll want to ensure a grazing plan is in place. The plan should capture your goals and objectives for soil health, pasture quality and animal nutrition.

What do I know about each paddock, such as forage quality, quantity and species?

What is the carrying capacity of this pasture?

What wildlife of concern, if any, are known to call this pasture home?

How might I adjust my grazing plan in a drought, in a flood or under insect pressure?

What schedule should I use to assess data on grazing to adjust as needed?

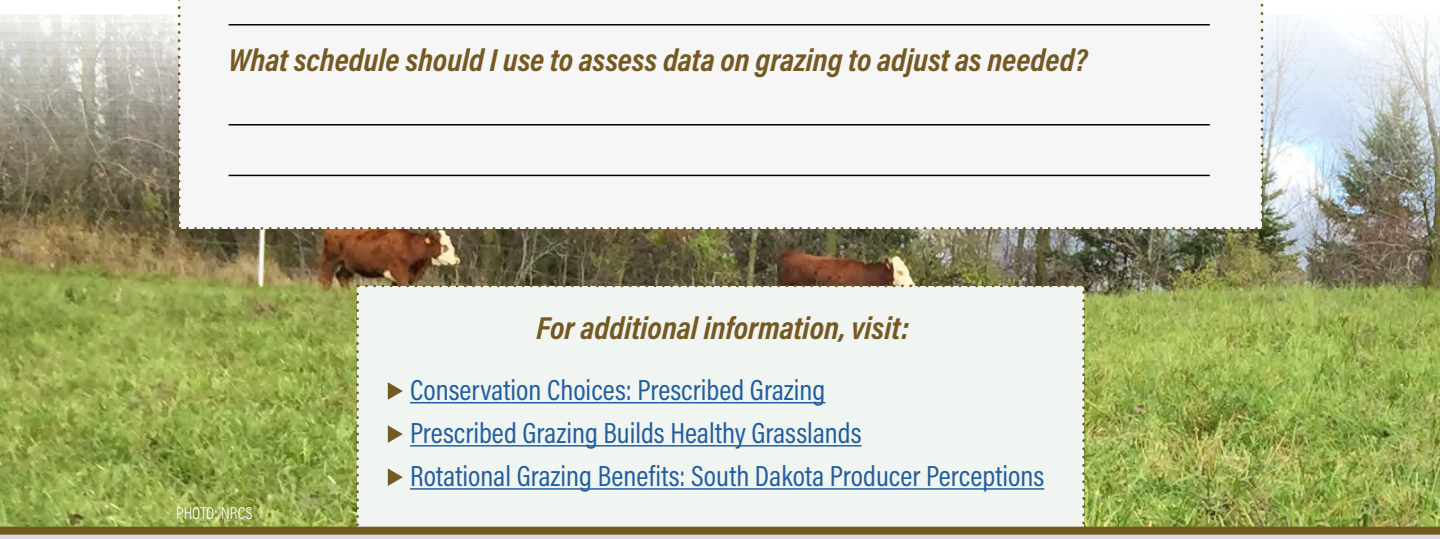

PHOTO: NRCS

For additional information, visit:

- Conservation Choices: Prescribed Grazing
- Prescribed Grazing Builds Healthy Grasslands
- Rotational Grazing Benefits: South Dakota Producer Perceptions

BEST PRACTICE: PRESCRIBED BURNING

Fire is often seen as a destructive force, but it can play an important role in natural processes. The key is to manage the burning process to yield specific results, otherwise known as prescribed burning.

"Prescribed burning releases beneficial nutrients into the soil that are otherwise locked away in dead plant material," says Ariel Cowan, central Oregon regional fire specialist, Oregon State University Forestry and Natural Resources Extension Fire Program. "Depending on the amount of heat and plant material, prescribed burning can increase soil microbial resilience over time. Soil heating can trigger certain types of microbial growth that aid in absorbing released nutrients before being washed away, thus making nutrients more available to plants."

The benefits of prescribed burning on soil health depend on your region, soil type, vegetation, burn frequency and other factors, Cowan says.

When it comes to incorporating prescribed burning into your management plan, work with a specialist to determine the best plan for your operation.

"There are several types of land where prescribed burning can be conducted, including forestlands, rangelands, agricultural lands, wildlife habitat, tribal lands, and other natural, cultural and working landscapes," says Amanda Rau, Willamette Valley/North Cascades regional fire specialist, Oregon State University Forestry and Natural Resources Extension Fire Program.

