



TRANSITION TO ORGANIC COURSE

CHAPTER 2

SOILS

TABLE OF CONTENTS

INTRODUCTION	2
LESSON 1: HEALTHY SOIL	3
LESSON 2: MONITORING	9
LESSON 3: PRACTICES	15
LESSON 4: COMPOSTS	21
RESOURCES	29



Photo Credit: Jack Sherman

CHAPTER 2

SOILS

INTRODUCTION

OVERVIEW

In this chapter, I'll explain why it is important to build the soil as the foundation of your organic future. Investing in a healthy soil ecosystem creates a hospitable and beneficial environment that accumulates and pays dividends over time.

This chapter has four lessons:

- Healthy soil
- Soil monitoring
- Soil management practices
- Composts

By the end of this chapter, you will be able to identify healthy soil and its relationship to healthy crops, understand soil testing, understand soil management practices and begin filling out your Organic System Plan.



Photo Credit: Rodale Institute

Soils from our organic (right) and conventional (left) research plots are very different in appearance due to the increase in soil organic matter in the organically managed soils. The organic soil is darker and its aggregates more visible, compared to the conventionally managed soil.

LESSON 1: HEALTHY SOIL

OVERVIEW

No matter what soil type or types you have, a sound soil-building program that includes the wise use of tillage, attention to soil organic matter, and the use of crop rotations, cover crops, soil amendments and compost will improve the health of the soil. Furthermore, this improved soil health will translate into more predictable yields, higher-quality products and greater returns.

Your soil is the foundation of your organic future. The beauty of “farming the soil” is twofold: you increase your ability to succeed year after year, and you leave a legacy of fertility and resilience for the next generation of farmers.

Through our decades of farming and research, we have learned a lot about developing poor soil into healthy, productive soil. As we move

through this course, I’ll share that knowledge, along with the experience of other farmers and researchers around the country. Our goal is to help you make a successful transition to certified organic production.

By the end of this lesson, you should appreciate the importance of soil biodiversity and know how to develop a soil fertility plan in keeping with NOP Standards. Understanding soil biodiversity and fertility is critical to how you will meet your obligation to improve soil under the USDA organic standards.

WHAT THE STANDARDS SAY ABOUT SOIL MANAGEMENT

Organic regulations direct farmers to use practices that will sustain or improve soil conditions without causing pollution of crops, soil or water by contaminants or prohibited substances.

Section §[205.203](#) of the NOP Standards identifies objectives that serve to protect the soil and the environment. These include:

- “Select and implement tillage and cultivation practices that maintain or improve the physical, chemical and biological condition of soil and minimize erosion.”
- “Manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant materials.”
- “Manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.”

SOIL LIFE BOOSTS PRODUCTIVITY

Healthy soil is living soil. Biological activity and diversity are critical benchmarks of healthy soil because each soil organism has its own special functions. These soil organisms digest soil organic matter and convert it into substances used by plants and other soil organisms.

Soil is the most complex and diverse ecosystem on earth, with more than a billion

microorganisms representing some 10,000 species of life per thimbleful, all interconnected in complex food chains, breaking down organic matter into smaller and smaller “bites” that feed crop plants and act as storehouses for water and nutrients.

These living organisms in soil—including microorganisms like algae and fungi and macroorganisms such as worms and beneficial insects—form a “soil food web” that works very much like a spiderweb. The more strands this web contains, the more likely it is to catch food and hold nutrients. The more creatures you have eating and being eaten in your soil, the more nutrients will be cycling in the system and available to your plants.

Healthy soil means healthier and more productive crops. Organic farming practices improve soil cumulatively over time. This cumulative soil improvement:

- Increases biological activity
- Makes the soil a better host for plants
- Improves soil structure
- Improves soil moisture holding and drainage capacity
- Can help reduce negative environmental impacts of agriculture, such as nitrate leaching and erosion
- Helps increase your land’s productivity and your profits each year

RESEARCH

In side-by-side comparisons at Rodale Institute over 36 years, organically managed crops surpassed production levels of chemically raised crops by 28 to 34% in drought years. This has been associated with a 25 to 50% increase in soil water infiltration.

Read more: [Organic challenges conventional for yield potential in current Rodale tests](#)

SOIL ORGANIC MATTER

In most soils, organic matter accounts for less than 5% of the total weight.

Soil organic matter (SOM) is the fraction

of the soil composed of anything that once lived and includes plant and animal remains in various stages of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Well-decomposed organic matter becomes humus, a dark brown porous, spongy material that has a pleasant, earthy smell.

As plants, insects and microorganisms that live in or on the soil die, they contribute to SOM. SOM may also be added to the system through incorporation of amendments such as compost or animal manure, or off-farm amendments such as rock phosphate and green sand. Beneficial fungi, bacteria and other soil organisms recycle SOM and convert it into nutrients and other substances that ultimately benefit your crop plants.

RESEARCH

Humus can store carbon in the soil for decades or even centuries. Recent studies of pre-Columbian indigenous agriculture in South America suggest that natives of the region used charcoal to convert infertile red soils to deep, dark fertile earth. Even after hundreds of years, these terra preta soils are rich in carbon and improve crop production in an area larger than modern-day France.

Read more: [Carbon is the key](#)

As SOM levels increase, more of it gets converted into humus. Humus is a relatively stable form of soil left over after myriad soil organisms—from earthworms to arthropods—have used and digested the decaying organic materials. Carbon-rich humus:

- Is resistant to further decay
- Acts as a reservoir for water and nutrients
- Improves soil structure
- Continues to feed beneficial soil microorganisms
- Sequesters significant amounts of atmospheric carbon to mitigate climate change

FARMING FOR THE FUTURE

In the 36 years we've been comparing organic and non-organic systems side by side, soil carbon in our organic plots has increased by as much as 30%, while soil nitrogen has increased by 16%. The conventionally farmed plots showed no change in soil carbon or nitrogen over the same time frame.

You will see the benefits and changes in how the soil looks, feels, and performs long before your test results show much of a change.

Investing in soil is like putting money in the bank: The value of that investment increases over time. Chemical fertilizers offer a short-term payoff; they are gone by the end of the season. Properly managed organic soils improve cumulatively over time.

It is important to determine what condition the soil is in now for two reasons—so you can set goals for improvement and so you can develop a plan for getting there. You will need a soil plan to boost your yields and profits. You will also need the soil plan for certification and as part of your formal Organic System Plan.

FARMER-TO-FARMER

"I remember one of my professors telling me years ago, 'If you can build the organic matter level in your soil, you can solve most of your production problems right away.' He was right."

—Bob Muth
Williamstown, NJ

ORGANIC MATTER RELEASES AVAILABLE NUTRIENTS

Annual cycles of plant growth and decay support both fertility and high organic matter levels in well-managed organic systems.

As organic matter decomposes, it produces large quantities of carbon dioxide, which dissolves in the soil water to form carbonic acid. This acid formation lowers the soil pH, which can increase the release rate of other elements such as boron, zinc, manganese, iron, and phosphorus.

Some of the intermediate products of organic matter decomposition such as fulvic and humic acids can hold and transport minerals that are

SOM LEVELS

Soil organic matter levels can be maintained and increased by incorporating amendments such as:

- Residues from cash crops
- Cover crops grown in the crop rotation
- Animal manures applied with organic bedding materials such as straw or shredded newspaper
- Compost, which will increase organic matter levels quicker than animal manures alone because it's already broken down, so the materials are longer lasting and more stable in the soil
- Perennial hay or sod crops grown for several years in the rotation

otherwise insoluble in the soil. This action, called chelation, is very important in the beneficial effects of soil organic substances. (Chelates are mobilizing minerals and metals in the soil, and for their uptake by microorganisms and plants.)

Phosphorus and some micronutrients attach to these ions and are maintained in a weakly ionized state, which makes them available to plants. Phosphorus and zinc—both very insoluble normally—are brought to plants by the far-reaching hyphae pipelines of beneficial mycorrhizal fungi, which flourish in organic farming systems.

THE ROOT ZONE

Roots are the interface between soil fertility and plant nutrition. The only soil nutrients that matter to a crop are those that can be absorbed by the plant through its roots.

GLOSSARY TERMS

Fulvic: One of two types of organic acidic polymer contained in humus, its name deriving from the Latin *fulvus*, indicative of its yellow color.

Humic: One of two types of organic acidic polymer contained in *humus*, its name deriving from the Latin *humus*, meaning earth, indicative of its brown color.

Chelating: Resulting in a chelate and by which process nutrients are held in the soil and made available for plant uptake.

