NCF-Envirothon 2027 Maryland

Current Issues Part A Study Resources

Key Topic 4: Soil Health Management Strategies

Learning Objectives

10. Understand agricultural management strategies and how they influence key soil functions.
11. Analyze the effects of agricultural management practices on soil health, identifying practices that enhance or degrade soil function.
12. Identify and evaluate best management practices (BMPs) that improve soil health while protecting water quality, reducing environmental impacts, and supporting biodiversity.
13. Assess how agricultural management decisions affect the long-term sustainability, productivity, and resilience of agricultural systems.

Resource Title	Sources	Page
Farming Practices That Can Put Soil Health at Risk, *Chapter 4*	*Hopwood, J., Frischie, S., May, E., Lee-Mäder, E., & The Xerces Society for Invertebrate Conservation. (2021). Farming with Soil Life: A Handbook …. (Chapter 4). The Xerces Society for Invertebrate Conservation.*	103
Healthy, Productive Soils: Checklist for Growers	*Healthy, Productive Soils: Checklist for Growers| USDA. (n.d.). Usda.Gov.*	111
NRCS Conservation Practices that Can Be Used to Support Soil Organisms, *Appendix A*	*Hopwood, J., Frischie, S., May, E., Lee-Mäder, E., & The Xerces Society for Invertebrate Conservation. (2021). Farming with Soil Life: A Handbook …. (Appendix A: Table 1). The Xerces Society for Invertebrate Conservation.*	113
Farming Practices that Support Soil Heath, *Chapter 5*	*Hopwood, J., Frischie, S., May, E., Lee-Mäder, E., & The Xerces Society for Invertebrate Conservation. (2021). Farming with Soil Life: A Handbook …. (Chapter 5). The Xerces Society for Invertebrate Conservation.*	120
Putting it all Together, *Chapter 24*	*Magdoff, F., & Van Es, H. (2021). Building Soils For Better Crops Sustainable Soil Management, 4th edition (Chapter 24).*	126
Regenerative Agriculture, *CBF*	*Chesapeake Bay Foundation (n.d.). Regenerative Agriculture. CBF.org*	136
Regenerative Agriculture, *TNC*	*TNC (n.d.). Regenerative Agriculture. The Nature Conservancy.*	138
Why Canadian Farmers and Ranchers Need a National Soil Health Strategy	*Craddock, T. (2025, October 7). Why Canadian farmers and ranchers need a national soil health strategy. Soil Conservation Council of Canada.*	141
Soil Searching: The Hidden Crisis of Soil Health in the Asia Pacific	*Schramski, S. (2024). Soil Searching: The Hidden Crisis of Soil Health in the Asia Pacific. Earth Journalism Network.*	144

4

Farming Practices That Can Put Soil Health at Risk

As a geological and biological matrix, healthy, living soil is protected and buffered against dynamic changes or degradation. However, physical or chemical disruption of the soil environment destroys the healthy function between minerals, water, gases, roots, and animals. Landslides, floods, and storms are naturally occurring disruptions to soils. Many conventional practices used in growing crops are damaging to soil health—in the short term and long term. External inputs or additional disturbance only mask the damage temporarily and are economically and ecologically costly. This chapter describes the negative effects on soil health caused by tillage, climate change, synthetic fertilizer applications, and pesticides. Chapter 5 covers practices that can build and protect soils that are healthy and alive.

Tillage

Tillage is destructive to the physical structure of soil and the living organisms within it. The primary reasons for tillage have been to destroy weeds and to achieve consistent planting conditions, but much more is destroyed in the process. The physical disturbance of tillage breaks up soil structure and destroys aggregates and soil pores. (Inversion tillage is the most destructive; plows, disks, shanks, and vertical tillage tools are increasingly less destructive.) Soil structure is critical to water infiltration, root growth, and nutrient and gas exchange. Existing channels from dead roots and earthworm or animal tunnels are lost with tillage. This impacts water infiltration and storage, as well as the habitat value for animals that use the tunnels.

FIGURE 27—Conventional tillage (left) compared with strip tillage (right) of rye.

When surface aggregates are destroyed, the fine particles form a crust that inhibits infiltration and impedes seedling emergence. Tillage churns soil and dramatically increases the exposure of soil surfaces to the atmosphere. This exposes carbon, previously held inside aggregates, to microbes in an oxygen-rich environment. Microbes quickly eat this carbon, and much is lost as carbon dioxide. The loss of soil cover and the exposure of dark soil surfaces to heating by the sun increases soil temperatures. Higher soil temperatures can be detrimental to many soil macrofauna, mesofauna, and microfauna and result in the loss of soil water needed by some animals to move around within the soil.

Tillage results in shifts in detrital food webs: undisturbed soils support extensive fungal networks, and fungi form the basis for detrital food webs in untilled soils, but plowed soils tend to shift toward bacterial decomposers at the base of the detrital food web.

Climate Change

The effect of climate change on soil health and soil organisms depends on a variety of factors, such as geographic region (variable and associated climate change projections), soil type, and land management practices. Most areas in the United States will experience an increase in extreme weather events, including droughts, flooding, and intense storms that can affect soil systems. Many areas, including much of the eastern half of the United States, will experience an increase in extreme rainfall events, which can lead to soil erosion. In the northeastern United States, precipitation intensity and amounts are expected to increase more than most other regions in the United States. In other areas, such as California and the Great Basin, drought will become more common and increasingly unpredictable. Some areas will have increased frequency and duration of flooding. Flooding can scour and wash away soil, and where water sits for days or more, the inundated soils have poor oxygen, which leads to plant and animal death. Increased drought and heat reduce plants' ability to persist, which could leave soils bare and exposed to erosion and result in a cascade of loss of soil animals that depend on plants for food and habitat. The general instability or unpredictability of seasonal temperatures will affect the timing of flowering and life cycles of insects and microbes. Sea level rise will increase the risk of flooding in coastal areas, where inundation with saltwater will be a problem for soil health and farmland productivity.

While climate change can have adverse effects on soil health, especially in systems where soil health is already poor or degraded, soils also have an important role to play in mitigating climate change. Healthy soils sequester more carbon than degraded soils, which means that improving soil health can turn farmland into a climate sink (land that stores more carbon than it releases). Thus, farmers have the potential to lead the fight against climate change—by implementing practices that prioritize soil health, farms become a key part in mitigating the climate crisis. All of the practices described in Chapter 5: **Farming Practices that Support Soil Health** will improve soil health and improve the carbon sequestration services of soil on your farm.