When incorporating prescribed burning into a management plan, Rau advises:

- Prepare a plan in advance and follow it.
- Select the area where you will conduct prescribed burning.
- Prepare the area to keep the fire within the desired boundaries.
- Assess the weather to ensure burning can be done under proper environmental conditions.
- Apply appropriate public and personnel safety precautions.

Could prescribed burning benefit soil health on your operation?

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Who can you contact to learn more about prescribed burning and/or prepare a plan?

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For additional information, visit:

- Managing the Land with Prescribed Fire
- USDA's Prescribed Burning Overview
- The Value of Fire

GOOD TESTS START WITH GOOD SAMPLES

Before gathering samples, map out each field in your operation, if you haven't already. Outline areas where you know soil type varies as well as marginal acres and trees. Then, use GPS to mark five to eight spots in each zone where you intend to take samples, or five to eight spots across the entire field. Keep a record of these spots for future reference.

Once you collect the soil samples, mix your zone or field samples to get a composite for that area. Don't forget to label the container so you can recall the origin of the samples.

1. **Make sure your collection tools are clean and dry.** Even the smallest amount of stray residue, such as trace amounts of lime, fertilizer or plants, can skew results.

2. **Test the soil you actively farm.** Avoid taking samples from overly wet areas and areas where brush has been burned or wildlife frequent.

3. **Take notes.** Document plant stage if sampling while plants are growing, GDD, etc.

Map It Out: Visualize Your Productivity

A farm map is a great tool to help you visualize your operation as a whole. If you don't have a farm map, here are four ways to get one:

- **Visit your local USDA service center and talk to the Farm Service Agency staff.** They can help you obtain maps for each of your fields, identify production versus non-production areas, home in on the zones and figure number of acres of each area.
- **Use an internet mapping website such as Google Maps.** Type in the address, zoom in on the desired field and capture a screenshot. Print out the picture and outline the zones based on where the field varies.
- **Hire a service to take aerial pictures of your fields using drones or satellites.**
- **Draw maps yourself.** You can easily map out your fields on paper and use it to identify zones within each field.

FOCUS ON SOIL HEALTH PRACTICE BY PRACTICE

Soil is common to every farm and ranch — yet no two soils are alike. That presents a unique opportunity: You can learn from the soil management experiences of peers and then apply those learnings to your unique operation. It all starts with the four principles of soil health: maximize soil cover, minimize soil disturbance, keep living roots in the soil and maximize biodiversity.

FARMER PROFILE: MIKE LANGSETH

When Mike Langseth began farming with his dad, their operation already had integrated several soil health principles. Yet Langseth saw the potential for more. His dad had been no-tilling soybeans for quite a while, spurred on by studies from North Dakota State University indicating "beans really didn't care if the ground was black or not."

At the time, they ran a full-width tillage tool, either a disk or a field cultivator, on soybean ground before planting corn.

"When I got involved with the operation, I started to look at things a little bit," shares Langseth, speaking on the "Field Work" podcast. "'Why are we doing this, exactly?'" Langseth asked himself.

Those questions, plus soils classes at the university, led Langseth to participate in a tillage study. Over four years, he and his researcher colleagues assessed different tillage types at multiple sites on different soil types. The results were a game-changer.

"The thing I was quite surprised to find was at the end of the day, yield wise, there wasn't much difference across the sites," Langseth says. "That gave me permission, in my mind, to see how much I could reduce tillage and how much labor, fuel and time I could save."

Langseth didn't have to invest a lot of money to shift toward less tillage. He did invest ample time to assess how the decision would affect his equipment and related attachments.

"The last time we traded corn heads, we made sure we got one that didn't chop because the more a corn stalk stands upright, the less of it you have to fight on the ground when you're trying to plant soybeans," Langseth says. "The only thing we really spent new money on, because we had the single disk opener style no-till bean drill, was a nice set of floating row cleaners for the planter."

"Every time you do anything on the farm, ask yourself: What am I getting out of this?"
~Mike Langseth, Barney, N.D.

Langseth encourages farmers to allow themselves to think differently.

"Every time you do anything on the farm, ask yourself: What am I getting out of this? This tillage pass — what am I accomplishing? If your answer is, 'Well, I'm not really sure,' then you should think again about doing that pass."