The area within 2 millimeters of a root (called the root zone or rhizosphere) is one of the richest and most diverse zones of soil microbial activity. Plants are farmers, too; about 60% of a plant's photosynthetic energy is exuded out through the roots to feed colonies of beneficial microbes and fungal associations that then mineralize soil nutrients and transport nutrients and water back to plants. Plant-root exudates, or secretions, create a supportive area for microorganisms to thrive and reproduce and protect the plant from soilborne disease organisms. The microorganisms decompose humus particles in the soil, converting nutrients into plant-available forms.

In addition, hydrogen released from root hairs acidifies the root zone, which also helps make soil nutrients more available for root absorption.

Soil nutrients are delivered to the root surfaces through interception by roots and root hairs that penetrate the soil and come in direct contact with the soil colloids and with the nutrients the colloids hold. Soil nutrients are dissolved in water and then flow to the roots.

Symbiotic relationships exist between some microorganisms and plants, such as nitrogen-fixing bacteria with legume plants, or beneficial soil fungi like mycorrhizae and the roots of plants that support them.

DIVERSITY AND CROP RESPONSE

We know from our own experience, and from those shared by other farmers, that there's a direct relationship between species diversity in our soil and positive crop response. One benefit of having a wide range of crops in your farming system is that the decaying plants encourage a diversity of life in

GLOSSARY TERMS

Colloids: The particles of soil with a large surface-area-to-mass ratio and generally having a net negative charge, essential to the absorption, holding, and release of ions and thus in the processes of nutrient fixation and uptake.

Soil aggregates: The building blocks formed when soil minerals and organic matter are bound together.

soil by providing a smorgasbord of food options to a wide range of soil microorganisms.

In the soil food web, these microorganisms produce myriad substances beneficial to healthy soil and crops, from the glues that hold the soil aggregates together, to substances that stimulate plant growth and improve the uptake of nutrients and water. Other soil organisms discourage plant pathogens, while still others can activate a plant's immune system to resist disease. The microorganisms that decompose decaying plant tissue in soil use carbon for energy and nitrogen to build tissue.

Planting a diversity of crops, instead of the same crop in the same space year after year, is one of a farmer's most effective tools for breaking weed, pest, and disease cycles.

SOIL TYPES

Most farmers are familiar with the concepts of "sandy," "clay," and "loamy" soils. Let's begin by looking at a comparison of these soil types.

"Aggregation" describes the ability of SOM to physically bind with the minerals in both clay and sandy soils. With clay soils, the process "opens up" the space between soil particles to allow optimal water retention and drainage, delivery and storage of nutrients, and circulation of oxygen.

Soils

Soil types	Soil characteristics
Sandy soils	<ul style="list-style-type: none"> Composed of large mineral particles Offer good drainage Deliver plenty of oxygen to a plant's roots Lack structural integrity Have poor capacity to hold water and nutrients
Clay soils	<ul style="list-style-type: none"> Composed of very fine mineral particles Have high water- and mineral-holding capacity Drain poorly Prone to compaction
Loamy soils	<ul style="list-style-type: none"> Mixtures of sand, clay, and soil organic matter Most productive soils

Good aggregate stability maintains the interconnected pores that the soil air can move through, maintaining an aerobic soil environment. This circulation of oxygen stimulates soil biological activity and release of nutrients to your crop plants. Plant roots need oxygen when respiring, and there must be sufficient air, especially oxygen, in the soil to support most forms of soil life. For sandy soils, organic matter allows the coarse particles to stick together to better capture water and nutrients.

SOIL WATER DYNAMICS

The concept of feeding the soil and not the plant is one of the most critical and basic concepts of successful organic farming. By creating a hospitable environment for a diversity of life underground, we increase our yields and the quality of our crops aboveground. This also improves the crops' ability to withstand pest, disease and environmental pressures such as drought.

Synthetic approaches to fertilizing plants have the opposite effect. "When you apply soluble nitrogen, you actually burn off organic matter and acidify the soil," says Paul Hepperly, Ph.D., former research manager for the Rodale Institute.

The importance of soil water to dissolve and deliver nutrients to plants cannot be overstated. Even if a soil has adequate nutrients, the plants cannot access the nutrients they need for growth if water is limited.

For crops dependent on irrigation, soil moisture should be maintained at 50 to 100% of field capacity (i.e. the water retained in a freely drained soil about two to three days after it has been saturated). In soils that receive adequate rainfall but are subject to periodic drought conditions, maintaining soil organic matter will increase both the water infiltration and water-holding capacities of a soil. We have seen this on our own Farming Systems Trial. During droughts, organic production fields have consistently outproduced the conventional ones. During excessive wet times, organic soils drain better, protecting crops and allowing farmers to get back on their fields sooner.

SOIL TILTH

Tilth refers to the physical condition of the soil, such as its texture and relative ability to hold moisture and circulate oxygen. It is a key indicator of soil's health. This definition from a Colorado State extension bulletin describes tilth very well:

"Soil tilth refers to the soil's general suitability to support plant growth—or more specifically, root growth. Tilth is defined as the physical condition of soil as it relates to ease of tillage, seedling emergence and root penetration, as well as its fitness as a seedbed."

A soil with good tilth has adequately sized pore spaces between soil particles for the air infiltration and water movement essential to plant growth. It also holds a reasonable supply of water and nutrients. Roots grow only where the soil tilth allows for adequate soil oxygen levels.

Improving soil tilth through the addition of soil organic matter is effective in any type of soil, from clay to sand. Developing good tilth in clay soils means increasing the size of pore spaces, since clay soils are more compacted and need more space for water and air movement. Developing good tilth in sandy soils means increasing the amount of water-absorbing material.

Good soil structure allows for the free flow of water, air, and nutrients surrounding crop plants' root systems, and the free flow of oxygen stimulates the activity of microorganisms to release nutrients to the plants.

Soil tilth also affects the ability of a plant's root system to expand and explore for nutrients. Many factors have an impact on soil's tilth: tillage,

GLOSSARY TERMS

Soil water: Water suspended in the soil, namely the region from which water is discharged by plant transpiration and evaporation.

Field capacity: The amount of water left in a given soil plot after free drainage has practically ceased, usually two to three days following its saturation.

Water infiltration: The process by which water on the ground surface enters the soil.

crop rotations, crop residue management, soil amendments, even vehicular and foot traffic. While the influence of these factors may not show up on chemical soil tests, they will affect the soil's productivity.

CATION EXCHANGE CAPACITY

Soils are mixtures of sand, silt, clay and organic matter in varying amounts. The relative proportion determines the soil type. Here's how the "macro" management practices actually play out at the "micro" level: both the clay and organic matter particles (called colloids) have a net negative charge. These soil particles will attract and hold positively charged particles of plant nutrients, called cations.

The cations attached to the clay and organic matter particles in soils can be replaced by other cations; so they are exchangeable. For example, potassium can be replaced by calcium or hydrogen, and vice versa. The total number of cations a soil can hold—or its total negative charge—is the soil's cation exchange capacity (CEC).

The higher the CEC, the higher the negative charge and the more cations that can be held. If more cations are held, then fewer are leached below the root zone. This, in turn, has a significant effect on soil fertility: the higher the CEC, the better the soil's fertility potential. Combined with other key indicators, CEC is a good measure of soil quality and productivity.

Cations include these positively charged plant nutrients: calcium (Ca⁺⁺), magnesium (Mg⁺⁺), potassium (K⁺) and ammonium (NH₄⁺). It is undesirable to add clay material to increase CEC, but adding organic matter improves CEC and tilth. Organic matter colloids are more chemically reactive and have a bigger impact on soil characteristics than do clay-based particles, which is why SOM is so important.

NPK

Nitrogen (N) and phosphorus (P) are almost always present in mineral soils and can be found in relatively large quantities. However, the largest portion of the total content is held in chemical complexes and is unavailable to plants. Even the simpler compounds of phosphorus are relatively

RESEARCH

The Rodale Institute's Farming Systems Trial, soils under organic management have gained about 0.025% carbon and 0.01% nitrogen annually, while there was no change under non-organic management. This suggests that, over time, organic soils can better supply the needs of beneficial soil organisms and crop plants.

insoluble in most soils.

The total quantity of potassium (K) is usually plentiful (except in sandy soils). But there is still a problem of availability.

Calcium (Ca) will vary more than potassium in soils, but it is generally present in lesser amounts. When a soil lacks calcium, it tends to be acidic. Calcium-containing limestone is generally added to correct this condition. (A proper pH level of around 6.0 to 7.5 is critical to soil microorganism populations.)

Magnesium is an important plant nutrient and, like calcium, neutralizes acid soils. Dolomitic limestone contains both calcium and magnesium; calcitic limestone contains primarily calcium. Magnesium deficiency is a major problem in many soils in the eastern United States.