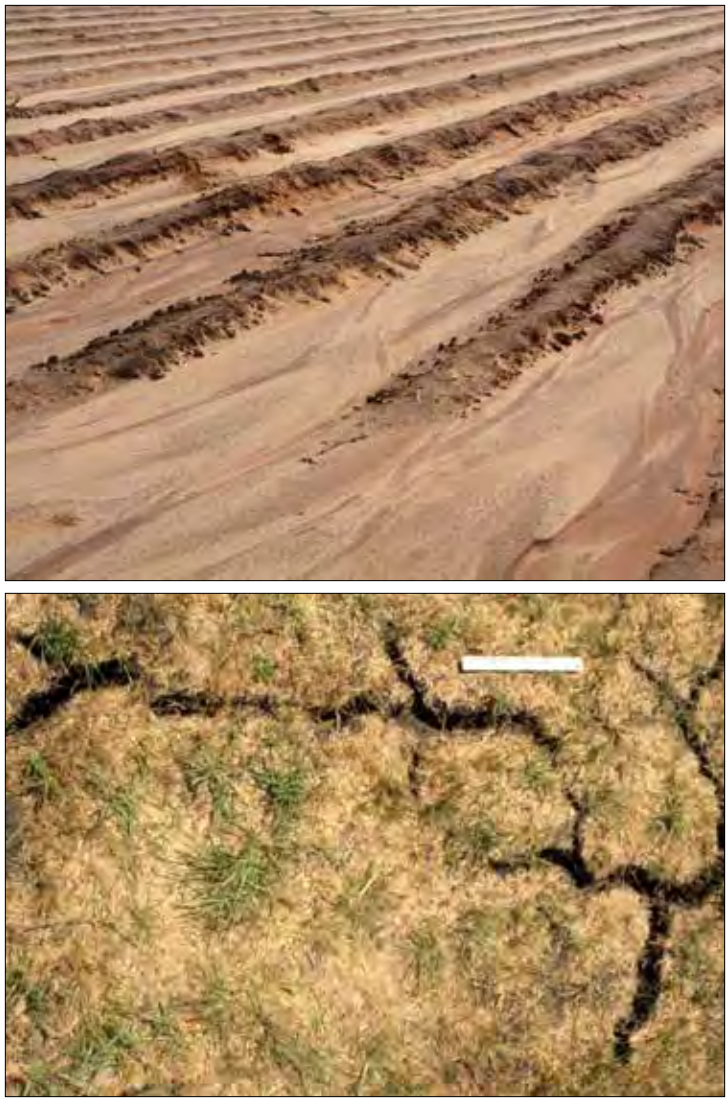

FIGURE 28—Bare soil is subject to erosion by water and wind (top). Soils with higher clay content may crack when dry (bottom).

Synthetic Fertilizers

Inorganic, synthetic fertilizer application creates spikes in the abundance of available nitrogen, phosphorus, and potassium, disrupting the processes of decomposition and nutrient cycling. The response of microbes to the nutrients affects available soil carbon and the diversity and abundance of soil animals. Some groups tend to increase in abundance following nitrogen fertilizer application, such as microbes and animals associated with plant roots and organic matter, while microarthropods decrease. However, long term use of nitrogen fertilizers—particularly ammonium-based N fertilizers—can accelerate soil acidification, which can in turn affect soil microbial communities. Synthetic fertilizers create an imbalance in the natural functioning of soil. USDA soil scientist Rick Haney compares

synthetic fertilizer use to a diet of only vitamins—without fiber (organic matter), the system can't be healthy in the long term. Sustained nutrient cycling and availability depends upon interconnected soil organisms and communities.

Pesticides

Pesticides—which include insecticides, fungicides, herbicides, and soil fumigants—are used to control insects, diseases, weeds, and other pests that can reduce the growth or productivity of agricultural crops. More than one billion pounds of pesticide active ingredients are used annually in the United States, with more than 90% of that usage in agricultural settings.

Impacts of Pesticides on Soil Invertebrates

A variety of pesticides can disrupt soil microbial and invertebrate communities, as well as the soil functions and processes these organisms mediate. Effects of pesticides in soils can range from lethal, including immediate death or shortened life span, to sublethal, such as diminished health, behavior, reproduction, and growth. Pesticides can also affect soil fauna indirectly by disturbing the soil food web and community dynamics (e.g., by reducing prey for natural enemies).

Pesticide residues in soils of crop fields and field margins are a possible route of exposure for the nearly 70% of bee species that nest in soil. Highly mobile systemic insecticides and fungicides move easily from treated fields into the soils and plants of adjacent habitats, including from dust off during the planting of treated seeds as well as movement through soils. (See "Neonicotinoid Insecticides" on page 28 for more information on neonicotinoids, a class of systemic insecticides.) Neonicotinoid residues in the soils of agricultural field margins have been associated with lower richness in bee species visiting those areas. Fungicide contamination could affect larval nutrition and development and make bees more susceptible to other stressors such as insecticide exposure and pathogen infection. Chronic exposure to pesticide residues—for example, bee larvae exposed to contaminated soils—could have a variety of impacts on development, longevity, and reproduction.

Earthworms and potworms, which provide key soil functions and represent the majority of soil faunal biomass in most terrestrial ecosystems, are impacted by pesticides at individual, community, and population levels—some insecticides, fungicides, and herbicides can increase these animals' individual mortality, reduce their growth and reproduction, change individual behavior (such as feeding rate), or decrease the overall community biomass and density. These effects can be mixed and sometimes short-lived, but chronic pesticide exposure in soils is likely to have long-term implications for soil life. Soil communities are likely to exhibit short- and long-term shifts in species composition, favoring soil life that are less susceptible to or that can more readily detoxify pesticides.

A soil organism's degree of exposure to soil pesticides depends on its lifestyle. Soil-dwelling invertebrates that are highly mobile, such as predatory arthropods, are more likely to be exposed as they move through contaminated soils than soil organisms that are fairly stationary. Invertebrates that live close to the soil surface are also more likely to be exposed to pesticides than those that live deeper below the surface.

In the long term, populations and species may adapt in order to survive in contaminated soils, including increasing expression of certain detoxification enzymes. However, these adaptations may come at an unknown energetic, behavioral, or reproductive cost.

It's important to remember that soil invertebrates and the ecological processes they mediate are not the only animals and processes affected by pesticides applied to the soil. Pesticide residues taken up and stored in the tissues of earthworms and other invertebrates can move up food chains, accumulating at higher doses in the birds and other wildlife that eat these soil-dwelling animals. One of the main legacies of the insecticide DDT was its devastating impacts on birds of prey. Modern insecticides, such as neonicotinoids, appear to be having similar cascading negative impacts on insectivorous birds. Pesticide use also poses risks to pesticide applicators, farmworkers, and other communities that are regularly exposed to pesticides. Agricultural workers experience pesticide injury and illness at rates many times higher than the general population, and both acute and chronic exposure to pesticide residues

can result in negative health outcomes for farmworkers and their families. Adoption of nonchemical management strategies for insect, disease, and weed management benefits both human health and the environment.

Fate of Pesticides in Soil

Depending on the method and timing of application, some or all of the pesticides applied to crops can end up in the soil. Some pesticides are applied directly to the soil as fumigants, granules, or pellets spread on the soil surface; soil drenches and injections; or seed coatings. Pesticides sprayed on plant foliage or via aerial applications can also move into soil and groundwater; for example, approximately 65% of high-volume sprays applied by ground equipment to blueberry bushes for mite control were found to pass through the bushes into the soil. Pesticides can also enter the soil from crop residues, leaf fall, and root exudates.

Pesticide interactions with soil organic matter and life are complex. Some pesticides bind to soil particles—primarily organic matter—while others may be taken up by plants or leached through the soil profile into water bodies. Adsorption (binding) to soil particles involves a variety of bonding mechanisms and strengths; only some pesticide residues in soil are bioavailable to plants and soil organisms.

Soil microorganisms largely mediate the degradation of pesticides in soil. Bacteria, fungi, algae, and other microbes in the soil metabolize or otherwise catalyze the transformation of pesticide active ingredients into less bioactive substances. At the soil surface, light and heat also work to break down pesticides. Persistence of different pesticides in the soil environment depends on many interacting factors, including climate, soil type, type or nature of the pesticide, and whether it was applied once or several times. Degradation is generally much slower in dry soils.

Soil amendments like compost and manure can affect the fate of pesticides. Increasing organic matter content may increase the adsorptive capacity of soils, as well as microbial activity and associated decomposition of pesticides. Tillage also interacts with pesticide residues in soil—some pesticides are intentionally incorporated into soil through tillage, and in other cases, tillage that brings pesticide residues to the soil surface may lead to volatilization (evaporation of residues into the atmosphere) or degradation of those residues. Pesticides that volatilize can move far from where they were applied as vapor drift before settling back out of the atmosphere.

