Soil Management: National Organic Program Regulations

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The National Organic Program Rule, §205.203, Soil Fertility and Crop Nutrient Management Practice Standard, does not define specific land practices that producers must use. But it does identify general soil management and environmental protection objectives. From these objectives, producers and the organic certifiers they work with must determine whether specific farming practices meet the NOP criteria. This publication provides management guidelines for meeting, and measurable parameters for monitoring, these objectives. It also discusses why these objectives are essential for maintaining sustainable, organic production systems.

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ATTRA is the national sustainable agriculture information service operated by the National Center for Appropriate Technology, through a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. NCAT has offices in Fayetteville, Arkansas, Butte, Montana, and Davis, California.

The National Organic Program (NOP) Rule, Section 205.203, outlines general goals for organic production. This publication does not intend to interpret these regulations in a legal sense. Instead, it explores ecological interactions that affect organic production and points out how understanding these interactions can help farmers, inspectors, and certifiers determine which soil management practices meet the National Standard.

Conservation tillage helps improve or maintain soil health and minimize erosion. Photo by Tim McCabe, USDA ARS.

The first part of this publication examines the three major provisions within Section 205.203 and discusses the relationship of each of the provisions to soil ecology. This is followed by a list of management options suggested by each provision. The second part of the publication discusses interactions among the three provisions and describes how certain management practices can meet multiple provisions within this section. It also examines methods for monitoring compliance with the provisions of this section.

Section 205.203(a)

Select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion.

This subsection provides guidelines for soil preparation. It requires that producers use tillage and cultivation practices that protect against soil erosion, while also maintaining or improving soil quality.

To better understand this subsection, we will first examine soil characteristics associated with improved physical, chemical, and biological conditions. Then we will look at how these changes in soil quality affect plant growth, health, and production. Finally, we will look at management practices that can facilitate these changes.

Improve physical condition of soil

Producers describe soil's physical conditions using terms such as "softness," "mellowness," "workability," or "tilth." Soil scientists measure soil physical conditions using the terms "bulk density," "penetrability," "water infiltration rate," "water holding capacity," and "erodibility." Soil that has good physical condition is porous, like a sponge, rather than tightly packed, like a ball of modeling clay. Soil in good physical condition provides several benefits for plant growth.

- Plant roots can grow through the soil without restriction.
- Air, water, and nutrients needed by plants and soil organisms can move through the soil with relative ease.
- Water from rainfall or irrigation seeps into the soil, rather than flowing over the soil surface as runoff.
- Soil organisms involved in decomposition and mineralization of plant and animal residues are able to thrive and disperse throughout the soil.

Soil that has good physical condition is porous, like a sponge, rather than tightly packed, like a ball of modeling clay.

Photo by Lynn Betts, USDA NRCS.

Improve chemical properties of soil

Producers describe soil chemical properties in terms of soil fertility, salinity, and acidity or alkalinity (soil pH). Soil fertility can be subdivided into nutrient availability for plant uptake, the soil's nutrient-holding capacity, and the balances among plant-available nutrients. You can evaluate your soils for good chemical conditions by monitoring the following characteristics.

- Soils have a near-neutral pH (unless the soil is used to grow acid-loving crops, such as blueberries or cranberries).
- Sufficient nutrients are available for productive crop growth, but not in excess that causes plant toxicities or contaminates nearby streams or aquifers.
- Soil nutrients are in forms available for plant uptake, but they are held sufficiently enough not to be easily leached or carried away by runoff.
- The availability of plant nutrients is sufficiently balanced to promote healthy plant growth and microbial activity. This objective recognizes that a plant is only as healthy as its most limiting nutrient allows.
- Soils do not contain toxins or heavy metals in concentrations high enough to inhibit plant growth or the growth of beneficial soil organisms.

- Soils contain enough moisture to facilitate nutrient movement to plant roots.
- Soils contain sufficient oxygen for plant growth and the growth of soil organisms.
- Soils contain relatively high levels of organic matter, which helps them hold water and nutrients.

Improve biological properties of soil

Improving soil physical and chemical properties is important for both conventional and organic production, but improving biological properties is particularly important for organic production. Producers describe soil biological health in terms of "earthy smell," "soil crumbliness," and "greasy feel." Soil scientists measure soil biological health in terms of microbial biomass, microbial communities, and rate of organic matter decomposition.

Organic production relies on nutrients released through the decomposition of plant and animal residues. Decomposition is a biological process involving a variety of soil organisms, including beetles and other insects, worms, nematodes, fungi, bacteria, and algae. You can evaluate your soils for healthy biological properties by monitoring the following characteristics.

- Plant and animal residues added to the soil are readily broken down and decomposed so that plant nutrients become available.
- A good soil structure, provided by stable organic compounds, remains following the decomposition of plant and animal materials.
- Soil is well-aggregated; that is, it is composed of soft clumps held together with fungal threads and bacterial gel.
- Legumes form healthy nodules and fix abundant nitrogen, especially in nitrogen-depleted soils.
- Plants have a relatively high resistance to soil-borne diseases.

Minimize soil erosion

Minimizing soil erosion is critical for sustainable agriculture.

Soil erosion is the loss of surface soil to forces of wind and water. Soil erosion reduces soil productivity and can cause water and air pollution. Minimizing soil erosion is critical for sustainable agricultural production, because the top layer of soil has properties—physical, chemical, and biological—that are much more favorable for crop production than the lower layers. The topsoil also contains more organic matter than the lower layers. This native soil organic matter—which represents centuries of plant growth, death, and decomposition in the soil—can both protect soil against erosion and be easily lost to it. Soil aggregates, held together by organic compounds, facilitate water infiltration and enhance water-holding capacity. They also are slow to erode because of their size and weight. However, if soil aggregates are broken down—by dry conditions, excessive tillage, or by raindrop impact—the resulting organic matter particles are very lightweight and easily removed by erosion.

Earthworms improve soil tilth by creating aggregates and forming passageways through the soil. Photo courtesy of USDA ARS.