Sulfur is usually as plentiful as phosphorus. However, it is more available in soils because its simple compounds remain soluble when reacting with other soil constituents, while the compounds of phosphorus do not. Adding sulfur to the soil through farm manure, rainwater, and composts resolves possible sulfur deficiencies in humid temperate regions. In certain areas, such as the

GLOSSARY TERMS

Crop residue: The plant parts remaining in a field after the harvest of a crop, which include stalks, stems, leaves, roots, and weeds. (*NOP definition*)

Cations: Positively charged ions

Dolomitic: Containing dolomite, a mineral and a sedimentary carbonate rock, both composed of calcium magnesium carbonate, CaMg(CO₃)₂

Calcitic: Containing calcite, a common crystalline form of calcium carbonate, CaCO₃

western and southern United States, specific additions of sulfur-containing compounds may be required.

SOIL RESPIRATION

While improving the chemical and physical properties of soil is important to organic and non-organic agriculture alike, building and maintaining the soil biology is absolutely critical to successful organic farming.

Soil organisms are the building blocks of healthy, productive soils. Like all other living things, soil organisms need food, water, and a place to live. Proper organic management creates this sustenance and habitat for both visible soil inhabitants—such as earthworms and insects—and those too small to see—such as beneficial bacteria and fungi (the primary decomposers that support this microscopic ecosystem).

Equally important is the activity in the soil. We call this activity respiration.

When plants die, the insects, worms and microorganisms in the soil begin to break down the plants' carbon and use some of it for food. Through the process of photosynthesis, living plants take in air containing a large percentage of carbon dioxide and convert it to cellulose, starches, and sugars in the plant tissue. When these plant residues are incorporated into the soil, microorganisms use the carbon, cellulose, starches, and sugars for their food. Through this same process, other nutrients and micronutrients from the decaying plant tissue are made available for subsequent crops. The "life in the soil" is what makes nutrients available to plants.

Scientists measure soil respiration by determining the amount of carbon dioxide being released. In our Farming Systems Trial, we have found that carbon dioxide respiration is significantly higher in the organic farming systems than in the non-organic system. This is because organically managed soils are able to store or sequester carbon for use by plants as needed. This means microorganisms are more active and numerous in the organic systems and are recycling more nutrients.

In good organic systems, soil is working hard for you. Here's what it looks like in equation

form: $C_6H_{12}O_6$ (carbohydrate in the form of plant material) + O_2 (oxygen) = CO_2 (carbon dioxide) + H_2O (water) + energy.

SUMMARY

This concludes the Healthy Soil lesson. Let's review some key points relevant to your Organic System Plan.

- Soil is an investment that builds up over time.
- You have an obligation to improve your soil under the NOP Standards.
- Soil organic matter plays a major role in healthy soil biology.
- Chemical, physical and biological processes interact in soils.
- Biodiversity is important below, as well as aboveground.

By now, you should be able to:

- Understand the concept of biodiversity related to your farming practices
- Keep nutrients cycling back into your system through chemical, physical and biological processes
- Meet your obligation to improve your soil under the National Organic Program Standards

In the next lesson we'll discuss how to evaluate your soil.

LESSON 2: MONITORING

OVERVIEW

In the last lesson, we looked at some basics of soil health and soil biology. Now, let's look into transitioning to healthy soil. We will discuss soil testing, building healthy soil and monitoring changes that may occur as you improve your soil.

On any given day, you make many decisions that could influence outcomes on your farm. Soil testing and observation are goals that you need to include in your farm plan. If you don't know where you're going, how will you know if you've arrived at the right place? These goals can help you establish where you're going and how you'll

get there, and help you determine if you have arrived at your ideal soil goals. In addition, your Organic System Plan requires you “to monitor the effectiveness of your fertility management program.”

Soil texture, water movement, crop response and earthworm populations are key indicators of soil health. You will need additional information from formal soil tests to help you set soil-improvement benchmarks and track changes over time.

By the end of this section, you will know how to create your soil fertility plan. To help you do that, we will lay out the highlights of how to build and measure soil health, control erosion and test your soil.

PLANNING YOUR SOIL IMPROVEMENT PROGRESS

Although the NOP Standards don’t spell out the particulars, your certifier is going to have questions if your fertility management plan simply substitutes expensive bags of organic fertilizers for chemical fertilizers. Your certifier will ask you to demonstrate how you’re improving your soil. The building blocks of your fertility program should be crop variety, cultural practices, composting, cover crop/green manure management, and manure management (whether you have animals on your farm or are importing manure from a trustworthy source nearby).

A soil fertility plan has several key ingredients to help fine-tune or verify target nutrients for each field. Let’s begin with nutrient goals:

- Set nutrient goals for each field
- Create a cropping system that provides the soil nutrients you need for successful crop production while protecting the environment (don’t forget to consider crops in the rotation that have the ability to tie up any excess nutrients)
- Monitor and record soil nutritional deficiencies or excesses
- Look at the entire rotation to balance what crops use with what comes back

by way of amendments and soil-building practices

- Verify or adjust soil nutrient target levels based on crop responses and yields

You will need to track your soil improvement and explain the monitoring tools you are using. Methods might include traditional chemical soil testing, microbiological testing, plant tissue testing and crop health observations.

Managing your soils is a critical requirement of your farm plan. The NOP Standards reference soil erosion at [§205.203a](#) and require a formal soil conservation plan adapted to your farm. Testing and amending your soil is a waste of time if your topsoil is eroding into the nearest stream.

KEEPING YOUR SOIL ON THE FARM

The first step toward healthy soil is the keep the soil you have in place. Topsoil is the fertile top layer of soil representing centuries of growth and decay and is both a protector from, and vulnerable to, erosion. Erosion is not always readily visible on cropland because farming operations may cover up its signs. Loss of only 1/32 of an inch of topsoil can represent a five-ton-per-acre loss. Watch for the following signs that you may be exporting soil

MAKING PROGRESS

Thanks to the efforts of the Natural Resources Conservation Service (NRCS) and partnering farmers, erosion is a declining problem. We still have a long way to go, though in preserving valuable topsoil resources. A 2011 NRCS report found that conservation practices used during the period 2003-2006 have: Significant gains in erosion control that were made between 1982 and 1997 were sustained between 1997 and 2001.

- Reduced wind erosion by 44%;
- Reduced waterborne sediment loss from fields by 47%;
- Reduced nitrogen lost with surface runoff by 43%;
- Reduced total phosphorus loss from fields by 39%;
- Reduced pesticide loss from fields to surface water, resulting in a 26% reduction in edge-of-field pesticide

[Read the full report](#)

fertility:

- Dust clouds
- Soil accumulation along fence lines or snowbanks
- A “drift” appearance on the soil surface
- Small rills and channels on the soil surface
- Soil deposited at the base of slopes
- Sediments in streams, lakes and reservoirs
- Pedestals of soil supporting pebbles and plant material

Erosion damage is twofold:

- Surface soil erosion causes a loss of nutrients and biodiversity within the system, and often creates a less favorable environment for plant growth.
- Soil nutrients enter and accumulate in bodies of water. The nutrients can cause problems such as algal blooms and related oxygen depletion due to high nutrient levels. This type of nutrient runoff is responsible for large “dead zones” in bodies of water such as the Gulf of Mexico and the Chesapeake Bay.

BIG PROBLEMS COME IN SMALL PACKAGES

Sheet erosion is very difficult to see from year to year. Soil is removed more or less uniformly from every part of the slope. Wind and the force of raindrops hitting bare soil dislodge particles of earth. Water that does not infiltrate the soil forms puddles. The puddles flow into one, and the water carries fine particles.

Rill erosion is indicated by tiny gullies irregularly dispersed, especially on bare, newly planted or fallow land. On close examination of fields, rill erosion is noticeable, but may not seem like a problem that needs immediate attention.

Gully erosion is dramatic and difficult to ignore. The volume of water is concentrated, forming large or small ravines.

Losses due to sheet and rill erosion are less noticeable than gully erosion but are even more important from the standpoint of field soil



A field with examples of several kinds of erosion

deterioration. On sloping or impermeable soils, most of the precipitation can be lost to runoff, depriving crop plants of water and carrying valuable topsoil with it.

PREVENTING EROSION

1. Keep the soil covered year-round with living crops or residue to prevent erosion by rainfall or runoff. Plant roots also help hold the soil in place, and the plants themselves act as a barrier to

slow the flow of water across the surface of the earth. The Natural Resources Conservation Service (NRCS) suggests that crop residues should cover at least 30% of the soil surface following harvest. Three ways to keep the soil covered are growing forage crops in rotation or as a permanent cover, growing winter cover crops, and interseeding a crop by establishing it with or under another crop. Clovers are often planted with or relay planted into small grains. The small grain shelters the legume seedling, and the clover continues developing after the small grain is harvested.