FARMER PROFILES: ERIC RADEMACHER & CHRIS DERR

Eric Rademacher is putting no-till and cover crops to work on his 560 acres of winter wheat, corn and soybeans in Gifford, Ill.

With a close eye on finances, he says a systems approach to farming has led to a reduction in costs and an increase in efficiency. Part of his systems approach includes planting non-GMO corn and soybeans to reduce seed cost and sell grain for a premium.

Rademacher's focus to improve soil heath with no-till practices and cover crops has reaped the following benefits:

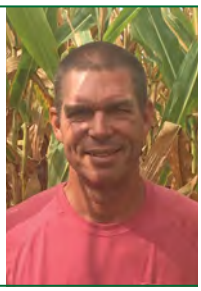
- An increase in the biological activity.
- An increase in water-holding capacity, water infiltration and nutrient cycling.
- The elimination of dry fertilizers. All starter fertilizer and UAN for corn are placed within 3" of the plant.
- A reduction in weed pressure.
- A reduction in white mold in soybeans almost immediately, and in some fields, it has been completely eliminated.
- A reduction in herbicide costs.
- A reduction in the use of insecticides. Instead, he is trying to promote beneficial insects in the ecosystem.

Through it all, Rademacher has found the soil has the ability to efficiently grow crops as he minimizes synthetic inputs.

Thus far on his journey to improve soil health, he purchased a roller crimper, is making use of variable-rate nitrogen, based on the Illinois Soil Nitrate Test, and he purchased a no-till drill to plant cover crops and wheat.

"We've reduced weed pressure and reduced or eliminated white mold in soybeans."

~Eric Rademacher, Gifford, Ill.



"With weather being so unpredictable, I want to protect the soil and hold onto moisture."

~Chris Derr, Middletown, Md.

A SYSTEMS APPROACH

Eastward in Middletown, Md., farmer Chris Derr runs a dairy operation with corn, soybeans, barley, BMR sorghum sudangrass and mixed hay on 200 acres. He uses no-till and cover crops to keep soil disturbance at a minimum.

"With weather being so unpredictable, I want to do whatever I can to protect the soil and hold onto moisture," Derr explains. "Building organic matter, reducing weed pressure and minimizing compaction are other reasons I make it a part of my operation."

Cover crops planted to keep fields green longer are paying off for Derr. He defines the return on investment of his soil health management system as: "Having even crop stands and being able to keep crops going during a dry spell."

To make the system work, Derr upgraded his planters to handle more residue and he invests in cover crop seed mixes.

"Cover crop combinations are the most important aspect of the system," he says. "Our goal is to keep our cover crop seed cost below $25 per acre. We also find it necessary to plant early maturing crops to get our covers established as early as possible in the fall."

FARMER PROFILES: BRYAN AND NICK JORGENSEN

"Diverse [forage] blends help grazing animals build and balance their own rations."
~Bryan Jorgensen, Ideal, S.D.

The foundation of Jorgensen Land & Cattle's approach to soil health — based in part on incorporating diverse forages — is a recognition that diversity is an important part of nature. "Second, from an animal nutrition aspect, diverse blends help grazing animals build and balance their own rations," explains Bryan Jorgensen, chief agronomy operations officer at the ranch based in Ideal, S.D. "Third, from the soil health perspective, having a diverse blend of plant species is important in helping build a more diverse soil biological community and thereby, increasing total carbon cycling in the soil system."

The ranch spends $20 to $80 per acre on seed for forages and cover crops. Higher-priced varieties tend to be full season and used for intense grazing in the summer and fall. Lower-cost varieties are seeded behind winter wheat for grazing mid-to-late fall through mid-winter. Substantial investments in fencing and watering facilities ensure cattle are able to graze most cropping areas.

According to Nick Jorgensen, CEO and CFO, native grass species returned to the ecosystem when they implemented rotational grazing and forage plantings. "We have found grazing forages and residues can increase organic matter 0.5% per year on average, and up to 1% in some cases," he says.

FARMER PROFILE: KEITH LONG

"Keeping livestock on the tall grass prairie keeps it healthy."
~Keith Long, Latham, Kan.

Prescribed grazing and burning on land in the Flint Hills of Kansas helps cattle and sheep rancher Keith Long keep invasive woody species, such as eastern red cedar, under control.