Tillage prepares land for seeding or transplanting. Cultivation practices—implemented either before or after crops are in the ground—

Use care in residue management. While crop residues provide organic matter and protect against erosion, they can also increase the risk of plant diseases.

manage weeds and improve soil aeration and water infiltration. Traditional clean tillage disrupts soil organisms, reducing their numbers and, often, their diversity. Clean tillage also breaks down soil aggregates and produces a bare soil that is vulnerable to erosion and more subject to temperature changes than soils that have a mulch or vegetation cover. Under direct exposure to sun and high temperatures, soil organisms break down soil organic matter rapidly. The rate of organic matter decomposition further increases when tillage breaks soil aggregates into smaller pieces, increasing their surface area and exposure to oxygen. While a rapid breakdown of organic matter can benefit plants by increasing nutrient availability, a substantial decrease in organic matter reduces aggregate stability, decreases soil tilth, and increases the potential for nutrient loss through leaching and runoff.

Conventional farmers control weeds through a combination of synthetic herbicides and physical cultivation, including cutting, burning, incorporation, or plowing. Herbicides can harm soil organisms, thereby reducing nutrient cycling and aggregate formation. Physical cultivation methods vary in their impact on soil ecology and soil susceptibility to erosion. For example, plowing under weeds or crop residues can disrupt microbial populations and produce a bare soil that is susceptible to erosion. In contrast, practices that cut weeds and leave them on the soil surface can protect the soil against raindrop impact, the heat of the sun, and drying winds, while providing soil organisms with a source of food and energy. (Unfortunately, these weeds may also be sources of plant diseases.)

As stated in §205.203(a), organic producers must use tillage and cultivation practices that "maintain or improve the physical, chemical, and biological properties of soil." Tillage and cultivation practices that meet these criteria will have the following general characteristics.

- Promote water infiltration
- Minimize soil compaction
- Minimize degradation of soil aggregates
- Protect soil from the erosive forces of wind and water
- Minimally disrupt the habitat of beneficial soil organisms
- Return or add plant or animal residues to the soil to serve as food and energy sources for soil organisms

Practices that you can use to reduce soil disturbance, provide a residue cover, or otherwise protect the soil surface from erosion and organic matter loss include

- Minimum tillage
- Undercutter or roll-chopper tillage
- Mulch tillage or otherwise mulching with organic materials
- Promoting rapid growth of the crop canopy
- Flame weeding

Choosing the appropriate tillage and cultivation practices and implements for your fields depends on the location of the farm, the soil type, the crop being produced, the time of year, the climate, and weather conditions in a particular year. Tillage tools that are most damaging to soil structure are those that shear soil particles, such as moldboard and disk plows, while sweeps and chisels cause less damage.

Environmental and management factors can interact with particular tillage or cultivation practices to increase risks of soil-borne plant diseases and insect infestations, delay seed emergence, or inhibit organic matter decomposition and nutrient mineralization. For example, farmers in New England and the upper Midwest rarely use no-till practices, because a thick residue cover does not allow the soil to warm up and dry out in the spring. The resulting wet, cool soil conditions increase the time needed for seed germination, while also increasing the risk of seed and seedling diseases. Instead, they use modified minimum till practices, such as ridge till, which leaves sufficient residues on the soil surface to reduce erosion but allows the seedbed to warm up and dry out.

To further "maintain or improve the physical, chemical, and biological properties of soil" you can use practices that replace organic matter lost to decomposition. These practices include the use of

- Cover crops
- Green manures
- Compost
- Mulch
- High residue crops
- Perennial crops

More details on these practices are included in the next section.

Related ATTRA Publications

For more information on tillage and cultivation practices appropriate for organic production, see the following ATTRA publications.

Pursuing Conservation Tillage Systems for Organic Crop Production

Flame Weeding for Vegetable Crops

Use of crop rotations and cover cropping as cultivation practices

Cultivation is any practice used to "improve soil aeration, water infiltration and conservation, and control weeds." In a well-managed cropping system, crop rotations and cover crops can provide the benefits of cultivation and compensate for many of its negative impacts.(1, 2) This is consistent with §205.205 Crop Rotation Standard, which states that a *"producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:*

(a) Maintain or improve soil organic matter content;

(b) Provide for pest management in annual and perennial crops;

(c) Manage deficient or excess plant nutrients; and

(d) Provide erosion control."

Rotating cold- and warm-weather crops can suppress weeds by disrupting their life cycles. Alternatively, some crops exude chemicals that suppress weeds.(3, 4) Good crop rotations involve crops that have different planting dates, rooting habits, lengths of production, cultivation requirements, and harvesting requirements.(5) All of these factors affect the ability of plants to compete with weeds.

Cover crops effectively reduce weed pressure by occupying the space and using the light, water, and nutrients that would otherwise be available to weeds. Cover crops can also be cut or lightly incorporated just prior to planting the main crop. The residues left after this cutting provides a cover over the soil surface that suppresses seed germination.(2, 3) Cover crops indirectly affect weed growth by increasing soil organic matter and soil tilth. Compacted or infertile soils favor the growth of some weeds, while crop plants compete better in fertile, well aggregated soils.(3, 4, 5)

Cover crops can be used to control weed growth.

Section 205.203(b)

Manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials.

Practices suggested by the requirement

This requirement makes implicit that fertility management in organic systems must involve, and rely on, biological processes. Section 205.203(b) does permit organic producers to use mined substances of low solubility, such as rock phosphate and greensand.(6) However, this section stipulates that at least some crop nutrients be provided through crop management practices and the application of organic residues.

This requirement also states that rotations, cover crops, and plant and animal materials must be used to manage crop nutrients and soil fertility, not just supply or provide crop nutrients. This provision encourages producers to protect water quality by growing crops that tie-up or immobilize excess nutrients. This reduces the potential for nutrients to be leached beyond the root zone, into groundwater, or carried away by runoff or erosion into nearby lakes or streams. For example, rye is capable of tying up large amounts of nitrates. Cover cropping to manage excess nutrients is particularly important for producers who farm soil that is sandy or that develops cracks in its profile. The permeability of these soils allows for ready leaching of excess nutrients.