The NRCS offers a pesticide risk screening tool, Windows Pesticide Screening Tool (WIN-PST). This tool can help evaluate the potential for a pesticide to leach or run off at a site based on the pesticide's physicochemical

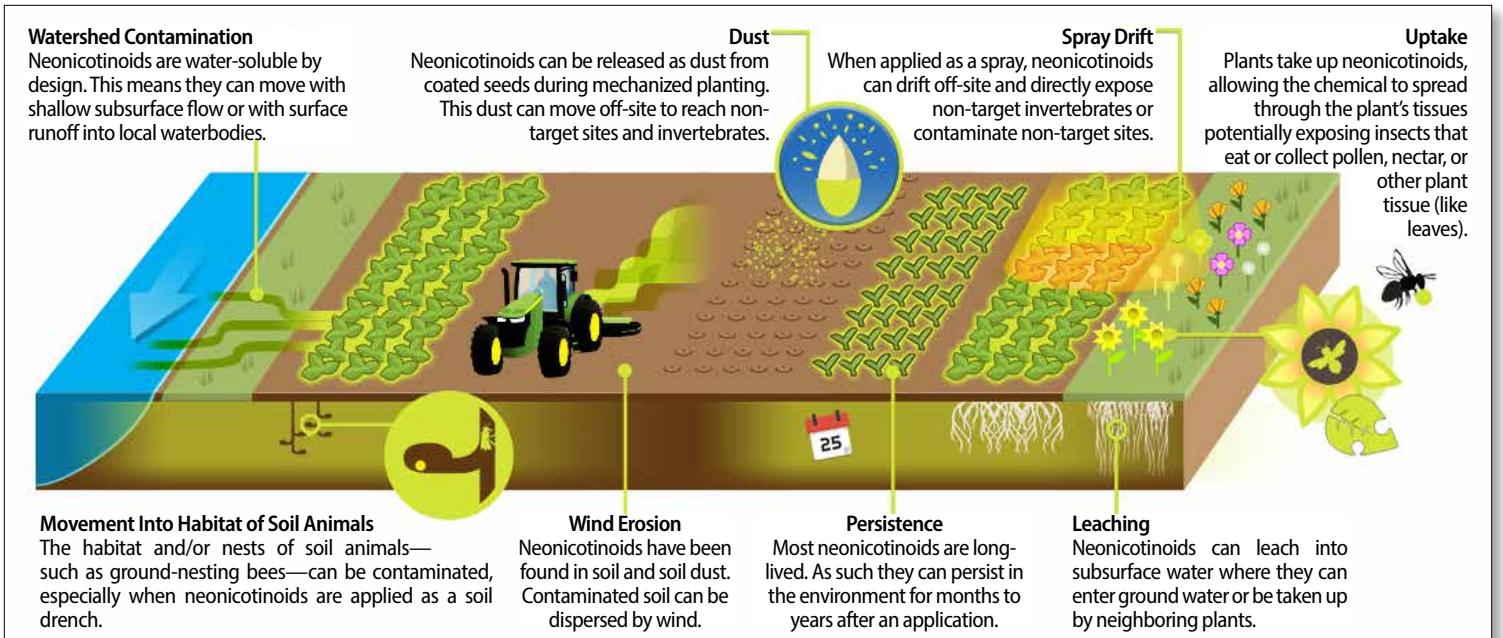

FIGURE 29—There are numerous potential routes of exposure to insecticides—especially neonicotinoids—for non-target organisms in or around agricultural settings.

characteristics and the site's specific conditions, such as soil type and slope. The downloadable WIN-PST database (see Resources) includes a variety of information about the toxicity and environmental fate of currently registered pesticides.

Insecticides

Insecticides, particularly broad-spectrum insecticides with a mode of action affecting many different types of insects, are generally the most toxic pesticides to arthropods in the soil. Broad-spectrum insecticides such as organophosphates, carbamates, avermectins, neonicotinoids, and synthetic pyrethroids can reduce the abundance, species richness, or biomass of predatory arthropods, isopods, earthworms, and potworms in the soil. Insecticides can have complex ripple effects in soil food webs: loss of predators following insecticide applications can result in

Neonicotinoid Insecticides

Neonicotinoids are the most widely used class of insecticides worldwide, representing more than 25% of total global insecticide sales. Neonicotinoids pose a particular risk to soil invertebrate communities due to their high toxicity to most insects, systemic properties, and persistence in soils. Half-lives of the nitro-substituted neonicotinoids (including imidacloprid, thiamethoxam, and clothianidin) range from about five to 25 weeks in soil, with some estimates ranging as high as two to three years. A general rule of thumb is that it takes approximately five half-lives to functionally eliminate a substance from the soil environment.

Neonicotinoid seed treatments can have complex effects on aboveground and belowground invertebrate communities. Only a small proportion (approximately 2–20%) of the active ingredient in neonicotinoid soil or seed treatments is taken up by plants; the bulk of the active ingredient remains in the soil and may pose risks to soil organisms. A meta-analysis of 20 field studies found that neonicotinoid seed treatments and pyrethroid insecticide applications had similar negative impacts on natural enemy abundance, reducing abundance of beneficial insects by an average of 16% compared with untreated fields. Natural enemies—including minute pirate bugs, lady beetles, lacewings, spiders, ground beetles, and rove beetles—were found to be significantly less abundant in surface litter in clothianidin-treated corn plots than untreated plots. Loss of these natural enemies and other soil macrofauna could result in disruptions to the ecosystem services they provide, including controlling insect pests and consuming weed seeds.

Residual imidacloprid in the fallen leaves of treated trees inhibited earthworm and aquatic insect feeding and reduced leaf litter breakdown in two studies. These sublethal effects on decomposers could have broad implications for organic matter breakdown and nutrient cycling in terrestrial and aquatic ecosystems. Agricultural plant litter with imidacloprid residues may have similar feeding inhibition effects on decomposers.

FIGURE 30—Neonicotinoid-treated seeds in a hopper.

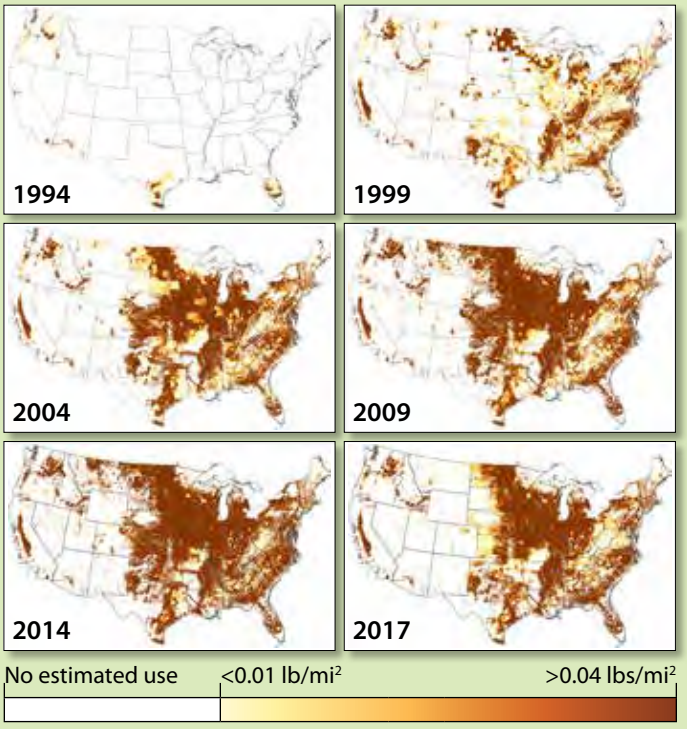

FIGURE 31—Estimated Annual Agricultural Use of Imidacloprid in the United States: 1994–2017. Source: http://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php

population spikes of their prey. Sometimes these population spikes become secondary pest outbreaks; pests that were previously suppressed by natural enemies reach a population level at which they cause economic damage to crops.

Systemic insecticides, including neonicotinoids, sulfoximines, and anthranilic diamides, are water-soluble pesticides that move easily within plants and can be translocated from the site of application to other parts of the plant. Typically, systemic insecticides are applied to soil and taken up by plant roots, but they can also be applied to foliage or injected directly into woody plants. Because these chemicals dissolve easily in water, they can be quite mobile in soils and prone to leaching and off-site movement. Large-scale use of systemic insecticides in agriculture has raised concern about negative impacts on decomposition, nutrient cycling, soil respiration, and invertebrate populations.