"It is inexpensive compared with mechanical or chemical brush control, and it is relatively easy to implement," Long says. Because he leases his land, investments to adopt these practices have been relatively minimal, primarily electric fencing materials and ATVs. Prescribed grazing happens twice per year to ensure plants have time to recover during the growing season and to ration standing forage during dormancy.

The process of grazing and resting has been in place for more than 20 years, and Long began seeing benefits the first year with more grass growth in-season and more forage entering winter. Recovery of native forage species and wildlife habitat took longer, and he still thinks there is room for improvement in the return of grassland bird populations.

Long uses prescribed burning to a lesser degree than his neighbors because grazing provides many of the same benefits. Burning adds value by controlling brush and removing old forage, which allows lands to green up a little faster in the spring. "This benefits the stocker cattle operators more than the cow-calf operations, however," he says.

HOW PRODUCTIVE SOILS CAN YIELD PROFIT

If you want to accelerate the economic benefits of soil health on your farm, it's important to at least run some back-of-the-napkin figures, including input costs and yield expectations, to establish a baseline. That will allow you to evaluate progress each year as you fine-tune your soil health system.

"I can see the wheels turning when we talk about a new practice as a farmer does the math to make sure it's a good fit or see how big of a risk financially it might be," explains Abbey Wick, soil health specialist at North Dakota State University (NDSU) Extension. "I'm not sure we'll ever have this broad number to tell a farmer they can save money using soil health practices, but I do think we can help them talk through the ideas to make them cost-effective for their operation."

A good foundation can also help farmers through challenging years, adds Dave Franzen, also a soil health specialist at NDSU.

"The healthy soil is more likely to yield better in extreme weather conditions, such as too wet or too dry," Franzen says. "The input costs to grow a crop are lower — less tillage, less nitrogen fertilizer, etc."

NRCS is collecting soil health economic case studies that show significant economic gains are being achieved by farmers who have successfully adopted soil health management systems in diverse production scenarios.

No matter where you stand in your soil-health journey, Wick and Franzen share practical steps at right to ensure you strengthen your financial position by paying attention to the underlying wellness of your soil.

"Healthy soil is more likely to yield better in extreme weather conditions. The input costs to grow a crop are lower."

—Dave Franzen, NDSU soil health specialist

PHOTO: NORTH DAKOTA STATE UNIVERSITY EXTENSION

FOR FARMERS JUST GETTING STARTED

- **Strive for progress rather than perfection.** "If you have to do something you didn't intend to do because conditions aren't ideal [such as tillage to repair ruts after a wet harvest], you might feel like you failed. Give yourself a break and pick up again next year," Wick says.

- **Manage risk with small steps.** Try a new practice on 20 acres versus 200 acres, Wick advises. For example, plant cereal rye, triticale or a mixture with oats to reduce termination issues. Talk to local experts and seek out resources. Ongoing learning can offset risk because it gives you better data.

FOR FARMERS WITH MODERATE EXPERIENCE

- **Fine-tune and scale.** Think about how practices you've tried successfully can be adjusted to work on different fields. This will help optimize your ROI across the operation. "For example, play around with reducing nitrogen rates, but always leave a check strip with the full rate so you know if you need to sidedress nitrogen," Wick recommends. Next-level experiments might also look like variable-rate cover crop planting or using different cover crop species or higher seeding rates on high clay soils and lower rates on sandier soils.

PHOTO: TIM RECKER

- **Play it smart.** Avoid getting glassy eyed with one conservation practice to help your soil. Doing so can prove costly if you fail to consider the business implication. "Keep your eye on the ultimate goal of farming, which in my opinion is to have a product to sell with a low cost of production while still protecting the environmental resources," Wick says.

FOR FARMERS WITH ADVANCED EXPERIENCE

- **Challenge yourself with diverse perspectives.** Once your farm advances to this stage, it will be difficult to make comparisons to other producers because every business is so different. Continue to build a network of people with diverse backgrounds with whom you can learn and share ideas and keep on track, Wick notes.

- **Experiment with precision focus.** Achieving a measure of soil health expertise can open the door to business ventures that might unlock new revenue streams. "A new specialty crop with a niche market may be introduced into the system, or broad-scale application of compost, integration of livestock or plenty of other out-of-the-box ideas," Wick says. "It's still important to continue trying new practices on small acres before talking large scale."