Reliance of soil fertility management on biological processes

A major difference between conventional cropping systems and organic systems is the role of biological processes in organic systems. Most synthetic fertilizers are immediately available to plants. They do not require biological processes to make them available. And they do not enhance the biological health of the soil. In fact, several synthetic fertilizers degrade soil by drying it out or making it acidic or saline.

Organic soil fertility management relies on feeding the soil a rich, complex diet of plant residues, animal manures, and compost.

In contrast, a primary principle of organic farming is to feed the soil so that the soil can feed the plants. A healthy soil has good tilth and mineralizes organic matter efficiently, to provide plants with their required nutrients. It also has a diverse population of soil organisms that enhance plant growth in various ways, such as through symbiotic relationships with the plant, exuding enzymes into the soil, degrading toxins, and competing with pathogenic organisms.

Practices and inputs used by organic producers (as well as many others in sustainable agriculture) promote biologically healthy soils that sustain fertility in ways different from conventional systems. Organic systems use legumes and algae to fix atmospheric nitrogen in the soil. They promote the decomposition of plant and animal residues to make nutrients from them available to plants. Additionally, soil organisms produce bacterial gels and microbial threads that bind soil into aggregates, form humates that hold water and nutrients, and develop symbiotic relationships with plant roots to help them reach and use water and nutrients.(7) Recent research indicates that enzymes formed by soil microorganisms can enhance the growth and nutritional value of plants.(8, 9) Managing soil fertility with biologically-created inputs ensures that organic production is a dynamic biological process. Fertility management that relies on nitrogen fixation, recycling the nutrients from plant and animal wastes, and stabilizing nutrients in the soil profile will also help ensure that production practices are environmentally sustainable.

Management of crop nutrients and soil fertility

Organic soil fertility management is based on feeding the soil a rich, complex diet of plant residues, animal manures, and compost. In contrast, conventional agriculture simplifies crop nutrient and soil fertility management by feeding the plant soluble nutrients. Thus, crop nutrition in conventional agriculture can be managed with three pieces of information: 1) the amounts of nutrients used by the crop during the growing season, 2) the amount of plant-available nutrients in the soil, and 3) the amounts of fertilizer nutrients that need to be added to account for differences between crop nutrient needs and available soil nutrients.

Nutrient management in organic systems is more complex. Organic inputs cannot easily be added to the soil to provide the exact balance of nutrients needed by the plant for at least three reasons. First, many organic inputs (such as cover crops, crop residues, weeds, and compost) are added to the soil for reasons other than fertility management, yet they contribute to the pool of nutrients in the soil. Second, most organic materials, including compost and manure, have only a small component of soluble nutrients; most of their nutrients must be transformed through biological processes before they become available to plants. Thirdly, most manures and composts do not have a consistent nutrient content (such as the 10%N-10%P-10%K found on bags of synthetic fertilizers). They also contain a ratio of nutrients different from that needed for optimal plant growth. For example, dairy manure has a nitrogen to phosphorus ratio of approximately 2:1. However, hybrid corn requires eight times more nitrogen than phosphorus.(10)

You could try to combine plant and animal residues to get a nutrient ratio similar to that required by your crops. But these residues may not provide nutrients in the amounts and at the times needed for optimal plant performance. Nutrient availability in organic systems is primarily the result of biological processes. Soil organisms feed on some of the nutrients in the added organic materials, retain some in the soil as humus, and slowly mineralize and release others over time. In addition, environmental factors, such as soil moisture and temperature, affect organic matter decomposition and mineralization. Consequently, mineralization is slow during dry periods and in the spring and fall, when the soil is cool.

While crop and animal residues do not afford precise nutrient management, the integrated mineralization and humification process provides soils with a buffered storehouse of nutrients. The diverse populations of soil organisms involved in decomposition store residue nutrients in their bodies (biomass). Biomass nutrients are available for plant uptake, but they are protected from runoff, leaching, or volatilization.(11) Microbial processes also make humus from residues that are resistant to decomposition. Humus is responsible for improving soil tilth, water-holding capacity, and nutrient-holding capacity. Following mineralization, soil nutrients provided by organic materials are subject to the same chemical reactions as soluble nutrients from conventional fertilizers, such as sorption of phosphorus by iron oxide or precipitation of calcium with sulfate.

This provision of the standard does permit fertilizers with high levels of soluble nutrients, as long as they are derived from allowed crop and animal materials (such as fish and soybeans). These organic fertilizers provide nutrients in standardized amounts that are immediately available to plants. Ideally, these products are used as a complement to compost or other slow-release organic inputs, in order to provide a better nutrient balance or meet temporary high nutrient demands of the plants. Producers can use these soluble products to manage nutrient availability in a manner that mimics conventional fertility programs, while legally complying with the materials section of the National Organic Standard.(12) However, these producers do not comply with the intent of the standards, nor will they reap the multiple benefits of integrated, soil-based fertility management.

Farmers are encouraged to test their soils for nutrient needs, and to apply only what nutrients are needed. Photo by Lynn Betts, USDA NRCS.

In summary, plant-available nutrients in organic systems include minerals, nutrients that have been mineralized from plant and animal residues, nutrients held in microbial biomass, and nutrients that are being mineralized from decomposing residues. As a good organic producer, you should account for each of these nutrient sources to determine current and future nutrient availability. You should also view nutrient management as but one component of an integrated crop and soil management plan. Cover cropping, for example, not only produces and conserves nutrients but is also used for weed and pest control and for soil conservation.

Crop rotations, cover crops, and green manures as nutrient management components

Crop rotations and cover crops can add, deplete, or conserve soil nutrients, depending on how they are managed. They can also affect nutrient availability through a variety of processes. They use soil moisture, but they enhance water infiltration and aggregate formation. They also influence populations of soil organisms.(13)

Crop rotations and cover crops can add, deplete, or conserve soil nutrients, depending on how they are managed.