Studies of neonicotinoid seed treatments have found mixed impacts on soil microbial activity and community composition, with some studies indicating that effects of seed treatments are short-term and even stimulatory, and others finding adverse effects on soil microbial communities and their function (e.g., lower respiration rate or metabolic activity, and shifts in community composition or diversity).

Fungicides

While insecticides are the pesticides likely to pose the greatest risk to soil-dwelling arthropods, fungicides may have larger impacts on soil microbial activity. Heavy metal fungicides (e.g., copper, zinc, and sulfur) significantly reduced the biomass, activity, and diversity of earthworms and soil microbial communities in orchard and vineyard soils. Soil and lab experiments have found that copper negatively affects survival and growth of earthworms, and that earthworms tend to avoid or move out of copper-contaminated soils, preferring soils with a lower copper concentration.

Fungicide applications that reduce earthworm abundance or activity may slow the breakdown of leaf litter that these soil fauna provide. Applications of the benzimidazole fungicides benomyl and thiophanate-methyl reduced surface earthworm populations and slowed leaf removal in apple orchards, with some residual effects on earthworm abundance lasting up to three years after benomyl applications.

Herbicides

Herbicides can have direct or indirect effects on soil invertebrates. Some herbicides, including paraquat and 2,4–D, can have direct sublethal or lethal impacts on a variety of beneficial insects, particularly their developing larvae. Glyphosate, the most widely used herbicide in the world, has been found to disrupt earthworm movement and reduce reproduction—although it is not clear whether these effects are due to direct toxicity or simply the loss of plant cover at the soil surface.

In some cases, exposure to herbicides may make invertebrates more susceptible to other pesticides they are exposed to in the soil environment. Triazine herbicides, such as atrazine and simazine, can synergize the toxicity of certain insecticides, particularly organophosphates. Atrazine has been found to increase the toxicity of the organophosphate insecticide chlorpyrifos to invertebrates by several fold. Glyphosate may synergize the effects of insecticide or fungicide seed dressings on earthworm activity.

Some herbicides, including atrazine, simazine, glyphosate, and paraquat, can have a repellent effect on predatory ground beetles, which play important roles for pest and weed seed control in agricultural fields. In one study, beetles did not return to treated fields for a month after application of glyphosate or paraquat. This effect may be a response by these predatory insects to the loss of plant cover in herbicide-treated fields.

Indirect Effects

In general, in agricultural settings, herbicides are used to reduce aboveground plant diversity in favor of monoculture in order to reduce competition with the focal crop. Aboveground plant diversity drives the diversity and abundance of soil organisms—and vice versa—and so the loss of plants due to herbicide use is likely to negatively impact the diversity and abundance of soil-dwelling organisms that feed on pollen, nectar, seeds, leaves, roots, and other plant tissues. Changing organic matter inputs may also affect populations of soil decomposers.

Soil Fumigants

Soil fumigants are pesticides that, when injected or incorporated into soil, form a gas that diffuses through the pockets of air in soils. Fumigants are typically used weeks to months before crop planting to control a broad range of soilborne pests, including insects, nematodes, bacteria, fungi, and weeds. Many fumigants are toxic to a broad spectrum of soil life and will kill beneficial organisms along with soilborne pathogens. The use of fumigants can cause long-term disruption in the balance of soil communities—some organisms are more susceptible to fumigants than others, and some are better able to recolonize soils following fumigation. Interestingly, fumigants are generally far more harmful to mycorrhizal fungi than soil-applied fungicides, and in some cases have led to plant stunting due to elimination of beneficial mycorrhizal fungi in fumigated soils.

Knowledge Gaps

There are major knowledge gaps regarding pesticide impacts on most soil invertebrates and the ecosystem functions they provide and regulate. Many of the pesticides used have toxicity data for fewer than five soil invertebrate species. The current pesticide risk assessment framework in the United States fails to capture the diversity of responses and sensitivity to pesticides among soil invertebrates. The model organism for soil invertebrates that is typically used for lower-tier testing of pesticide toxicity, the red wiggler (*Eisenia fetida*), a habitat specialist earthworm, was chosen mainly for its amenability to laboratory testing rather than for its ecological relevance. Other soil invertebrates, such as springtails (Collembola), may be far more sensitive to pesticides than earthworms.

We also know little about community and population responses of soil invertebrates to the complex mixture of pesticides and their metabolites likely to be present in crop soils. Few studies have examined the interactive effects of different pesticide mixtures (e.g., whether mixtures are additive, synergistic, or antagonistic in their toxicity to soil organisms).

Many pesticides can persist via a variety of binding mechanisms for months to years in the soil. While some residues are biologically inactive once adhered to soil particles, some remain bioavailable or can become bioavailable through interactions with soil microbes. There are few long-term studies examining the effects of chronic low-dose exposure to pesticide residues in the soil, including the metabolites produced as pesticides break down over time.

Recommendations

The first line of defense in managing pests is prevention. There are many cultural, biological, and mechanical methods that can break pest and disease cycles and keep pest populations at tolerable levels, reducing the need for pesticide applications. Use pesticides as a last resort if preventive strategies are not feasible, or if scouting and monitoring determine that pests have reached damaging levels despite preventive management. Do not apply pesticides before knowing if there is a problem. Neonicotinoid and other pesticidal seed treatments are often used without knowing whether the target pests are present or a problem in the fields where they are planted. Prophylactic use of these seed coatings across millions of acres of cropland is a waste of resources and poses a variety of environmental risks.

Scouting and monitoring can help determine what pests are present and whether populations are high enough to result in economic damage to crops. Once you know what's in your fields, you should seek resources on pest life cycles and habitat requirements to figure out the best approaches for keeping their populations low over time. Think of it this way: if you have ants in the kitchen, you'd clean your sink and counters to remove the food sources that are attracting them. The same principle is true for removing food or shelter for insect pests and cleaning up infested plant materials in crop fields.

If you use pesticides, take steps to reduce the risk to soil life:

- Use the principles of integrated pest management to increase prevention-based strategies and reduce reliance on chemical management. Scout and monitor for insect pests and diseases and only apply pesticides if a pest has reached economically damaging levels.

- If using pesticides, target applications to the areas where pests are present. Reduced coverage methods like spot spraying and band or alternate-row applications can reduce pesticide use and cost while maintaining efficacy for a variety of crop pests.
- Do not use soil fumigants, which disrupt the balance and reduce the diversity of soil communities.
- Avoid tank mixing wherever possible, particularly mixes of insecticides, fungicides, or herbicides that are known to jointly increase toxicity when applied together. The University of California IPM Bee Precaution Pesticide Ratings tool (see **Resources**) can help identify some of these synergistic mixtures.
- Choose less persistent and more selective options to reduce impacts on nontarget organisms.
- Minimize drift and off-site movement into natural areas near crop fields. These areas are refuges that allow soil organisms to recolonize crop fields after disturbances like tillage or pesticide applications. Consider use of electrostatic sprayers that improve deposition onto the target plant foliage and therefore reduce the amount of pesticide applied and the amount likely to reach soils.
- Follow all label instructions and apply pesticides at the lowest effective rate and frequency to minimize the amount reaching soils.

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USDA United States Department of Agriculture

NATURAL RESOURCES CONSERVATION SERVICE

HEALTHY, PRODUCTIVE SOILS
Checklist for Growers

unlock the SECRETS IN THE SOIL

Managing for soil health is one of the easiest and most effective ways for farmers to increase crop productivity and profitability while improving the environment.

Results are often realized immediately, and last well into the future. Using these four basic principles is the key to improving the health of your soil.