A FIELD MAKEOVER IN THE MAKING

Once upon a time there were two farms a mile apart. Both had the same silty clay loam and silt loam soils. Both used a corn/soybean rotation and no-till practices. However, Farm A had been no-tilled for three decades and Farm B for only two years (prior to that, it was farmed using horizontal tillage). The big difference: Farm A's corn yields were 70 bu. to 75 bu. per acre more than Farm B.

When Farm Journal Field Agronomist Ken Ferrie set out to address the yield discrepancy in 2011, he found it was in part linked to poor soil health.

To set Farm B on the path to better health, Ferrie used several tools and tests to identify problem areas. Chief among his concerns were surface and subsurface compaction, soil acidity, low biological activity and low nitrogen-supplying power.

1. DECIDE WHERE TO START

Soil density and acidity are the first issues Ferrie and the farm operator set out to address.

After evaluating the options, they decided to fix subsurface compaction and remove dense layers with deep tillage. To break up surface compaction and mix in limestone, they used a chisel plow as part of a vertical tillage system.

"Over the course of three years, we were able to make great strides toward uniform soil density," Ferrie says. "The operator was then able to put the field back into a no-till system for the most part."

To correct acidity and fix structural problems, lime was applied in the fall for three years and incorporated with fall vertical tillage. As a result, pH values increased from the 4.9-to-5.2 range to the 5.8-to-6.4 range.

"When a field gets extremely acid, it destroys structure and stops water infiltration," Ferrie says. "When we apply lime, we are attempting to flush out the acidity. If we have poor infiltration, we can't get water into the soil to make the lime work."

Aggressive vertical tillage, to mix in limestone and improve water and air infiltration, and correcting soil pH increased Farm B's corn yields to within 20 bu. to 30 bu. per acre of Farm A's yields in three seasons. The yield improvement also made the farm profitable.


Farm A


Farm B

Using Cornell University's Comprehensive Assessment of Soil Health, Farm B's silty clay loam rose from 48.3 to 59. The silt loam score climbed from 40.4 to 47 (out of 100).

2. ADDRESS THE HARD PARTS

Encouraged by the progress, Ferrie and Farm B's operator focused on improving the chemical and biological aspects of the soil.

That's where cover crops come in — to diversify soil microbes, suppress weeds, recycle nutrients and improve soil aggregation, water filtration and storage.

"Because the soil was acid for so long, and subjected to too much tillage, much of Farm B's soil structure was destroyed," Ferrie says. "We can't fix structure with a single treatment; although the lime applications helped because the calcium flocculates clay particles (while the carbonate corrects acidity)."

Poor structure causes soil particles to run together and seal. That leads to erosion and surface crusting, which leads to stand issues.

Ferrie and the operator decided to fly annual ryegrass seed into soybeans in 2015. Unfortunately, the cover crop failed to establish.

That fall, the farmer drilled cereal rye into cornstalks. "The timely seeding produced a good stand," Ferrie says. In the spring, he no-tilled soybeans into the cereal rye.

In the more productive silty clay loam, the cover crop had no effect on yield, but in the less productive silt loam soil there was a 1-bu. to 2-bu. increase.

The 2016 yield increase was not enough to pay for the cost of the cover crop, Ferrie notes. "But at least it wasn't a yield drag," he adds.

3. ANALYZE THE RESULTS

Attempting to explain the yield effect, Ferrie ran several soil health tests. The results for the water-soluble (ortho) phosphorus and aggregate stability tests provided a clue.

"Water-soluble phosphorus is a pretty good indicator of soil health," Ferrie says. "The increase from 1 ppm to 2 ppm in some locations is significant."

Under the cover crop, the aggregate stability score increased slightly. "Eventually, improvements in aggregate stability should result in improved water infiltration and the soil's carbon/nitrogen ratio," Ferrie says.

Farm B's operator continues to evaluate cover crops in plots across the 400-acre field.

"The days of deep tillage are history," Ferrie says. "The soybeans are no-tilling well. To address crusting issues when planting corn, we're still experimenting with cover crops in conjunction with no-till, strip-till and spring vertical till," Ferrie says.

He was aware of his soil's low nitrogen-supplying capacity, so the farm operator also implemented variable-rate fertility to make sure the crop never ran short.