- **Nutrient additions.** Legumes fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing bacteria. Although some nitrogen is added to the soil while these plants are growing, the majority of fixed nitrogen becomes available when they die and decompose. The amount of nitrogen added by legumes depends on the type of legume, the soil conditions, and cropping practices. Alfalfa and clover fix around 175 pounds of nitrogen per acre, while soybeans fix only around 50 pounds. Most legumes fix more nitrogen when available nitrogen in the soil is low. Thus, growing legumes in nitrogen-depleted soil, underseeded with grasses or as companion crops with non-legumes, will stimulate them to fix more nitrogen.

- **Nutrient cycling**. Deep-rooted plants can retrieve nutrients that have leached below the root depth of other plants. Other plants are hyperaccumulators—they take up higher-than-normal concentrations of specific nutrients. While these plants do not add nutrients to the soil, their ability to capture or accumulate nutrients can help build soil fertility. Nutrients absorbed by these deep-rooted or hyperaccumulating plants are not available until they are cut or incorporated and allowed to decompose.

- **Nutrient depletion and tie-up.** Crop rotations remove nutrients from the soil if the crops are harvested and portions are removed from the field. Even when they remain in the field, cover crops and crop residues can deplete nutrients temporarily, if they do not decompose before the nutrients they contain are needed for crop production. If the added plant materials are woody or dry, they may immobilize or tie up nutrients. Immobilization means that plant materials do not contain enough nitrogen for microorganisms to effectively decompose them. When this occurs, the microorganisms must take nitrogen from the soil as they proceed with decomposition and mineralization. As a result, nitrogen availability is temporarily depressed. While this process can hinder plant growth, it can also conserve nutrients for later use, since those same microorganisms release nutrients as they die and decompose.

- **Nutrient conservation and management.** Nutrient management in organic systems is not only the addition of plant nutrients but also their conservation. Good nutrient management uses crop rotations and cover crops to provide the main crop with nutrients when they are needed and to conserve nutrients in the soil between cropping seasons, when they otherwise might be lost through leaching, erosion, or volatilization. For example, organic matter decomposition and nutrient mineralization can continue to release nutrients into the soil following crop harvest. If not held in microbial biomass or taken up by other plants, these mineralized nutrients, particularly nitrate, can leach through the soil profile, beyond the root zone, or into the groundwater. In another example, you may apply manure that contains a ratio of nutrients different from that needed by your crops. This can cause excess levels of nutrients, particularly phosphorus, to build up in the soil.

Crop rotations can reduce or tie-up excess nutrients in the soil. Cover crops take up plant nutrients as they grow, then release these nutrients back to the soil when they are cut or incorporated and undergo decomposition.(7, 14) Rye and other grasses are good scavengers of excess nitrogen; legumes are good for taking up excess phosphorus. Applying woody residues can help hold excess nutrients in the soil. Organisms involved in the decomposition of these carbon-rich and nutrient-poor residues need to use nutrients from the soil to make up for nutrients not available from the residues.

Planting rotations or mulches that include legumes, succulent crops, and woody crops favor a large and diverse population of soil organisms. These organisms retain nutrients in their biomass, which protects against nutrient loss through leaching, runoff, or volatilization.(11) Producers can also use cover crops to control weeds that otherwise would compete with crop plants for nutrients.

Related ATTRA Publications

For more information on methods for using crop rotations and cover crops to manage soil and plant nutrients, see the following ATTRA publications.

Organic Crop Production Overview

Intercropping Principles and Production Practices

Diversifying Cropping Systems

Rye as a Cover Crop

Protecting Water Quality on Organic Farms

Also see the SAN handbook *Managing Cover Crops Profitably* (2nd edition).The handbook can be ordered at *www.sare.org/publications/index.htm#books*. The pdf version of this publication is also available at this Web address.

Section 205.203(c) and (d)

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. (These sections go on to list acceptable and prohibited plant, animal, and mineral nutrient inputs.)

Practices suggested by the requirement

This requirement specifies that nutrient inputs—plant, animal, or mineral—not only supply crops with necessary nutrients but also help build soil quality. It also requires producers to manage nutrient inputs in a way that ensures food safety and protects the environment. To meet these objectives, you need to be careful not to apply more nutrients than the plant needs or to apply them in a way that leaves them vulnerable to runoff or erosion. You also need to be aware that some composts, manures, or other inputs may contain substances that can be harmful to human health or to the environment.

Photo by Steve Diver.

The green manure Crimson Clover provides robust growth and high nitrogen fixation.

Maintain or improve soil organic matter content

Soil organic matter is a central component of soil quality. Composed of relatively stable, decomposed or humified material, soil organic matter enhances soil quality by improving

- Water absorption and water holding ability of soil
- The ability of soil to prevent nutrient leaching
- Soil tilth and aggregation
- Plant roots' ability to grow through the soil
- The ability of nutrients, water, and air to flow through the soil
- Soil organisms' habitat and access to nutrients

Not all plant and animal residues are equally effective in maintaining or improving soil organic matter content. Soil organisms readily decompose fresh manure and very young

Contaminants include excessive levels of plant nutrients, introduced pathogenic organisms, heavy metals, and residues of prohibited substances.

and fresh plant materials. As they decompose these materials, they release plant-available nutrients into the soil. In contrast, fewer soil organisms are able to break down and mineralize woody or dry materials, such as corn stalks, wheat stubble, or woodchips. As a result, decomposition of these materials takes longer than it does for more succulent ones. In addition, soil organisms are not able to decompose some of this organic material, and they transform it into soil humus instead. Humus gives good quality soil a soft and somewhat greasy feel. It is also responsible for building soil aggregates and increasing the capacity of the soil to hold water and nutrients. Thus, if you add a combination of succulent and woody residues to a field, you will fulfill a key objective of sustainable organic soil management—supplying crops with necessary nutrients while building soil organic matter and enhancing soil microbial health.