- Keep the soil covered as much as possible
- Disturb the soil as little as possible
- Keep plants growing throughout the year to feed the soil
- Diversify as much as possible using crop rotation and cover crops

Use the checklist on the back of this page to determine if you're using some or all of the core Soil Health Management System farming practices.

It is important to note that not all practices are applicable to all crops. Some operations will benefit from just one soil health practice while others may require additional practices for maximum benefit. But these core practices form the basis of a Soil Health Management System that can help you optimize your inputs, protect against drought, and increase production.

More Information

To learn more about Soil Health Management Systems and the technical and financial assistance available visit **farmers.gov/conserve/soil-health** or contact your local NRCS office. To find your local NRCS office, visit **farmers.gov/service-center-locator**.

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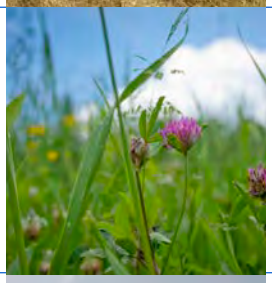
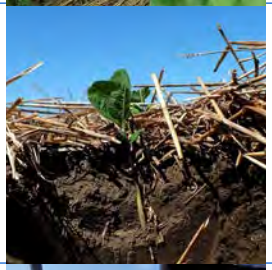
WHAT IS IT?		WHAT DOES IT DO?	HOW DOES IT HELP?
☐ **Conservation Crop Rotation** A planned sequence of crops grown on the same ground over a period of time (i.e. the rotation cycle).		• Increases nutrient cycling • Helps manage plant pests (weeds, insects, and diseases) • Reduces sheet, rill, and wind erosion • Holds soil moisture • Adds diversity so soil microbes can thrive	• Improves nutrient use efficiency • Decreases use of pesticides • Improves water quality • Conserves water • Improves plant production
☐ **Cover Crop** Grasses, legumes, and forbs planted for seasonal vegetative cover.		• Increases soil organic matter • Prevents soil erosion • Conserves soil moisture • Increases nutrient cycling • Provides nitrogen for plant use • Suppresses weeds • Reduces compaction • Feeds soil life • Reduces residual nutrient loss	• Improves crop production • Improves water quality • Conserves water • Improves nutrient use efficiency • Decreases use of pesticides • Improves water efficiency to crops • Improves water infiltration
☐ **No Till** Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year-round.		• Improves water holding capacity of soils • Increases organic matter • Reduces soil erosion • Reduces energy use • Decreases compaction • Reduces soil evaporation	• Improves water efficiency • Conserves water • Improves crop production • Improves water quality • Saves renewable resources • Improves air quality • Increases productivity
☐ **Reduced Tillage** Using tillage methods where the soil surface is disturbed but maintains a high level of crop residue on the surface.		• Reduces soil erosion from wind and rain • Increases soil moisture for plants • Reduces energy use • Increases soil organic matter • Reduces soil evaporation	• Improves water quality • Conserves water • Saves renewable resources • Improves air quality • Improves crop production
☐ **Mulching** Applying plant residues or other suitable materials to the land surface.		• Reduces erosion from wind and rain • Moderates soil temperatures • Increases soil organic matter • Controls weeds • Conserves soil moisture • Reduces dust	• Improves water quality • Improves plant productivity • Increases crop production • Reduces pesticide usage • Conserves water • Improves air quality
☐ **Nutrient Management** Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.		• Increases plant nutrient uptake • Improves the physical, chemical, and biological properties of the soil • Budgets, supplies, and conserves nutrients for plant production • Reduces odors and nitrogen emissions • Reduces excess nutrient applications	• Improves water quality • Improves plant production • Improves air quality
☐ **Pest Management Conservation System** A system that combines an integrated pest management (IPM) decision-making process with natural resource conservation to address pest and environmental impacts.		• Reduces pesticide risks to water quality • Reduces threat of chemicals entering the air • Decreases pesticide risk to pollinators and other beneficial organisms • Increases soil organic matter • Increase soil organism diversity and activity	• Improves water quality • Improves air quality • Increases plant pollination • Increases plant productivity • Supports pollinators and other beneficial insects

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NRCS Conservation Practices That Can Be Used to Support Soil Organisms

SOURCES: This table was derived directly from USDA NRCS conservation practice standards; the language used is specific to NRCS practices at the time of publication (March 2023). For more information about these and other conservation practices, visit national practice standards available through the electronic Field Office Technical Guide (FOTG) at **https://efotg.sc.egov.usda.gov**. Lists and PDFs for each practice are also available at **https://www.nrcs.usda.gov/resources/guides-and-instructions/conservation-practice-standards** or your local NRCS field office.

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Access Control	472	The temporary or permanent exclusion of animals, people, vehicles, and equipment from an area.	• Achieve and maintain desired resource conditions by monitoring and managing the intensity of use by animals, people, vehicles, and equipment in coordination with the application schedule of practices, measures, and activities specified in the conservation plan. Note: Access Control is often applied with conservation practices like Prescribed Grazing (528) or Tree/Shrub Establishment (612).
Alley Cropping	311	Trees or shrubs are planted in sets of single or multiple rows with agronomic, horticultural crops or forages produced in the alleys between the sets of woody plants that produce additional products.	• Enhance microclimatic conditions to improve crop or forage quality and quantity • Reduce surface water runoff and erosion • Improve soil health by increasing utilization and cycling of nutrients • Alter subsurface water quantity or water table depths • Enhance wildlife and beneficial insect habitat • Increase crop diversity • Decrease offsite movement of nutrients or chemicals • Increase carbon storage in plant biomass and soils • Develop renewable energy systems • Improve air quality
Conservation Cover	327	Establishing and maintaining permanent vegetative cover.	• Reduce sheet, rill, and wind erosion and sedimentation • Reduce groundwater and surface water quality degradation by nutrients and surface water quality degradation by sediment • Reduce emissions of particulate matter (including particulate matter precursors and greenhouse gases) • Enhance wildlife and pollinator and beneficial organism habitat • Improve soil health

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Conservation Crop Rotation	328	A planned sequence of crops grown on the same ground over a period of time (i.e., the rotation cycle).	• Reduce sheet, rill, and wind erosion • Maintain or increase soil health and organic matter content • Reduce water quality degradation due to excess nutrients • Improve soil moisture efficiency • Reduce the concentration of salts and other chemicals from saline seeps • Reduce plant pest pressures • Provide feed and forage for domestic livestock • Provide food and cover habitat for wildlife, including pollinator forage, and nesting
Contour Buffer Strips	332	Narrow strips of permanent, herbaceous vegetative cover established around the hill slope, and alternated down the slope with wider cropped strips that are farmed on the contour.	• Reduce sheet and rill erosion • Reduce water quality degradation from the transport of sediment and other waterborne contaminants downslope • Improve soil moisture management through increased water infiltration • Reduce water quality degradation from the transport of nutrients downslope
Cover Crop	340	Grasses, legumes, and forbs planted for seasonal vegetative cover.	• Reduce sheet, rill, and wind erosion • Maintain or increase soil organic matter quantity • Improve soil aggregate stability, soil organic matter quality, and habitat for soil organisms • Reduce water quality degradation by utilizing excess soil nutrients • Reduce weed and plant pest pressure • Improve moisture management • Reduce soil compaction • Supply nitrogen to the subsequent crop • Improve habitat for pollinators, beneficial organisms, or natural enemies of crop pests
Critical Area Planting	342	Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting practices.	• Stabilize areas with existing or expected high rates of soil erosion by wind or water • Stabilize stream and channel banks, pond and other shorelines, and earthen features of structural conservation practices • Stabilize areas such as sand dunes and riparian areas
Deep Tillage	324	Performing tillage operations below the normal tillage depth to modify adverse physical or chemical properties of a soil.	• Bury or mix soil deposits from wind or water erosion or flood overwash • Reduce soil compaction by fracturing restrictive soil layers. Note: This practice applies to all land uses having adverse soil conditions which inhibit plant growth, such as compacted layers formed by field operations, restrictive layers such as cemented hardpans (duripan) in the root zone, or overwash or deposits from wind and water erosion or flooding. This practice does not apply to normal field operations and tillage methods.