2. Apply organic matter. The conservation and addition of soil organic matter such as compost, green manures and animal manures help soil resist erosive forces. The infiltrating (soaking) capacity is influenced heavily by the structural stability of soil (especially near the surface) as well as its texture and organic matter content. Soil depth, the kind and amount of clays, and the presence of impervious layers also influence infiltration capacity.
3. Minimize tillage to maintain and enhance soil aggregate size and stability. The stability of soil aggregates has great bearing on the extent of erosion damage. The resistance of surface granules to the beating action of the rain saves soil; the bigger and more stable the soil granules are, the more they will resist the erosive action of rain. Wind and water run hard and fast through long, straight lines. The

following techniques can mitigate these problems:

4. Plant shelterbelts of trees, shrubs or tall crops to slow down wind and its negative effects. Shelterbelts can do double duty as buffers, which are planted barriers that are required between adjacent organic and non- organic fields.
5. Modify the landscape with contours or terraces to slow runoff and reduce the amount of soil it can carry. Other techniques such as strip cropping interrupt the flow of soil and water down steep exposed slopes.

PRACTICAL SOIL ASSESSEMENT

Once you have made sure you are not exporting your existing soil, you can begin to assess the health of your soil. Healthy soil must contain the essential nutrients for vigorous plant growth and retain moisture without becoming soggy. In addition, healthy soil provides good aeration to plant roots and soil microorganisms, and resists the erosive effects of wind and water.

Healthy soil is:

- Soft and porous at the surface—not crusty—allowing water to infiltrate and reducing the potential for runoff erosion
- “Greasy” feeling but not pasty; it should ball up in your hand but readily crumble if you gently poke the ball with your finger
- Earthy smelling—a sign of bacteria breaking down organic matter
- Teeming with visible beneficial organisms
- Well drained and warms up quickly in spring
- Free of clods and hardpan layers

But how do we measure these qualities?

Some biological processes cannot always be measured exactly, but they can be verified through observation over time. Some of the physical signs that soil is improving include:

- An abundance of earthworms
- The presence of organic matter residues

RESEARCH

Scientists at the Institute of Plant Nutrition and Soil Science and the Institute of Organic Farming in Germany have demonstrated that organic farming could help prevent flooding. Researchers measured seven times more earthworms and infiltration rates twice as high in organically managed soils as in conventionally managed soils.

Read more: [FAL Study](#)

- Dark topsoil
- Vigorous, healthy (white) root growth
- Loose subsoil
- No runoff or signs of erosion and no ponding up
- Ability to hold water well, supporting plants in dryer times
- Vigorous, healthy (dark green) crop growth
- Fertility improving over time (as indicated by soil tests)

THE WATER TEST

Perform a simple soil aggregate stability test at home. Collect soil clod samples including your worst as well as your best fields. Allow the clods to dry at room temperature for a few days. Fill two glass jars halfway with water. Place a dry clod of soil from each sample into a jar.

If the soil clod remains intact and sends up air bubbles, you have a good level of organic matter. If the clod disintegrates and clouds the water, then the organic matter content of that soil is too low and requires attention.

FERTILITY INDICATORS

Fertility is basically the ability of your farming system to grow healthy, vigorous crops. Organic agriculture is like preventive medicine and proactively seeks to address fertility imbalances to mitigate symptoms of an unhealthy system, such as pests and diseases. Following are some signs that might indicate the need for fertility intervention:

Weeds. Certain weed species can be indicators of specific soil conditions. If there are large, vigorous populations of weeds that prefer hard, compacted soil (foxtail) or that thrive on excess nutrients (lambsquarter, pigweed), you may need to correct a fertility imbalance.

Crops. Do they grow vigorously and outcompete weeds? Are the leaves a healthy green and the stems strong? Or do the plants lodge easily, with foliage showing yellow or purple

streaking? The latter may be an indicator for a need to build soil fertility.

Insects. Which are more prolific, the beneficial or the harmful insects? Harmful insects are attracted to stressed plants, indicating that soil nutrients may be imbalanced and microbes may not be thriving as well as they could be.

SOIL LAB TESTS

Although careful observation is key in organic farming, soil lab tests can still offer valuable benchmarks. The first part of the standard soil-test report shows levels of critical nutrients, soil acidity and soil nutrient exchange dynamics. The second part offers recommendations to adjust fertility, salinity or acidity for the target yield of the anticipated crop.

Generally, soil tests:

- Classify the soil based on the percentage of sand, clay and loam. This information can help to better estimate how the soil will respond to cultivation and additional organic matter, as well as the soil's nutrient and water-holding capacity.
- Measure pH, exchangeable acidity and cation exchange capacity—important indicators of fertility in organic soils.
- Measure “plant-available” levels of phosphorus, potassium, calcium,



Our researchers once sent a soil sample from the Rodale Institute to 70 different labs. The pH of the sample ranged from 4.7 to 6.9, with lime recommendations ranging from “none necessary” to 7 tons per acre. Readings and recommendations for NPK and micronutrients were just as varied. Our advice: Find a lab that's familiar with organic farming and with your general geographic area. Compare your results year to year from the same lab, rather than trying a different lab each year. Collect samples around the same time each year, and if you're using a consultant, make sure he or she knows you're transitioning to organic.

magnesium, sodium, sulfur, manganese, copper and zinc.

As an organic farmer, you will use your soil test recommendations differently than a non-organic farmer would. In non-organic agriculture, the goal is to buy just enough fertilizer to produce optimum yield without allowing excess nutrients to escape into the environment.

Organic management, on the other hand, focuses on improving soil nutrient levels and soil health over the long term, balancing use of manures, cover crops, composts, approved organic fertilizers and naturally occurring mineral supplements so the soil tests better and better each year. So, for soils under organic management, a chemical soil test will not give the full picture of your soil's health and productivity. Soil tests estimate the nutrients present in the soil, but they can't measure the nutrients the crop will receive through biological activity during the growing season.

TILTH, SOIL CARBON AND BIOLOGICAL ACTIVITY MEASUREMENTS

Three tests can be helpful in further assessing your soil health: tilth measurement, total soil carbon and biological activity:

- **Tilth measurement:** tilth can be measured by calculating soil density. You can measure tilth by weighing out 100 grams of dry soil and noting the volume it occupies in a measuring vessel. The weight divided by the volume will give the soil density in grams per cubic centimeter.
- **Total soil carbon:** Total soil carbon is measured in a lab by igniting a soil sample of known weight, weighing the dry remains and then calculating the weight lost to determine the amount of soil carbon in the sample. Since soil organic matter is approximately 50% carbon by weight, doubling soil carbon values gives a good approximation of soil organic matter.
- **Biological activity:** Biological activity involves measuring soil respiration, or the release of carbon dioxide. "What you are measuring in the breathing of the soil

is the activity of the microorganisms and their ability to break down soil organic matter," Paul Hepperly, TRI research manager explains. "This is done by measuring the release of carbon dioxide, which is a decompositional gas. It's the opposite of photosynthesis."

RESEARCH

[Dr. Ray Weil](#) has developed an inexpensive, easy-to-use kit to help farmers determine the active organic matter fraction in their soil. Remember, when soil is mismanaged, active organic matter is the type that is lost first. Farmers can use the test to determine which of their fields need the most urgent input of organic materials.

Using the kit, you can mix a solution of potassium permanganate with soil, then use the color of the solution to determine active organic matter. The only expensive component is the hand-held colorimeter, sold by Hach Co, for about \$200. (To avoid this expense, you can also use a color chart for more approximate comparisons.) All the other items should cost less than \$20. (Find more soil biology test kits under "Resources" at the end of this module.)

SUMMARY

Improving your soil health and crop performance begins with careful observation and good recordkeeping. If your crops show poor growth, look at the growth environment and take plant tissue samples to see which nutrients your crop may be lacking. Record all soil fertility and plant-tissue test results, along with yields and management practices.

Sampling and recordkeeping are essential because they help you assess the agronomic and economic success of farming practices over time. Also, these records are required by the NOP. Develop a site-specific, long-term fertility plan based on the characteristics of the soils on that site, the crops in the rotation and the farmer.

In building soil health and your long-term fertility plan, taking several approaches is more effective than trying to put all your soil improvement tactics in one basket. Many practices

TIMING IS EVERYTHING

If your fertility plan includes plant or animal residue application in the fall, you should soil test in the spring, once your microbial community has had a chance to do its thing and make nutrients available. To find out if you need to plant a cover crop to store excess nutrients for the next planting cycle, soil test again after harvest. (Testing should be done at the same times of the year and at similar soil temperatures.)

can influence crop response to nutrients. Some of these practices include:

- Timing and type of tillage
- Planting a hybrid or a particular variety of plant
- Adjusting planting dates
- Using crop rotations, green manures and cover crops
- Interplanting two or more crops in the same area
- Incorporating crop residues
- Subsoiling
- Adding approved amendments, foliar fertilizers and soil inoculants

We'll talk more about these practices in the next lesson.