Soil and water contamination

Soil can become contaminated if harmful or prohibited substances are

- Applied as components of otherwise allowed materials, like compost
- Contained in irrigation water
- Contained on seed coatings
- Permitted to leach or flow into certified fields from conventional farms

For agricultural practices to contaminate either groundwater (aquifers) or surface water (lakes, streams, rivers), there must be a source of contamination, and the contaminant must be transported into the groundwater or the surface water. Contaminants leach into groundwater most readily when the soil is very porous, when the contaminant is not held in the soil either by organisms or by chemical forces, and when the water table is high. Runoff and erosion can transport contaminated soil from fields into rivers, lakes, or streams. Runoff dissolves and transports weakly-bound contaminants from the soil surface and off plant leaves. Erosion detaches soil particles from the surface, carrying with them any adhered contaminants. Erosion occurs most readily when the soil is not covered with growing plants or plant residues.

Types of contaminants

Contaminants include excessive levels of plant nutrients, introduced pathogenic organisms, heavy metals, and residues of prohibited substances.

- Plant nutrients are most readily removed and carried by water when their concentration in the soil is well in excess of that needed by the plants. This happens when heavy applications of manure are made many years in a row.
- Pathogenic organisms are usually associated with the application of uncomposted manure. Organisms of particular concern include E. coli, Salmonella, Giardia, and Cryptosporidium. The compost practice standard §205.203(c)(2) was incorporated in the National Organic Standard—along with rules limiting fresh manure application, §205.203(c)(1)—to reduce health hazards from pathogen contamination. Contaminated irrigation water can also be a source of pathogens. Irrigation water may be contaminated by manure-storage or sewage-treatment facilities. Over time, the activities of beneficial soil organisms will reduce populations of pathogenic organisms.
- Heavy metals. Arsenic is added to broiler poultry feed to reduce diseases and stimulate growth. This heavy metal passes through the birds and is deposited in the poultry litter, thereby contaminating this source of plant nutrients. Litter from layer operations may contain copper or zinc that leaches from the cages. Composts may include residues of plants that were treated with pesticides containing heavy metals. Additionally, fertilizer pellets made from manure or litter may have additives that contain heavy metals or other non-allowed substances.

- Residues of prohibited substances. Organic producers must be sure that inputs they use for nutrient management, pest control, or building soil quality do not contain materials listed as "prohibited substances" on the National Organic Program National List.(15)

Related ATTRA Publications

For more information on methods for building soil organic matter, selecting organic fertilizers, protecting water quality, and minimizing risks of contamination, see the following ATTRA publications.

Sources of Organic Fertilizers and Amendments

Farm-Scale Composting Resource List

Protecting Riparian Areas: Farmland Management Strategies

Protecting Water Quality on Organic Farms

Arsenic in Poultry Litter: Organic Regulations

For more information on soil conservation and methods for protecting against runoff from manure or compost piles, contact your local NRCS, Soil and Water Conservation District, or Cooperative Extension office.

Monitoring Practices for Section 205.203

The remainder of this publication provides producers, organic inspectors, and organic certification agencies with a set of observable or measurable indicators to monitor compliance with this section of the NOP regulations.

Monitoring soil nutrient levels

A good nutrient management plan involves on-going monitoring of soil nutrients. You can request a standard soil test through your Cooperative Extension Service. These tests provide an assessment of plant-available nutrients, as well as soil acidity or alkalinity (pH), nutrient holding capacity (CEC, or cation exchange capacity), and trace substances such as sodium (Na) and boron (B) that may be present at toxic levels. Organic producers and inspectors should use these tests to

- Determine levels of nutrient inputs to add to achieve productive plant growth
- Identify any excess nutrients (If so, cropping and nutrient management practices should be developed to decrease these nutrient levels and minimize their movement from the root zone into groundwater or surface water.)
- Monitor soil organic matter (Note: This test often is not included in the standard soil test, but it is available at an extra charge. You will need to specify that you want this test done.)
- Manage nutrient imbalances (Plant heath is determined by the availability of the least sufficient nutrient. High levels of sodium can degrade soil tilth and aggregate stability, while soils with high calcium to magnesium ratios usually have better water permeability.)

How often you conduct soil tests depends on your cropping intensity and the nutrient inputs you use. Annual or bi-annual soil testing is sufficient for general nutrient management. However, if you are a transitioning producer, changing your nutrient management practices, or testing new management methods, you may want to conduct soil tests

Most state soil testing laboratories provide nutrient management recommendations in terms of pounds of conventional fertilizers per acre. To determine the appropriate amount of manure, compost, or other organic nutrient input to apply, organic producers must make calculations based on soil test results, crops being grown, and the nutrient content of any crop residues returned to the soil. Many organic growers prefer working with specialized private soil testing laboratories that will help them with these calculations. Several of these soil testing laboratories recognize that organic growers are interested in more than just the chemical characteristics of their soils. Thus, they also provide microbial assessments and other analyses of soil biological health

For an annotated list of private soil testing laboratories, see the ATTRA publication *Alternative Soil Testing Laboratories.*

more frequently to better understand how your practices are affecting nutrient availability. As discussed below, sampling at different seasons can provide you with an indication of changes in nutrient availability throughout the year.

Timing of soil tests is important. If plant and animal residues are applied in the fall, conduct soil tests in the early spring, prior to planting, to determine the plant-available nutrients from these additions. This allows time for the organic materials to decompose. To determine whether you need cover crops to hold excess nutrients in the soil over winter, conduct soil tests after harvesting the main crop.

Nitrogen is a major plant nutrient and a central component of organic nutrient management.

Nitrogen is a major plant nutrient and a central component of organic nutrient management. However, standard soil tests do not provide an accurate assessment of soil nitrogen levels. (While most standard soil tests provide an assessment of nitrate [NO3], the level of this soil nutrient is highly affected by when the sample was taken and how it was handled between then and the analysis. As a result, this reading provides little useful information for nutrient management practices.) Soil test strips provide a simple indicator of nitrogen availability (or excess). Soil testing meters and organic matter mineralization tests (Solvita™ and others) provide a more accurate assessment.

Tissue tests (i.e., leaf analysis) measure a plant's nutrient uptake. These tests are useful indicators of available soil nutrient levels during the cropping season. Tissue testing is particularly useful for identifying nutrient imbalances or toxic concentrations of nutrients in the soil. Unless it is used in conjunction with soil tests, it cannot provide a good indication of the availability of nutrients for the following crop or cropping season.