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Field Border	386	A strip of permanent vegetation established at the edge or around the perimeter of a field.	• Reduce erosion from wind and water and reduce excessive sediment to surface waters (soil erosion) • Reduce sedimentation offsite and protect water quality and nutrients in surface and ground waters (water quality degradation) • Provide food and cover for wildlife and pollinators or other beneficial organisms (inadequate habitat for fish and wildlife) • Reduce greenhouse gases and increase carbon storage (air quality impact) • Reduce emissions of particulate matter (air quality impact)
Filter Strip	393	A strip or area of herbaceous vegetation that removes contaminants from overland flow.	• Reduce suspended solids and associated contaminants in runoff and excessive sediment in surface waters • Reduce dissolved contaminant loadings in runoff • Reduce suspended solids and associated contaminants in irrigation tailwater and excessive sediment in surface waters.
Forage Harvest Management	511	The timely cutting and removal of forages as hay, green chop, or ensilage.	• Optimize quantity and quality of forage at the desired levels while promoting vigorous plant regrowth • Manage the species composition to enhance desirable species • Reduce excess soil nutrients • Reduce pest pressure (insects, disease, weeds, invasive plants or plant toxins) • Improve or protect wildlife and their habitat • Optimize soil microbial life and aggregate stability • Reduce soil compaction
Forest Stand Improvement	666	The manipulation of tree and shrub species composition, structure, or density to achieve desired forest conditions.	• Maintain or improve forest carbon stocks • Maintain or improve forest health and productivity • Maintain or improve forest structure and composition • Maintain or improve wildlife, fish, and pollinator habitat • Manage natural precipitation more efficiently • Reduce forest pest pressure • Reduce forest wildfire hazard
Grassed Waterway	412	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross-section to a stable outlet.	• Convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding • Prevent gully formation • Protect/improve water quality
Hedgerow Planting	422	Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.	• Habitat, including food, cover, and corridors for terrestrial wildlife • To enhance pollen, nectar, and nesting habitat for pollinators • Food, cover, and shade for aquatic organisms that live in adjacent streams or watercourses • To provide substrate for predaceous and beneficial invertebrates as a component of integrated pest management • To intercept airborne particulate matter • To reduce chemical drift and odor movement • Screens and barriers to noise and dust • To increase carbon storage in biomass and soils • Living fences • Boundary delineation and contour guidelines

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Herbaceous Weed Treatment	315	The removal or control of herbaceous weeds including invasive, noxious, prohibited, or undesirable plants.	• Enhance accessibility, quantity, and/or quality of forage and/or browse • Restore or release native or desired plant communities for wildlife habitat • Protect soils and control erosion • Reduce fine fuel loads and wildfire hazard • Control pervasive plant species to a desired level of treatment
Herbaceous Wind Barriers	603	Herbaceous vegetation established in narrow strips within the field to reduce wind speed and wind erosion.	• Reduce soil erosion (wind erosion: saltation, creep, and suspension) • Reduce soil particulate emissions to improve air quality. • Improve plant health by reducing crop damage by wind or wind-borne soil particles
Mulching	484	Applying plant residues or other suitable materials to the land surface.	• Improve the efficiency of moisture management • Reduce irrigation energy used in farming/ranching practices and field operations • Improve the efficient use of irrigation water • Prevent excessive bank erosion from water conveyance channels • Reduce concentrated flow erosion • Reduce sheet, rill, and wind erosion • Improve plant productivity and health • Maintain or increase organic matter content • Reduce emissions of particulate matter
Nutrient Management	590	Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.	Improve plant health and productivity • Reduce excess nutrients in surface and ground water • Reduce emissions of objectionable odors • Reduce emissions of particulate matter (PM) and PM precursors • Reduce emissions of greenhouse gases (GHG) • Reduce emissions of ozone precursors • Reduce the risk of potential pathogens from manure, biosolids, or compost application from reaching surface and ground water • Improve or maintain soil organic matter
Pest Management Conservation System	595	A system that combines an integrated pest management (IPM) decision-making process with natural resource conservation to address pest and environmental impacts.	• Reduce plant pest pressure • Reduce injury to beneficial organisms • Reduce transport of pesticides to surface and ground water • Reduce emissions of particulate matter (PM) and PM precursors (chemical droplet drift) • Reduce emissions of ozone precursors (pesticide volatilizations)
Prescribed Burning	338	Planned fire applied to a predetermined area.	• Manage undesirable vegetation to improve plant community structure and composition • Manage pests, pathogens, and diseases to reduce plant pressure • Reduce wildfire hazards from biomass accumulation • Improve terrestrial habitat for wildlife and invertebrates • Improve plant and seed production, quantity, and/or quality • Facilitate distribution of grazing and browsing animals to improve forage-animal balance • Improve and maintain habitat for soil organisms and enhance soil health

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Prescribed Grazing	528	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives.	• Improve or maintain desired species composition, structure and/or vigor of plant communities • Improve or maintain quantity and/or quality of forage for grazing and browsing animals' health and productivity • Improve or maintain surface and/or subsurface water quality and/or quantity • Improve or maintain riparian and/or watershed function • Reduce soil erosion, and maintain or improve soil health • Improve or maintain the quantity, quality, or connectivity
Range Planting	550	The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals.	• Restore a plant community to a state similar to the ecological site description reference state for the site or another desired plant community • Provide or improve forages for livestock • Provide or improve forage, browse, or cover for wildlife • Reduce erosion by wind and water • Improve water quality and quantity • Restore hydrologic function • Increase and/or stabilize carbon balance and sequestration
Residue and Tillage Management, No-Till/Strip Till/Direct Seed	329	Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year-round.	• Reduce sheet, rill and wind erosion and excessive sediment in surface waters • Reduce tillage-induced particulate emissions • Maintain or increase soil health and organic matter content • Increase plant-available moisture • Reduce energy use • Provide food and escape cover for wildlife.
Residue and Tillage Management, Reduced Till	345	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.	• Reduce sheet, rill, and wind erosion and excessive sediment in surface waters (soil erosion) • Reduce tillage-induced particulate emissions (air quality impact) • Improve soil health and maintain or increase organic matter content (soil quality degradation) • Reduce energy use (inefficient energy use)
Restoration of Rare and Declining Natural Communities	643	Reestablishment of abiotic (physical and chemical) and biotic (biological) conditions necessary to support rare or declining natural assemblages of native plants and animals.	• To restore the physical conditions and/or unique plant community on sites that partially support, or once supported, a rare or declining natural community. Application of this practice addresses resource concerns of a degraded plant condition and/or inadequate wildlife habitat.