LESSON 3: PRACTICES

OVERVIEW

In the previous lesson, we discussed soil and testing to help assess your soil building program. Now, we'll move to practical organic soil management during crop tillage and cultivation. We will also discuss the value of planting cover crops and implementing crop rotations.

Tillage can be used to manage weeds, incorporate organic amendments and crop residues into your soil and ready the soil for seed establishment. However, too much tillage, or tilling under the wrong conditions, can harm your soil in a number of ways. Even though opening up the space between soil particles for oxygen can

RESEARCH

Organic farming is a developing science, one that might someday be considered a real Green Revolution because of emerging evidence of its ability to put the brakes on global warming. Here at the Rodale Institute we're demonstrating how organically managed soils actually act as carbon sinks, storing carbon in the form of soil organic matter rather than releasing it into the atmosphere as CO₂, a major greenhouse gas.

Read more: [Organic farming sequesters atmospheric carbon and nutrients in soils](#)

stimulate microbial life and increase soil carbon, ripping the lid off your soil can burn up carbon at an alarming rate.

Tillage and any wheeled-implement traffic can also cause soil compaction, particularly in clay soils. Loose, uncovered soil is more susceptible to erosion by wind and water.

Strip cropping can mitigate soil erosion. Alternating strips of sod crops with row crops in strips perpendicular to the slope slows water movement and has the added benefit of increasing diversity.

In organic systems, conserving and increasing soil organic matter (SOM) are keys to a productive system. There are several ways to offset the reduction of SOM from tillage:

- Adding compost
- Using cover crops in the rotation
- Using fast-growing catch crops for soil protection between crops
- Using longer rotations
- Using rotational no-till
- Incorporating several years of sod pasture or hay in rotation

GLOSSARY TERMS

Subsoiling: A method of deep plowing used to break up compacted subsoil, or hardpan, produced by many conventional tillage methods.

COVER SOIL, MINIMIZE TILLAGE

Under NOP Standards, cover crops need to be part of your plan to build the soil. §205.203 of the Standard states that plant materials must be managed to maintain or improve soil organic matter.

Covered fields conserve topsoil and nutrients. Here in Pennsylvania, a winter crop of vetch or rye works well with our principal crops of corn and soybeans. Vetch provides nitrogen for the corn, while rye soaks up nutrients and helps manage weeds in the soybeans.

Much of what you know about tillage from non-organic farming also applies to organic farming. Most conscientious farmers are careful to restrict tillage activities. However, because of the explicit NOP requirement to protect and build soil quality, organic farmers must plan their tillage regime before the season begins and document the actual tillage that occurs.

PLOWING TIPS

Plowing fields that are too wet or too dry can produce dense soil clods that are difficult to manage and prevent good seed-to-soil contact. Even after careful tillage that leaves lots of residue on loosened soil, a heavy rain can badly impact the quality of your soil bed.

To plan your tillage, you have to use your best judgment to factor soil type, field slope, depth of loosened soil, field drainage and the weather forecast in balance with the benefits you hope to achieve.

Tillage is like fire in a forest. Both have to be managed wisely, and both generate inevitable physical changes to achieve their benefits. However, tillage has risks in that it:

- Accelerates the rate and extent of decline in soil quality
- Increases subsoil compaction
- Increases fossil fuel use and labor costs
- Can lead to soils that are too wet, and crusting of bare soils

TILLAGE TO INCORPORATE AND PREPARE

Tillage accelerates decomposition of crop residues, compost and animal manures into soil organic matter. Successful incorporation of tillage:

- Encourages the rapid growth of soil organisms, given sufficient warmth and moisture, by adding extra nitrogen, oxygen and carbon to their environment. Organically managed soils encourage soil animal predators that feed on weed seeds, helping to lower weed pressure.
- Increases soil contact with plant and manure residues. By breaking down residue into smaller pieces, incorporation increases the surface area for microbes to contact, consume and digest the materials.
- Decreases the bulk density of the soil, promoting both drainage in wet times and moisture-holding capacity during drought.
- Deepens the aerobic (oxygenated) soil layer that is rich in microbial activity due to favorable temperature and moisture conditions.



Photo Credit: Steven Lybeck

Careful tillage incorporates crop residues, in this case alfalfa, into the soil without pulverizing soil aggregates or overly disturbing the microbial community. The incorporated plant residues feed the microbes in the soil, which in turn feed the next crop planted.

- Helps maintain soil tilth in the upper horizon when soil is worked at the proper moisture content and receives sufficient organic residue.

The goal of tilling for seedbed preparation is to work the topsoil just enough to allow optimum seedling vigor. Successful seedbed preparation provides:

- Good seed-to-soil contact in firm, moist soil for vigorous seed germination and root development.
- Sufficient soil aeration for plant growth without creating large voids and clods and without stirring soil any more than necessary.
- Warmer soil to enhance seed germination. Bare soil warms faster than mulched soil but is vulnerable to erosion and moisture loss.

The “stale seedbed” technique uses a series of light cultivations to sprout weed seeds, then tills them, exhausting the surface weed supply.

REDUCING TILLAGE IN ORGANIC SYSTEMS

At the Rodale Institute, we evaluate our tillage as carefully as we choose our crops and our crop rotation. We want to make sure each tillage pass returns more than it costs by increasing yield and/or improving soil conditions. The soil needs to be worked only enough to ensure optimum (not maximum) crop production and weed control. Optimum production is a yield that is as high as is practical and efficient, given other considerations. Any tillage activity beyond that is of questionable value because there is no benefit in coaxing maximum yields from a field using practices that cause long-term damage to the soil.

We’ve found that occasional plowing offers significant weed-management advantages. Our soil organic matter levels continue to increase, especially with the addition of cover-crop biomass, so we believe we can overcome the limited amount of tillage-generated carbon loss by use of cover crops.

We’re developing a one-pass no-till system that uses fall-planted winter annual cover crops to



The no-till roller in action.

Photo Credit: FarmHack

suppress weeds. In this system, we mechanically knock down the standing cover crop and plant right into it, mimicking a garden mulching system. Our system utilizes a specially designed front-mounted steel roller and a rear-mounted precision no-till planter.

Some farmers use reduced-tillage methods in which soil disturbance is restricted to the seed zone. Attachments such as vertical coulter blades on a no-till planter prepare a planting slot by cutting through crop residues down into the top soil. A subsoiling foot can create a deeper slot for transplants.

NO-TILL CONSIDERATIONS

Machinery: Both organic and non-organic systems require specific no-till machinery. For example, no-till planters are equipped with coulters that slice the soil (and cover-crop mat, if present), allowing the double-disk opener that follows to place the seed at the proper depth. The slot is closed with a spring-wheel press, cast iron wheels or a combination of star coulters and press wheels. In any no-till system that uses cover crops, the biomass mat created by the killed cover crop is much heavier than the residue from a previous year’s crop; thus, no-till planters must be weighted and adjusted accordingly to cut through

the cover-crop mat and place the seed effectively. As we've found here on our farm, calibrating and modifying your equipment to facilitate a good roll-down and adequate seed-to-soil contact is a matter of trial and error.

Soil temperatures: In most areas of the United States, spring soil temperatures are lower in untilled fields than in tilled soils. Dry, bare soil warms faster than mulch-covered soil, so no-till plantings may be slower to germinate. Also, most soil microorganisms responsible for crop nutrition "awaken" when soil temperatures climb above 60°F. As a result, no-till planting may have to be delayed to a later date and shorter-season seed varieties may need to be planted. Colder soil temperatures under mulch may also present problems in abnormally cold or wet seasons. However, most locally adapted crops can tolerate some temperature variations.

Pests and diseases: Increased insect and rodent pest problems have been reported in some non-organic no-till systems. Dense covers may incite disease and insect problems. In all such cases, crop rotation to break weed, insect and disease cycles is a key factor in managing insect and disease problems in an organic system.

CROP ROTATION

Crop rotation is the practice of strategically selecting the sequence of crops grown on a specific field. The goal is to plant annual crops of different species or families in each consecutive year on a field in order to avoid fertility depletion and buildup of crop-specific pest and disease problems.