Monitoring nutrient mineralization

As mentioned above, you can use standard soil and nutrient mineralization tests to monitor soil nutrient availability. However, organic nutrient management relies not only on nutrients available at the time of soil sampling but also on the nutrients released through mineralization during the growing season. Unfortunately, there is no easy or inexpensive test that assesses when, which, or how many nutrients are released from crop residues or mineralizing organic matter. Instead, you will need to estimate mineralization rates based on the following criteria.

- For compost, manure, poultry litter, or mulches
  - Nutrient analyses of material
  - Application rate (pounds per square foot or tons per acre)
  - Date of application
- Cover crops and green manures
  - Crop grown as a cover crop or green manure
  - Whether a legume cover crop was inoculated with nitrogen-fixing bacteria (*Rhizobia* species)
  - Growth stage at which it was cut or incorporated (Cut the cover crop when it is at 50% bloom, unless your farm is in an arid area where this level of cover crop growth would deplete water needed for your primary crop. This is the prevailing recommendation for maximum nutrient availability for the next annual crop.)
  - Yield level
  - Nutrient value of the residues left in the field
  - Management of the cover crop after its growth was terminated (Was it left on the soil surface as a mulch or was it incorporated into the soil?)
- Environmental conditions following application of plant or animal materials (Mineralization occurs most rapidly under warm, moist conditions. It will slow down considerably during winter or during drought.)
- Mineralization over time (Only a portion of the nutrients from organic matter becomes available during the first year following application. Accurate nutrient management accounts for nutrient mineralization over several years, not just during the current planting season.)

See References for publications and Web sites that provide detailed information on how to estimate nutrient availability based on these criteria.

For information on potential nutrient availability from various organic inputs, see the ATTRA publication *Protecting Water Quality on Organic Farms*.

Building and monitoring soil organic matter

Standard soil organic-matter tests provide a general guideline for monitoring soil organic matter levels and should be conducted at least once every two years. In addition, soil management should include practices that add or return organic matter to the soil, as well as practices that protect organic matter against erosion and excessive mineralization. These practices include

- Growing cover crops and green manures that are cut and left on the soil surface or incorporated into the soil
- Leaving crop residues in the field
- Adding manure, compost, or mulch to the soil
- Maintaining residues or plant growth on the soil surface for as many months as possible throughout the year
- Using soil conservation practices such as contour farming

Building and maintaining soil physical condition

General indicators you can use to monitor soil physical conditions:

- The soil surface does not have any visible soil crust. (Microbial crusts, found in arid soils, are positive indicators of soil quality, not negative indicators.)
- When handled, soil feels soft and crumbles readily. It does not form hard blocks or break down into a fine powder.
- When a clump of soil is placed in a clear glass of water, the clump retains its shape and soft bubbles form around it. It does not break apart rapidly or explosively. The water remains relatively clear, not turning muddy or silty.
- The soil is relatively easy to dig. Soil samples to a depth of at least seven inches have properties as described above. Plant roots grow throughout the soil and do not appear to be inhibited in either their downward or sideways growth.
- A wire rod (like a straightened, heavy-duty clothes hanger) can be inserted into the soil with only minor bending. Soil compaction typically occurs as a crust on the soil surface or as plow pans beneath the surface.

Soil management should include practices that add or return organic matter to the soil.

Building and maintaining soil chemical condition

Degradation of soil chemical condition is usually visible only when conditions become severe enough to significantly harm crop growth and yields. Severely degraded chemical conditions include

- Salinity or high levels of anions (negatively charged particles) (This condition is usually found in arid, irrigated environments. Degraded soils have a surface layer with a whitish coat and a salty odor.)
- Sodicity or high concentration of sodium relative to magnesium (This condition is also found in arid, irrigated environments. Degraded soils have a soil crust, poor aggregation, and limited soil pores.)
- Inappropriate pH for crops being produced (Most crops grow best at a pH between 6.5 and 7.5. This is because chemical reactions at this range enhance the availability of plant nutrients. However, some plants, such as blueberries and cranberries, require a low pH. Plants produced on soils with inappropri-

ate pH grow poorly and often exhibit symptoms of nutrient deficiencies.)

- Low nutrient holding capacity (cation exchange capacity or CEC) (The ability of soils to hold nutrients is affected by both the mineral and organic matter components of soils. Soils with low nutrient holding capacity easily lose nutrients to runoff or leaching, resulting in low fertilizer-use efficiency and high potential for surface or groundwater contamination.)
- Toxic levels of nutrients or contaminants (Symptoms exhibited by plants growing on these soils will depend on the toxin or contaminant.)

Standard soil tests provide a general assessment of soil chemical conditions.

Standard soil tests provide a general assessment of soil chemical conditions. Soil salinity is measured in terms of electrical conductivity or EC. You can assess soil sodicity by calculating the ratio of sodium (Na) to magnesium (Mg). Soil pH and CEC are standard assessments on soil tests. Appropriate pH levels for crop plants are available in agronomy, horticulture, or forage guides. Often the seed packet or bag provides this information. Standard soil tests will identify whether micronutrients are present at toxic levels. If not corrected, they may cause deformities or changes in plant coloration typical of toxicity symptoms. Soil tests for specific contaminants are available, at an extra cost, if necessary.

Building and maintaining soil biological quality

Viable soil organisms are critical for effective organic matter decomposition and nutrient management. Soil organisms also enhance nutrient holding capacity, build soil aggregates, and facilitate nutrient uptake. Rhizobia, the bacteria that form nodules on the roots of legumes, transform atmospheric nitrogen into nitrogen available for plant use. Mychorrhizae are fungi that form at the tips of plant roots and effectively extend the root length, giving the plant greater access to nutrients and water. If you use soil management practices that provide soil organisms with food, air, water, and other necessities for their growth and reproduction, you will also build or maintain soil biological quality.