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Riparian Herbaceous Cover	390	Grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats.	• Provide or improve food and cover for fish, wildlife and livestock • Improve and maintain water quality • Establish and maintain habitat corridors • Increase water storage on floodplains • Reduce erosion and improve stability to stream banks and shorelines • Increase net carbon storage in the biomass and soil • Enhance pollen, nectar, and nesting habitat for pollinators • Restore, improve or maintain the desired plant communities • Dissipate stream energy and trap sediment • Enhance stream bank protection as part of stream bank soil bioengineering practices
Silvopasture	381	Establishment and/or management of desired trees and forages on the same land unit.	• Provide forage, shade, and/or shelter for livestock • Improve the productivity and health of trees/shrubs and forages • Improve water quality • Reduce erosion • Enhance wildlife habitat • Improve biological diversity • Improve soil quality • Increase carbon sequestration and storage • Provide for beneficial organisms and pollinators
Stripcropping	585	Growing planned rotations of erosion-resistant and erosion-susceptible crops or fallow in a systematic arrangement of strips across a field.	• Reduce sheet and rill erosion • Reduce wind erosion • Reduce excess nutrients in surface waters • Reduce sediment transport to surface waters • Reduce pesticide transport to surface waters • Improve plant productivity and health
Tree/Shrub Establishment	612	Establishing woody plants by planting seedlings or cuttings, by direct seeding, and/or through natural regeneration.	• Maintain or improve desirable plant diversity, productivity, and health by establishing woody plants • Create or improve habitat for desired wildlife species compatible with ecological characteristics of the site • Control erosion • Improve water quality • Reduce excess nutrients and other pollutants in runoff and groundwater • Sequester and store carbon • Restore or maintain native plant communities • Develop renewable energy systems • Conserve energy • Provide for beneficial organisms and pollinators
Upland Wildlife Habitat Management	645	Provide and manage upland habitats and connectivity within the landscape for wildlife.	• Treating upland wildlife habitat concerns identified during the conservation planning process that enable movement, or provide shelter, cover, food in proper amounts, locations and times to sustain wild animals that inhabit uplands during a portion of their life cycle
Vegetative Barrier	601	Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow areas.	• Reduce sheet and rill erosion • Reduce ephemeral gully erosion • Reduce sediment transport to surface waters
Wildlife Habitat Planting	420	Establishing wildlife habitat by planting herbaceous vegetation or shrubs.	• Improve degraded wildlife habitat for the target wildlife species or guild • Establish wildlife habitat that resembles the historic, desired, and reference native plant community

Table 1. NRCS Conservation Practices That Can Be Used to Support Soil Organisms *continued*

CONSERVATION PRACTICE	CODE	DEFINITION	PURPOSE. Each practice is used to accomplish one or more of the following purposes:
Windbreak/ Shelterbelt Establishment	380	Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.	• Reduce soil erosion from wind • Enhance plant health and productivity by protecting plants from wind-related damage • Manage snow distribution to improve moisture utilization by plants • Manage snow distribution to reduce obstacles, ponding, and flooding that impacts other resources, animals, structures, and humans • Improve moisture management by reducing transpiration and evaporation losses and improving irrigation efficiency • Provide shelter from wind, snow, and excessive heat, to protect animals, structures, and humans • Improve air quality by intercepting airborne particulate matter, chemicals, and odors, and/or by reducing airflow across contaminant or dust sources • Reduce energy use in heating and cooling buildings, and in relocating snow Increase carbon storage in biomass and soils
Woody Residue Treatment	384	The treatment of residual woody material that is created due to management activities or natural disturbances.	• Reduce hazardous fuels • Reduce the risk of harmful insects and disease • Protect/maintain air quality by reducing the risk of wildfire • To improve access for management purposes • Improve access to forage for livestock and wildlife • Develop renewable energy systems • Enhance aesthetics • Reduce the risk of harm to humans and livestock • Improve the soil organic matter • Improve the site for natural or artificial regeneration

5

Farming Practices that Support Soil Health

Farming practices that support soil health often need to be customized or adapted to local conditions. However, some overarching strategies are used in nearly all climate zones, soil conditions, or crop systems. Broadly speaking, some of the strategies that support soil health focus on a few key actions:

- Minimize the potential for erosion through conservation systems that protect crop fields from wind and water runoff.
- Cover the soil as much as possible year-round or maintain continuous living root systems in the soil.
- Reduce mechanical cultivation and compaction.
- Increase organic matter with natural inputs while reducing or eliminating synthetic fertilizer inputs.
- Maximize crop diversity.
- Integrate crops and livestock. For example, rotate them in succession or graze cover crops.
- Increase soil biodiversity by reducing or eliminating pesticides, including soil fumigants.

Any one of these strategies is worthy of its own book (and indeed there are lots of books on all of these topics). Moreover, most of these strategies are deeply interconnected. For example, controlling erosion, increasing soil organic matter, and maintaining living cover might all be addressed through a single practice, such as cover cropping. Describing all of the conservation practices, crop management systems, and specialized tools that can help optimize soil health seems nearly impossible. Yet, it is worth reviewing at least a few of the most established, well understood, and accessible soil conservation practices.

FIGURE 32—An example of a diverse cover crop of common vetch, spring forage pea, spring oats, triticale, purple top turnip, forage collard, safflower, sunflower, and phacelia planted in rotation with spring wheat and winter wheat in eastern Oregon.

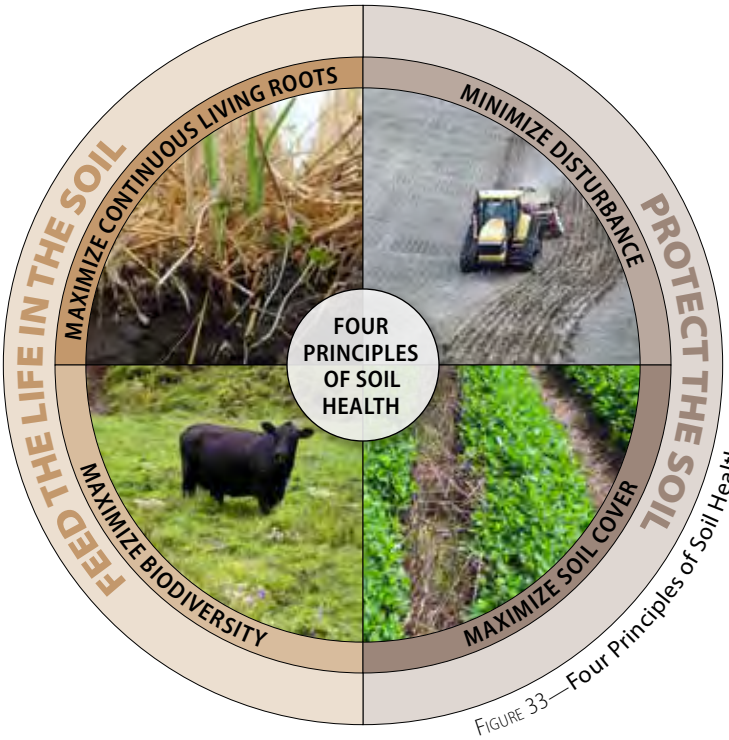

FIGURE 33—Four Principles of Soil Health.

FIGURE 34—Terraced crop fields in Iowa.

FIGURE 35—Contour buffer strips are established around a slope, and alternate down the slope with cropped areas farmed on the contour.

FIGURE 36—Aerial view of windbreaks, rows of trees that are separating crop fields.

Erosion-Control Buffers

The loss of soil to wind and water erosion is a natural, ongoing process that occurs on most soils in both natural and agricultural settings. While this loss is typically a slow process that may be largely unnoticed in natural settings, it is often accelerated by cultivation and grazing, requiring active work to counteract erosion and keep soil on the farm. To reduce soil loss on farms, various conservation systems have been developed:

- **Terracing.** Terraces are horizontal landforms constructed on slopes to provide stable, relatively non-erodible surfaces for crop production. Examples can be found of terraced fields that have sustained continuous crop production for hundreds of years in southern Europe and Asia.
- **Contour buffer strips.** A smaller-scale version of terracing is the use of contour buffer strips where strips of perennial vegetation alternate with wider strips of row crops on sloped fields. The vegetated strips help capture sediment washing downslope in the form of sheet erosion, and they provide a barrier against rill formation.
- **Windbreaks.** Also known as shelterbelts, windbreaks consist of one or more linear row plantings of trees or shrubs surrounding farm fields, pastures, and farm buildings. In the United States, where windbreaks have been promoted since the 1930s as a soil protection feature, typical designs call for three to 10 rows of trees and shrubs. Based upon these very generalized specifications, windbreaks are typically able to reduce wind velocity for a distance of at least 20 times the windbreak height.

These conservation features help prevent the direct loss of soil from farm fields. Other conservation features, such as grassed waterways, filter strips, and riparian buffers, also exist to manage or capture eroded soil once it has been dislodged from crop fields.