Organic farmers rely on crop rotations as their primary tool for managing nutrients and breaking weed, pest, and disease cycles. According to the NOP, producers must use appropriate crop rotations to:

- Maintain or improve soil organic matter content
- Provide for pest management in annual and perennial crops
- Manage deficient or excess plant nutrients
- Provide erosion control

Most organic crop rotations include at least three primary crop species and two or more secondary cover-crop species. Some rules of thumb for rotation design are:

- Keep the soil covered. Bare soil is the worst-case scenario for soil health and carbon/organic-matter depletion.
- Position nitrogen-demanding crops (corn, vegetables) after nitrogen-building crops (legumes). In the second or third year after the legume, grow a less-nitrogen-demanding crop.
- Use sod crops (grasses, clovers, alfalfa) periodically to build soil structure and fertility.
- Maximize active root growth throughout the year.
- Include deep-rooted crops such as alfalfa, sunflower, and safflower to help open up channels to deeper layers and bring up nutrients from the subsoil.
- Use perennial crops for longer periods on sloped or erodible land.
- Change the variables of plant families, rooting depth, seasonality, nutrient demand, cultivation requirements and incorporation method.

CHOOSING A COVER CROP FOR BETTER SOIL

There are lots of things to think about when you select a cover crop for a given field. Begin by focusing on your soil-improvement needs. Then think about crop sequencing, labor and equipment availability. Some questions to consider:

- What condition is your soil in now, and what are your soil-improvement goals?
- What are your "windows of opportunity" between frost dates and cash-crop planting and removal?
- How consistent is rainfall when you need it to induce germination and early growth, or will you have irrigation to assist you?
- What equipment options do you have to sow, kill and incorporate covers?

Last but not least, consider what your cover crops can do for subsequent cash crops. Effects include everything from providing fertility to weed suppression.

Some of these questions can be answered right away; others will be answered with time and observation. Here at the Rodale Institute, we continue to evaluate our approaches and change our rotation lineup as we accumulate knowledge, field conditions and markets change.

We'll talk more about cover crops in the Crops chapter.



Hairy vetch

Photo Credit: Resmsburg, Inc.

LEGUMES IN ROTATION

Legumes are a mainstay of organic rotations because they can supply nitrogen (N) to companion or succeeding crops. Used for hay or pasture, they can supply large amounts of high-quality forage rich in plant proteins while still offering benefits as a cover crop.

About 78% of the atmosphere by volume is nitrogen, but it is unavailable to most plants directly. A group of soil-dwelling bacteria called Rhizobia attach to the roots of legumes and cause nodules to form. Within these nodules, the bacteria "fix" free nitrogen from the soil air to make proteins and other nitrogen-containing

compounds. Some of the nitrogen is excreted into the soil and can be used by other plants growing nearby. More is released by decomposition of the root and plant tissues after plow down or senescence.

The amount of nitrogen fixed by a legume planting will vary depending on:

- How effectively the roots are colonized by the bacteria, either from existing soil bacteria or inoculum added to the legume seed
- How much nitrogen is already present in the soil
- The growth stage and total biomass of the legume

The nodule bacteria on the roots from air within the soil fix 50 to 80% of the total nitrogen in a mature legume; the remainder is drawn from plant-available nitrogen in the soil. In forage or hay crops, legumes grown in combination with grasses generally supply enough nitrogen for both crops.



Photo Credit: Resmsburg Inc.

Crimson clover is one example of a legume crop that can benefit from use of an inoculant to help it fix nitrogen from the atmosphere.

GREEN MANURE

A green manure is a crop that is incorporated into the soil when it is green, or soon after flowering, for the purpose of improving the soil. Widely used green-manure crops in North America include winter rye and the common legumes, such as vetches, clovers and alfalfa. Rye also has the ability to tie up large amounts of nitrates.

A major benefit of green manures is the addition of organic matter to the soil. The addition of crop residues combined with the physical penetration of cover-crop roots—and their chemical interactivity with soil microbes—helps to build complex soil structure. Nutrient availability also improves, because a high percentage of the sugars a plant produces are released by the roots. These sugars feed the soil-building microorganisms, which liberate nutrients from insoluble sources, then store them for the crop that follows.

If building SOM is a primary goal, look for high-biomass-producing cover crops such as sorghum-Sudangrass, cereal rye, annual ryegrass and triticale. High-biomass legume covers include subclover, woolly-pod vetch, cowpeas and hairy vetch. Mixes of legumes and cereal crops can be used as well.

Increased plant biomass residues delivered by cover crops will improve the ability of your fields to host beneficial organisms. These include microorganisms that cannot be seen and larger earthworms and insects that can. All are hard at work improving your soil structure and nutrient availability as they make and break down organic matter.

SCAVENGE NUTRIENTS AND PREVENT EROSION

Once a cash crop has been harvested, remaining soluble nutrients, particularly nitrogen, are susceptible to leaching. Well-timed cover crops can “catch” these nutrients, store them in their tissues, then slowly release them as they decompose. With no catch crop, soluble nutrients can be leached out of the soil by rain and snowmelt.

Good nutrient scavengers include cover



Photo Credit: Edwin Remsberg

Buckwheat is fast-growing, warm-season cover crop that readily outcompetes weeds, offers excellent insect habitat, and help mine phosphorous for use by subsequent crops.

crops with extensive root systems and those that develop rapidly after planting:

- Winter annual grasses, such as rye, wheat, barley and triticale
- Annual ryegrass
- Fall-seeded cover crops such as oats, winter-kill, or rye, which can gather in as much as 80 pounds per acre of nitrogen
- Summer-seeded buckwheat, which sequesters phosphorus for use by the following crop and suppresses weeds
- Deep-rooted brassicas such as rapeseed, oilseed radish and mustards, which can send roots down more than 9 feet

A short-season catch crop (millet or buckwheat, for example) may be planted in short rotation windows or if a cash crop fails.

Deep-rooted cover-crop species can help break through compacted soils and improve drainage. Soil scientist Ray Weil refers to these crops as “bio-drills” because of their remarkable ability to substitute for mechanical tillage.

Bell beans and the clovers, especially biennial sweet clover, are excellent choices to break through subsoil. Winter cover crops with

large taproots can penetrate the compacted layer when the soil is wet and relatively soft. The roots of brassica and mustard species are known to penetrate about 1 foot deeper than cereals and nearly 2 feet deeper than grain legumes.

MANAGE SOIL MOISTURE

Well-managed crop rotations that increase soil organic matter to sufficient levels help to moderate soil moisture, retain moisture in dry conditions and allow excess moisture to drain away in wet seasons.

Shifting crop types also helps vary water demand within the soil profile. Spring-seeded small grains use water in the 2-to-4-foot range and sunflower, safflower, corn and sugar beets pull water from the 5-to-6-foot range. The deeper-rooted crops following shallow-rooted crops can access moisture reserves as well as capture any nutrients that have leached below the shallower root zones before they reach groundwater. Following with a grass crop allows the field to build its moisture reserve back up.

Mulch effect: Generally, the higher the carbon-to-nitrogen ratio (C:N) of the cover crop residue, the longer the residue will serve to suppress weeds and conserve moisture. Small grain cover crops are well suited for this; most legume residues with higher nitrogen content will decompose more rapidly and be less effective as mulch.

The microbes that decompose crop residues use carbon as an energy source and nitrogen to build tissue. If residues have a C:N ratio higher than 20:1, such as mature rye, the microbes will need to gather nitrogen from the surrounding soil to do their work.

This concludes the Practices lesson. By now, you should have an understanding of tillage and cultivation practices related to organic agriculture. You should also realize the value in planting cover crops and using crop rotations.

LESSON 4: COMPOSTS

OVERVIEW

Mature, well-made compost is fundamental to organic farming. It is a stable, slow-release

fertilizer that builds up soil life and will not “burn” plants. Synthetic amendments and manure can provide soluble nutrients for plant growth but do not build the soil’s long-term biological reserves as well as compost does. At its best, compost can:

- Recycle nutrients
- Stabilize volatile nitrogen (composted organic matter contains nitrogen in a relatively stable form (nitrate) that is readily usable by plants)
- Improve soil structure and stability
- Add a concentrated supply of humus and plant nutrients to the soil
- Convert wastes into resources
- Increase moisture retention (one hundred pounds of dry humus can absorb as much as 195 pounds of water)
- Buffer pH (Optimal pH for compost is 6.5 to 7)
- Suppress soilborne diseases

The basic secret of making good compost is the right mix of nitrogen-rich green materials, such as green leafy crop residues, and carbon-rich brown materials, such as cornstalks or old straw bedding.



Unfinished compost at Rodale Institute

Photo Credit: Jack Sherman

Because compost is alive with microbes (bacteria and fungi), the composting process continues even after compost is applied, breaking down raw materials and reassembling them into more-stable humus.

WHAT THE STANDARDS SAY ABOUT COMPOST

NOP Standards define compost as “the product of a managed process through which microorganisms break down plant and animal materials into more available forms suitable for application to the soil.” The definition continues with a precise description of how to make compost (NOP§[205.203](#)):

1. Established an initial C:N ratio of between 25:1 and 40:1; and
2. Maintained a temperature of between 131°F and 170°F for 3 days using an in-vessel or static aerated pile system; or
3. Maintained a temperature of between 131°F and 170°F for 15 days using a windrow composting system, during which period, the materials must be turned a minimum of five times.