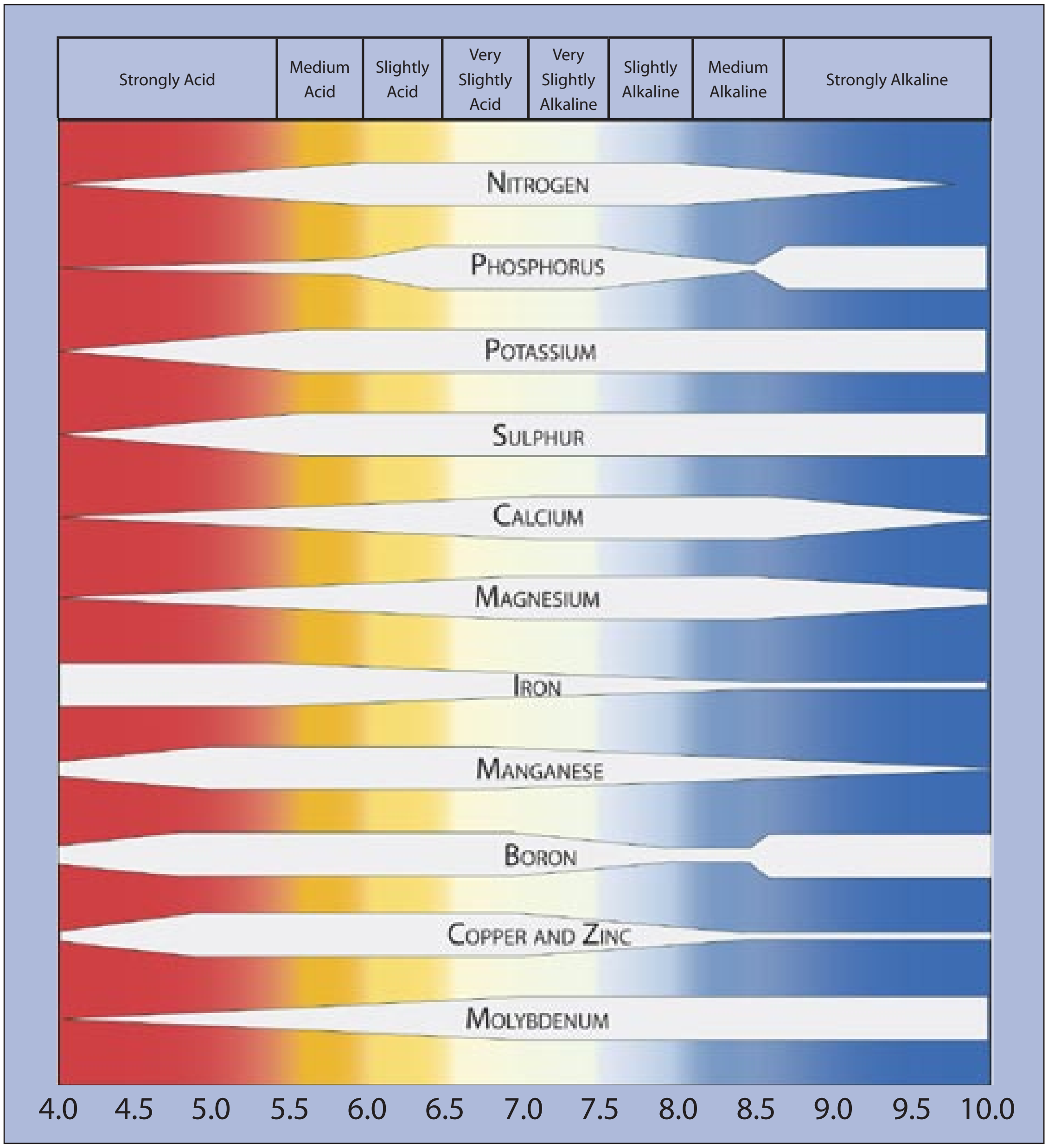
Methods for monitoring and assessing soil biological quality will differ according to soil types, location, and crops being produced. However, you may find the following assessment criteria effective.

- Soil smells sweet and "earthy."
- Legumes form abundant nodules when nitrogen levels are relatively low.
- Crop residues and manure decompose relatively rapidly (especially when the temperature is warm and the soil is neither arid nor flooded).
- Soil organisms such as earthworms, dung beetles, and springtails are present.
- Soil has good tilth and is well-aggregated.

Controlling runoff and erosion

Soil conservation practices that control runoff and erosion minimize the risks of ground- and surface-water contamination. Management practices you can use to minimize the risk of surface water contamination include the following.

- Provide a vegetative cover over the soil surface that protects the soil from direct raindrop impact and promotes water infiltration.
- Avoid the surface application of manure or compost prior to rainfall.
- Cover compost or manure piles or establish water diversion areas upslope from the piles and nutrient runoff buffer areas downslope from the piles.
- Do not apply fertilizers or manure in a way that allows nutrient levels in the soil to become excessive.
- Avoid excess traffic within fields, especially when the soil is wet, to minimize compaction.



The availability of plant nutrients in soils is affected by the soil's pH.

Avoiding the addition of contaminants

Use special care when using any manure, compost, mulch, or similar substance for nutrient management.

- Any equipment used in organic nutrient management that is also used to apply prohibited substances to conventional fields must be adequately cleaned to prevent contamination with prohibited materials prior to use in organic fields.
- Compost must be produced in a manner that meets NOP regulations and must not contain sewage sludge or other sources of heavy metals or toxins.
- The organic certifier may require testing of manure or litter for antibiotics or heavy metals prior to approval. In addition, the certifier may require that you keep records on the amount of these contaminants applied to fields over time.
- Use mulches that do not contain contaminating residues. The organic certifier may require testing of the material to see whether it is acceptable.

Related ATTRA Publications

For more monitoring information and tools, see the following ATTRA publications.

National Organic Program Compliance Checklist for Producers

Organic Field Crops Documentation Forms

- Check irrigation water to ensure that it does not contain contaminants. The organic certifier may require testing of the irrigation water to see whether its use is acceptable.