"He applies nitrogen in his dry fertilizer, weed-and-feed treatment and starter fertilizer at planting," Ferrie says. "He sidedresses the rest, using soil nitrate tests to determine rate."

4. NARROW THE YIELD GAP

Gradual improvements in soil health has led to gradual improvements in yield. From 2017 to 2019, the yield gap between the two farms has steadily closed. In 2019, Farm B's corn yields ranged from 240 bu. to 270 bu. per acre, which is still 10 bu. to 15 bu. per acre behind Farm A. However, soybeans are within 5 bu. per acre.

"We're making headway with Farm B's soil health. Using the rain simulator, we know water infiltration has improved," Ferrie says. "The field's pH is more balanced."

Healthier soils create a more sustainable farm for future generations.

"That's the goal we have to keep in mind as we invest time, money and effort in improving soil health. It is worth the effort," Ferrie says.

ODDS AND ENDS LAND MATTER, TOO

They say absence makes the heart grow fonder. It's even true for farmland without crops or livestock, often referred to as associated agricultural land. Why should non-cropped acres tug at your soil health heartstrings? Strategically managing these areas can increase soil fertility, improve soil structure and reduce soil erosion.

Non-cropped acres can also offer economic and ecological perks, such as:

- Retention of in-field nutrients.
- Filtration of runoff resulting from weather events.
- Enhancement of wildlife and pollinator habitat.
- Establishing windbreaks for increased crop protection.
- Carbon capture and storage.
- Improved business efficiency by focusing on growing crops or livestock using only your most productive acres, rather than farming acres that drag down yields.

PHOTO: LINDSEY POUND

5 Programs to Advance Your Efforts

If you have non-cropped acres that could benefit from conservation, consider:

Conservation Stewardship Program (CSP)

- CSP, which operates on five-year contracts, helps farmers build upon their existing conservation efforts while fortifying their entire farm operation.

Conservation Reserve Program (CRP)

- CRP provides an annual rental payment to farmers for the removal of environmentally sensitive land from production and establishment of conservation practices such as grassed waterways, erosion control structures and buffers.

Environmental Quality Incentives Program (EQIP)

- EQIP provides financial and technical assistance for farmers interested in initiating conservation practices on their operation.

Conservation and Wildlife Easements

- An easement involves voluntarily selling or donating land rights to protect conservation values and provide public benefit while providing an economic return to the owner.

Carbon and Ecosystem Service Market Participation

- Carbon market participation incentivizes farmers to implement conservation practices that mitigate negative environmental consequences in exchange for payment.

AMERICA'S CONSERVATION AG MOVEMENT

Farmers leading the way on conservation: past, present and future

America's Conservation Ag Movement connects with more than 1 million farmers across our country's most essential value chain. Together with these partners, the Movement helps producers accelerate the on-farm adoption of stewardship practices that ensure more food, fuel, and fiber for Americans today, and healthy soil and clean water and air for future generations. Because conservation agriculture is just good business.

USDA United States Department of Agriculture
Natural Resources Conservation Service

www.farmers.gov
www.nrcs.usda.gov

USDA's Natural Resources Conservation Service provides America's farmers and ranchers with financial and technical assistance to voluntarily put conservation on the ground, not only helping the environment, but agricultural operations, too.

American Farmland Trust

www.farmland.org

American Farmland Trust was founded in 1980 to save America's farms and ranches. As leaders in conservation agriculture, we have three priorities: protecting farmland, promoting environmentally sound farming practices and keeping farmers on the land.

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At Corteva Agriscience, our purpose is to enrich the lives of those who produce and those who consume. We equip farmers with the solutions they need to produce what our food system and global population demands, while conserving resources and sustaining the land.

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DUCKS UNLIMITED

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www.usdairy.com/sustainability

NATIONAL CORN GROWERS ASSOCIATION

The National Corn Growers Association represents nearly 40,000 corn farmers nationwide and the interests of more than 300,000 growers who contribute through checkoff programs in their states. Our vision is to sustainably feed and fuel a growing world.

www.ncga.com

pork checkoff

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www.porkcares.org

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Sanderson Farms is committed to doing our part to promote a healthier planet. Our obligation to protect our environment by conserving natural resources, recycling resources utilized in our operation and creating renewable resources when possible is at the heart and soul of our farming process.

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The Nature Conservancy

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www.nature.org/workinglands

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