All feedstock materials must be approved for organic systems, as listed in [§205.203](#) and [§205.601](#), and free of prohibited contaminants.

Adding composts to your fields can:

- Introduce diverse and abundant populations of microorganisms
- Speed the development of soil humus
- Add slow-decomposing materials that will become humus
- Improve soil structure and soil aggregate stability

Microorganisms continually mineralize soil nutrients, making them available to crop plants in the soil. Compost provides carbon-rich

food for these microbes, which secrete glue-like compounds to help bind soil particles together, improving soil structure.

RODALE INSTITUTE'S TAKE ON COMPOST

At Rodale Institute, we import and experiment with a variety of compost feedstocks. Our research indicates that it's entirely possible to build and retain fertility without the use of animal manures. But if you have livestock on your farm (or another good manure supply close to home), our advice is to use it.

Making your own compost minimizes external inputs and expenses, and offers you more control of the product. Your choice to compost on-farm livestock wastes or apply them directly to the field will depend on your availability of labor, space and equipment. Composting has added value in that it:

- Reduces the volume and weight of feedstock materials by more than half
- Kills weed seeds and pathogens
- Eliminates flies and odors
- Stabilizes nutrients



Photo Credit: Jack Sherman

Commercial compost turners can cost \$250,000 or more.



Stay tuned. Discussions of possible changes to the compost regulation are ongoing. Check with your certifier for the latest information.

GUARDING AGAINST CONTAMINATION

NOP Standards define compost strictly to guard against contamination of food crops with animal wastes that can carry dangerous bacteria such as the infamous E. coli 0157H7. NOP Standards define all manures, including those that have been stockpiled and/or mixed with plant materials, as “raw” unless they can be shown to have been composted according to NOP Standards.

A few words of warning: There are serious concerns about the consistency of ingredients, levels of foreign matter and possibility of toxins.

To minimize potential problems, try to keep your number of feedstock suppliers to a minimum. Be aware of state and local waste-handling regulations that may affect what materials you can receive and how and where you store them.

90/120-day rule

If you're growing crops for human consumption, the NOP stipulates that no manures may be applied within:

- 120 days prior to harvest for crops whose edible portion has direct contact with the soil surface (such as lettuce, carrots, or potatoes), or
- 90 days prior to harvest for crops whose edible portion does not have direct contact with the soil surface (such as sweet corn, tomatoes and peppers).

Properly made compost, on the other hand, may be applied within these time windows. In general, these restrictions will affect only vegetable growers, who commonly raise short-season crops with high nutrient demands in tight rotations. Many organic grain and dairy farmers “compost” on-farm livestock manures without having to worry about maintaining time-temperature-and- turning logs. In practice, most certified organic farmers either abide by the 90/120-day rule or use thermometers that automatically record time and temperature data within their compost piles.

BUYING QUALITY COMPOSTS

If you can find a reputable compost producer reasonably nearby, the quickest way to get organic compost is to buy it.



Photo Credit: Rodale Institute

Some commercial composters, such as Vermont Natural Ag Products (makers of Moo Grow, above), sell compost products by the bagful or the truckload. Some farmers augment their income by selling their excess compost.

Before you place an order, be sure you know what you're getting. Ask for references, test results and other information. The main quality criteria for commercial compost, assuming there are no toxins present, include:

- Compost maturity (immature compost can be harmful to plant growth because it can rob nutrients to finish composting, but overmature compost may lack microbial activity)
- Feedstock sources
- Percentage of nitrogen (0.5 to 4% is a good range)
- Particle size
- Salt content (lower salt content indicates greater maturity)
- Organic matter content (20 to 30% dry weight is optimum)
- Presence of weed seeds
- pH-buffering capacity

MAKING YOUR OWN COMPOST

It's easier than you think. Don't shy away from the challenges of making your own compost.

Many people have succeeded and now include compost sales as an important income stream in their total farm economic picture.

Site location for your compost operation will be critical to your success and may involve local and/or state approval. Avoid areas near surface water, such as streams, lakes, ponds and rivers, and your own well. Use of biofilters such as sod fields will go a long way toward avoiding potential pollution problems.



Photo Credit: Jack Sherman

Here at the Rodale Institute, we use most of the compost we make right here on our farm.

The three key mixing factors that set the stage for good composting are:

- A carbon-to-nitrogen ratio of somewhere between 25:1 and 50:1
- Adequate pore space for air to promote beneficial aerobic microorganism
- The right moisture content—around 50 to 60%

As you construct your piles, use the right combinations of high-carbon materials (such as straw, leaves and crop residues) and nitrogen rich materials (such as manures or green plant material) to ensure targeted carbon-to-nitrogen ratio and pore space structure.

Give the compost the squeeze test to check the moisture. If the material releases a few drops when squeezed, moisture is probably in the right range. If water drips out liberally, the compost is too wet, in which case you may want to cover your pile with a tarp or blanket to prevent more water from getting into the pile. If the material falls apart in your hand, it's too dry, indicating that you should wet the pile to improve the speed and quality of the composting process.

TURNING COMPOST

You will need to turn the compost three or four times a month for the first two to three months. After that, your turning regime will depend on your labor availability and how fast you need to produce compost. Here at our farm, we sometimes let the piles sit for six months, which slows the compost-making process but saves on labor. The more compost is turned, the faster it matures.

As with tillage, turning exposes microorganisms and organic materials to oxygen and accelerates their biological breakdown. It also promotes the escape of airborne ammonia, which not only reduces the nitrogen level of the pile but contributes to acid rain and greenhouse-gas production.

A less common, but allowable, option for compost aeration is to force air into a static (untuned) pile via pipes. Using hollow-stemmed, oxygen-containing grasses such as reed canary grass as a compost feedstock also introduces a source of air into the pile without turning it.

HEATING AND CURING

In the first stage of compost making (the thermophilic stage), heat-loving microbes (mostly bacteria) bloom, organic matter is degraded and particle size is reduced. Pathogens are destroyed above 131°F, and most weed seeds are destroyed at temperatures above 145°F. Even though 170°F is the top of the NOP Standards' temperature range, compost temperatures above 155°F are generally undesirable because they can kill the beneficial microbes so important to bioactive composts and healthy soils. Composts that have reached these temperatures are often black in color.

The curing stage is the post-thermal stage of the composting process, when most of the available carbon has been consumed. This is the growth stage for fungi and actinomyces, two important members of the compost microbial roster.

Attaining proper compost maturity is critical to compost performance as a soil amendment, because immature composts can increase salt levels in the soil, may not provide adequate nutrients, can rob nutrients in order to finish breaking down and could even burn the crop (mostly a concern with vegetables). Mature composts have converted much of the raw organic matter to stable humic substances. At maturity, compost does not generate a microbial bloom with accompanying heat, and it contains low levels of ammonium and salts.

COMPONENTS OF COMPOST QUALITY

In mature high-quality compost:

- Parent feedstock material should not be recognizable
- Structure includes medium- and fine-size particles and humus crumbs
- Moisture content should be 40 to 50%, dry enough that the compost doesn't ball up in your fist
- Smell should be earthy, like humus or forest soil (this is the actinomycete microbe population); no ammonia, sour, putrid or manure odors, which are byproducts of anaerobic microorganisms
- Temperature should be near that of the air temperature; the material shouldn't steam unless the ambient temperature is below freezing

If quick-germinating seeds like cress, radish or wheat sown in a sample grow well, the compost is mature and likely of good quality. You can also buy on-farm test kits and laboratory analysis services for compost.

The carbon-to-nitrogen (C:N) ratio plays a crucial role in the availability of nitrogen from any organic material added to the soil. The higher the C:N ratio, the more the balance favors carbon, and

the slower the release of the nitrogen will be.

According to the NOP, the initial C:N ratio of a newly mixed compost pile should be between 25:1 and 40:1. Finished compost C:N ratios generally range from 14:1 to 22:1, depending on the feedstocks.

If the C:N ratio is much above 30:1, then the microorganisms that use the carbon in the material as an energy source will also immobilize the nitrogen. The nitrogen will remain in the soil, unavailable for use by plants until later.

FINISHED COMPOST

Finished compost is a dilute organic fertilizer with analyses in the range of 1-1-1 to 2-1-2 (nitrogen-phosphorus-potassium (N-P-K)). Values will vary according to the types of materials used and how they were composted.