Tailoring to local conditions

As in selecting tillage and cultivation practices, the "correct" soil fertility and crop nutrient management practice will vary according to location, soil type, crop being produced, time of year, climate, and weather conditions in a particular year. Consequently, practices that you use to comply with the regulation may vary from field to field, from crop to crop, and from year to year. Also, because organic soil nutrient management is an on-going process that operates over time, you should examine the practices you use to meet the standard over the course of a rotation cycle or on some other multi-year basis.

Planting on the contour and leaving residues on the soil helps control erosion.

Photo by Lynn Betts, USDA NRCS.

Table 1. Soil management practices that fulfill elements of the NOP Section 205.203 requirements.

Soil Management Practice	203a	203b	203c	Comments
Standard soil test	X	X	X	Examine soil test results for any nutrients that are excessively high or toxic. Check pH, CEC, and EC.
Test for soil organic matter	X		X	Not part of standard soil test; must make special request, requiring an extra cost. See **References** for alternative organic matter tests.
Nitrate assessments		X	X	Conduct prior to calculating amount of nutrients to add to the soil. Also conduct following harvest to determine need for nutrient-conserving cover crop.
Special tests for contaminants or heavy metals			X	Conduct on fields prior to initiating organic practices to determine baseline levels of any suspected contaminants. Conduct on commercial broiler litter or other organic input that may contain contaminants.
Plant tissue testing of cover crops		X	X	Determines nutrient content of plant material that will be returned to the soil.

(continued next page)

Soil Management Practice	203a	203b	203c	Comments
Calculate cover crop biomass yield		X	X	Weight of biomass x percent nutrient = weight of nutrient in biomass. Compare this amount to the amount of nutrients needed for growth by crop plants.
Nutrient tests for manure or compost added		X	X	Determines nutrient content of organic material added to the soil.
Record amount of manure or compost added		X	X	Weight of compost or manure x percent nutrient = weight of nutrient in the amount of compost added. Divide this number by the number of acres to which this amount of material was applied to determine nutrients per acre. Compare these numbers to the amount of nutrients needed for growth by crop plants.
Record time and method of application of nutrient inputs		X	X	These factors determine the rate of nutrient mineralization, potential availability for plant uptake, and potential risk of loss through erosion or runoff.
Calculate nutrient availability over time from each added plant or animal residue		X	X	Use to determine the amount of nutrients that need to be added to meet crop requirements. Also alerts producer to need for conserving nutrients by planting cover crops.
Plant tissue testing of crop plants		X	X	Identifies any nutrient deficiencies or toxicities. Special tests may be requested to identify uptake of potential contaminants in the environment.
Know nutrient needs of each crop grown		X	X	Nutrient additions should be based on the equation: crop nutrient needs – (nutrients available from soil + nutrients available from prior additions of plant or animal materials)
Know soil texture and mineralogy	X		X	Soil texture and mineralogy affect water infiltration and water holding capacity, nutrient holding capacity, and susceptibility of soil to compaction, erosion, and runoff.
Applications of NOP-approved nutrient sources based on soil nutrient availability, crop nutrient needs, and expected mineralization of previously added residues		X	X	Carefully check all inputs from off-farm sources for potential contaminants. Apply nutrients based on the nutrient needs of crops to be grown and on the amount of nutrients expected to be mineralized from each nutrient source applied.
Cover crops are grown during the "off season"	X	X	X	Cover crops can be grown to build soil organic matter, conserve soil nutrients, enhance soil tilth, and manage weeds.
Compost or manure added to fields	X	X		Compost and manure are applied as a source of nutrients and to build soil organic matter.
Crop residues left on the field	X	X	X	Crop residues and mulches cover the soil surface, enhance water infiltration, protect against runoff and erosion, control weed growth, and build soil tilth and organic matter.
Mulches used to cover soil surface	X	X	X	
Soil conservation practices used, especially on sloping fields	X		X	Contour cropping controls soil erosion. Good buffer management around streams and lakes protects against movement of nutrients or sediment into these water bodies.

(continued next page)

Soil Management Practice	203a	203b	203c	Comments
Excessive traffic on fields is avoided, especially when fields are wet	X	X		Using minimum tillage or "one-pass" tillage systems minimizes tillage traffic; using cover crops to control some weeds minimizes traffic needed for cultivation. Avoid driving on wet fields during harvest.
Protection measures used to minimize runoff from compost and manure piles		X	X	Compost or manure piles should be built on concrete pads or on soil that is compacted and sealed against leaching. Diversion trenches built upslope from the pile protect it from contaminating clean water. A grass buffer downslope protects against movement of nutrients into water bodies.
Use separate equipment for organic fields or thoroughly clean any equipment used in fields with non-approved substances before the equipment is used for organic production			X	Protect against the introduction of contaminants into organic fields.
Check irrigation water to ensure that it does not contain contaminants			X	Protect against the introduction of contaminants into organic fields. Protect exposed edible portions of crops from potential microbial contamination.
Prominently display "Organic – No Spray" signs around farm boundary			X	Protect against the introduction of contaminants into organic fields.

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Resources

The following documents describe practices involved in determining how much manure (or compost) to apply to fields, when to apply it, and application practices that reduce the risk of nutrient runoff. While they are designed for use by dairy farmers or feedlot operators, most of the calculations provided in the workbooks can be readily adapted for use by organic producers.

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Acknowledgements

I would like to thank NCAT colleagues George Kuepper and Ann Baier for recommending that I address the critical interface between the legal language of the NOP regulations and the practical considerations of nutrient management. I would also like to thank them and NCAT colleague Nancy Matheson for their careful review of early drafts of this paper. George's technical and working knowledge of the NOP, Ann's practical insights as a farmer and organic inspector, and Nancy's hands-on awareness of organic dryland farming systems, as well as her critical word-smithing, allowed me to make some very useful and well-informed revisions.

Soil Management: National Organic Program Regulations
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Ashley Rieske and Robyn Metzger, Production

This publication is available on the Web at:
www.attra.ncat.org/attra-pub/organic_soil.html
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IP 270
Slot 272
Version 063005