Like soil, compost can be lab-tested for major and minor elements (phosphorous, potassium, calcium, magnesium, zinc, boron, iron, manganese, and copper), water content, pH, organic matter, total nitrogen, nitrate, ammonium, C:N, soluble salts, and extractable heavy metals. This information can be used to determine how much compost to apply for maximum plant growth and minimum nutrient loss.

Some labs can also analyze the microbial makeup of your compost, but the value of such testing is more difficult to assess. To evaluate compost's effect on soil fertility, test soils several months after application (but not during the winter or under drought conditions).

The pH of finished compost tends to be slightly alkaline. Compost usually does not raise field soil pH to undesirable levels, because the total amount of compost applied is small relative to the amount of soil in the field. In greenhouse applications, where the amount of compost as a percentage of the growing medium is much higher, you'll need to monitor the compost's pH

GLOSSARY TERMS

Actinomycete: One of a class of bacteria largely responsible for the decomposition of organic matter in soil, and thus for the production of humus and replenishment of soil nutrients.

more closely. The alkalinity of the media can be neutralized if necessary with an NOP-approved sulfur or acidifying compound.

MANURES IN COMPOST

Manures can be especially useful after crops that leave little plant residue, such as silage corn. You can realize the full benefits of the manure by coordinating its use with cover crops, liming and other soil management practices.

The nutrient value of manures is influenced by what the livestock are fed. In general, about 75% of the nitrogen, 80% of the phosphorus, 90% of the potassium and 50% of the organic matter in livestock feed are recovered in the “end product.” After losses to volatilization and leaching, only about a third to half of these values is realized in crop production.

Even “solid” manure is 50 to 80% water, so an application of 10 tons per acre provides 2 to 5 tons of organic matter. Liquid manure, produced in many confinement operations, will lose nitrogen rapidly through volatilization if it is not incorporated into the soil.

Combining liquid manure with high-carbon organic matter and composting will vastly improve its benefits for your fields.

RESEARCH

Research by the Rodale Institute found that raw manure, synthetic fertilizer and broiler litter/leaf compost lost 100, 75 and 32 pounds of nitrate, respectively, during a 9-year trial. Each material was applied to optimize vegetable crop yield within a rotation including corn and wheat, and each produced statistically equivalent yields over the 11-year trial. However, compost did more to increase soil carbon levels than the manure or chemical fertilizer, suggesting that it has greater positive impact on soil stability, tilth and fertility with long-term use.

GUARDING AGAINST NUTRIENT LOSSES

Organic manure poses as much of a risk of nutrient loss as non-organic manure. Nutrients from any source can become pollutants when



Photo Credit: Jack Sherman

Nutrient runoff can be a problem on organic farms, too. Well-made compost is much less susceptible to this problem than straight manure.

they move below the root zone, beyond the reach of plants. Slurry (semisolid) and liquid manure contain highly available nutrients, which increase the need for careful handling and application.

In order to prevent leaching and runoff of manure nutrients:

- The receiving crop should be a heavy feeder able to use all the available nutrients.
- The crop should be already present, or planted shortly after application, to ensure maximum uptake of the nutrients.
- The soil should be capable of absorbing and storing those nutrients not used by the production crop.
- Never apply manure when conditions will allow runoff to waterways, such as on frozen soils.
- Other soil amendments permitted in organic systems

§[205.203\(d\)](#) of the NOP Standards provides for a fourth category of soil amendment, other than composts, manures and uncomposted plant materials. Producers may apply:

- A crop nutrient or soil amendment included on the National List of synthetic substances allowed for use in organic crop production;
- A mined substance of low solubility;
- A mined substance of high solubility ... provided that the substance is used in compliance with the conditions established on the National List of nonsynthetic materials prohibited for crop production;
- Ash obtained from the burning of a plant or animal material ... provided, that the material burned has not been treated or combined with a prohibited substance;
- A plant or animal material that has been chemically altered by a manufacturing process ... provided that the material is included on the National List of synthetic substances allowed for use in organic crop production.

Allowable fertility products can provide supplemental nitrogen (from bloodmeal, cottonseed meal, fish byproducts, feathermeal and processed livestock manure); phosphorus (from soft rock phosphate or bone meal); potassium (from sulfate of potash or greensand); and calcium (from oystershell lime or mined limestone in low-pH soils and from gypsum in balanced or high-pH soils).

PROHIBITED PRACTICES AND AMENDMENTS IN ORGANIC SYSTEMS

§205.203(d) of the NOP Standards prohibits burning as a disposal strategy for crop residues produced on the farm except “to suppress the spread of disease or to stimulate seed germination.”

In addition, organic producers may not use any fertilizer or composted plant or animal material that contains a synthetic substance not included on the National List of those allowed for use in organic crop production. Sewage sludge (commonly called biosolids) also may not be used.

As mentioned in the “Why organic?” chapter, the NOP Standards include a set of guidelines governing materials for use in certified organic

systems. In general, natural materials are considered “innocent until proven guilty,” while synthetic materials are considered “guilty until proven innocent.” The National List of Allowed and Prohibited Substances is a list of exceptions to that rule: allowed synthetic substances and prohibited natural substances



Photo Credit: Miracle Gro

Just because a soil amendment uses the word “organic” in the label, don’t assume it’s approved for organic production. The word is not regulated for agronomic products in the same manner that it is for crops, livestock feed and human food. Always check with your certifier.

BUYER BEWARE

Just because a soil amendment label says “organic” doesn’t necessarily mean it meets NOP Standards. Soil amendments cannot be “certified organic,” because they don’t fall under the NOP Standards. Some materials may be labeled “organic” based on the fact that they contain carbon.

Even if a soil amendment says “meets NOP Standards” or bears the Organic Materials Review Institute (OMRI) logo, you should still check with your certifier before you use it. It’s your responsibility to make sure everything you bring onto your organic farm meets NOP Standards and your certifier’s approval.

Review package ingredients against the National List, consult OMRI and check with your

certifier before using any new product. Failure to do so could cost you three years' certification. And remember, any equipment used to apply organic amendments that might also be used to apply prohibited substances to non-organic fields must be thoroughly cleaned to prevent contamination.

This caution holds true for purchased compost and livestock feed mixes as well. If a product claim sounds too good to be true, it probably is.

OMRI

The [Organic Materials Review Institute](#) OMRI is a nonprofit technical- assessment entity specializing in the review of substances for use in organic production, processing and handling. OMRI tests items submitted to it by manufacturers, then lists those that comply and may bear the OMRI label. However, final determination of product use rests with individual certifiers, in compliance with the NOP.

CONCLUSION

This concludes the Soils chapter. You should now be able to identify healthy soil when you see it—and touch it and smell it—and have a basic idea of the various types of soil tests and how you can make use of them as you move forward. You now have the basic tools to begin feeding—and building—your soil, so your soil can feed your crop plants.

Remember, building a healthy organic system isn't about expensive packaged inputs; it's about encouraging a diverse web of life both above and below the ground. Your soil is much more than a medium that holds up your plants; healthy soil actually breathes, delivers nutrients to plants more efficiently, comes to the aid of your crop in time of stress such as drought, and is less susceptible to the erosive power of wind and moving water.

In this chapter, we discussed crop rotation and cover crops as they relate to building healthy soil. In the next chapter, Crops, we will cover these topics in more detail and learn how cover crops can not only help protect your soil and

build fertility, but can help break pest and disease cycles, suppress weeds and more.

It's time to update your Organic System Plan. Then, go out and take a walk around your farm, let what we've covered so far sink in a little bit, and I'll meet you back here when you're ready to continue.

RESOURCES

Resources are free online unless otherwise noted.

SOIL HEALTH

[Organic and Conventional Beyond Transition](#)

Steve Peters
(The Rodale Institute, 1991)

[Edaphos : Dynamics of a Natural Soil System](#)

Paul Sachs
(Edaphic Press, 1999)
197 pp. \$15.00+

[ATTRA soils page](#)

[Cornell Soil Health website](#)

[Soil Food Web](#)

[Alternative Soil Testing Laboratories](#)

Steve Diver
(ATTRA, 2002)
24 pp

SOIL MANAGEMENT

[Building Soils for Better Crops](#)

Fred Magdoff and Harold van Es
(SAN, 2000)
241 pp.

[Soil Management: National Organic Program Regulations](#)

B. Bellows
(ATTRA, 2005).
20 pp.

[Effect of tillage and intensity on nitrogen dynamics and productivity in legume based grain systems](#)

Laurie Drinkwater, et al
Plant and Soil 227(2):99-113.

[Pursuing Conservation Tillage Systems for Organic Crop Production](#)

George Kuepper
(ATTRA, 2001).
28 pp.

COMPOSTING

[Biodynamic Farming and Compost Preparations](#)

(ATTRA, 1999)
20 pp.

[Woods End Research Laboratory, Inc.](#)

Compost analysis pioneers and specialists.