No-Till Cropping

No-till and reduced-tillage cropping systems (using no-till seed drills and planters) provide good protection against soil erosion, reduce compaction, reduce disruption to fungal hyphae, and improve habitat for wildlife and beneficial insects (e.g., ground cover provided by thatch and crop residue). Additionally, no-till cropping can reduce some greenhouse gas emissions.

However, soil organic carbon (SOC) is not permanently sequestered by no-till cropping. Because no-till cropping primarily builds soil carbon in aggregates close to the soil surface, a single tillage event can lead to a large flush of microbial activity and loss of that soil organic carbon. To maintain any reduction of greenhouse gas emissions, no-till systems need to be continuously undisturbed in order to protect the soil organic carbon that is physically stabilized in soil aggregates.

Although most no-till systems are still dependent on herbicides for weed suppression, newer no-till alternatives to weed control are gaining more use, including cover crops, rotations to outcompete weeds, and roller crimpers (rather than herbicides or tillage) to terminate cover crops. Potential crop pests like slugs and voles can thrive in the crop residue of no-till fields. There are several ways to manage against these potential pests in no-till systems while supporting soil health. Create and protect perennial, bunchgrass habitat for beneficial predatory insects—including rove beetles, soldier beetles, ground beetles, and firefly larvae, which consume slugs and flatten spikes in their populations. As part of an integrated pest management plan to support populations of beneficial predatory beetles, avoid using treated seeds and insecticides. The neonicotinoids on treated cash crop seeds can kill off these beneficial insects but do not affect slugs, leaving seedlings, especially soybeans, vulnerable to slug damage. Make space on the farm landscape for coyotes and owls, which are important predators of small mammals and vital to wider agricultural and mixed land use, especially fields with cover crops and voles.

Cover Cropping

Cover crops provide temporary or permanent vegetative cover to control erosion, reduce nutrient runoff and leaching, suppress weed growth, improve soil fertility, and increase biological diversity. Farmers can customize particular cover crop mixes and management practices to meet their specific goals.

As an example, in regions with winter rainy seasons, cover crops such as triticale, cereal rye, or barley are frequently planted to reduce erosion by slowing the velocity of rainfall and preventing soil splashing. Additionally, the root systems of winter cover crops create pore spaces in the soil that enhance water infiltration, decrease surface runoff, and recharge groundwater supplies.

Figure 37—No-till planting of cover crops into corn residue.

Figure 38—A roller crimper is an implement that breaks and flattens the stems of cover crops. This is a non-chemical termination method with minimal soil disturbance.

Figure 39—Cover crop cocktail (crimson clover, mustard and buckwheat) in bloom.

To maximize soil fertility benefits, those who plant cover crops typically prioritize legumes that support nitrogen-fixing rhizobia, a category of bacteria. Compared to synthetic equivalents, nitrogen-fixing cover crops produce sources of fertility that are less likely to be quickly lost through denitrification or volatilization (biological conversion and loss to the atmosphere), since the nitrogen is released slowly as the cover crop decomposes. While these kinds of green manure crops have traditionally depended on tillage to be incorporated back into the soil, farmers have pioneered new roller-crimper methods to terminate cover crops and press some residue against the soil surface without tillage.

Cover crops may also consist of species that fulfill other goals, such as mustard for biofumigation to reduce soil pathogens, forage for livestock, or lacy phacelia (Phacelia tanacetifolia) to provide nectar for beneficial insects, including honey bees. Alternatively, multispecies cover crop mixes increase overall field-scale biological diversity and fill multiple ecological niches and functions. Components of multispecies cover crop mixes can range from two species to more than a dozen, including cereal grains, legumes, and oilseed crops planted in combination.

Occasionally, cover crops are also interseeded between rows of a primary cash crop. Sometimes these cover crops are planted at the same time as the primary crop. More often, they are interseeded after the primary crop is actively growing in order to reduce competition. Such systems can provide farm benefits beyond just soil health. At least one study also found that songbird densities were higher in row crops that had been intercropped with a flowering cover crop. In that study, researchers pointed to the value of the intercrop in providing cover and nesting sites for the birds, but perhaps most significant was the higher abundance of beneficial insects in the flowering intercrop.

While cover cropping is mostly used on a rotational basis with annual crops, perennial crop farmers, such as orchard and vineyard crop producers, can also maintain a continuous cover of biologically diverse vegetation. In California, Xerces biologists have worked with almond producers to test and develop flowering cover crop mixes consisting of native wildflowers for use between the rows of trees. Such perennial ground cover sometimes raises concerns about weed competition with crops, exacerbated pest or disease problems, or detrimental changes in the microclimate of the farm. However, our work and various case studies continue to show how understory plantings in perennial crop systems can successfully support beneficial insects and remain compatible with normal farm operations. Farmers should take care to minimize pesticide exposure to understory plantings designed to support beneficial insects.

Crop Rotations

Along with cover crops, nitrogen-fixing cash crops (primarily legumes, such as peas or beans) can provide an additional source of soil nitrogen. Although most research examining the benefits of crop rotations focuses on soil fertility, research also confirms that increasing crop diversity through multispecies rotations produces a corresponding increase in soil species richness. For example, one 12-year study in Michigan, led by L. K. Tiemann, compared seven different crop rotations ranging from a corn monoculture to a highly diverse rotation of multiple legumes. Researchers observed significantly higher indicators of biological activity in soils with the most diverse crop rotations, including increased decomposition rates and the presence of microbial exudates, such as glue-like compounds that form soil aggregates. Rotating annual crops with perennial forage crops, which may contain multiple species or a single species, benefits soil health by keeping the ground covered for many years, eliminating tillage and maintaining a living plant for most of the year during that portion of the rotation.

Organic Soil Inputs

When focusing on soil health, nutrient management emphasizes the role of natural inputs over synthetic ones. Common natural inputs include compost, animal manure and bedding, bone meal and blood meal, seaweed and algae, and green manure crops, especially legumes. Rotating livestock in fallowed fields provides an additional approach for manure-based fertilization. Adaptive nutrient management is important during a transition to a soil health management system and depends on cropping systems and the availability of natural inputs.

These natural inputs vary in chemical composition. They also have to decompose before the nutrients they contain are available to crops, a process that happens over an extended period of time. Nutrient release from natural

inputs can also fluctuate based on temperature, soil moisture, and soil species richness. Despite the variability and slow release of natural sources of soil fertility, natural inputs eliminate some of the waste, expense, and pollution resulting from synthetic fertilizers. Care is needed in vegetable cropping systems to follow food safety rules regarding the use of animal manures.

These benefits are well illustrated in a paper by J. P. Reganold comparing wheat yields on farms in eastern Washington over an 80-year period beginning in 1908. In the earliest recorded years, all of the land was essentially farmed organically since synthetic inputs were not available. However, beginning in 1948, some of the farmland was regularly treated with synthetic fertilizers, while some of it continued to be farmed without any synthetic inputs. Researchers found that net yields were basically the same in both types of fields throughout their history. The farm not using synthetic fertilizer had less income overall because the land was fallowed every third year in a green manure crop of alfalfa. However, that farm also had lower expenses without the cost of synthetic fertilizers. The same study also revealed that the fields in a wheat and alfalfa rotation had an average of 5.9 in. (15 cm) more topsoil than the fields using synthetic fertilizers.

Figure 40—Turning a compost pile to aerate the compost, increase drainage and help it mature more thoroughly.

Of course, natural sources of soil fertility are dependent on complex soil food webs for decomposition. Indeed, research demonstrates greater numbers and types of soil organisms are typically found on farms managed with natural inputs. In one study, led by E. Gagnarli, comparing organic versus conventional vineyards in Italy, researchers noted that the organic soils they studied resembled undisturbed forest soils in their richness of soil life.

Ley Farming

Ley farming, in which annual crop fields are not tilled but rather are sown with a perennial cover of a grass or legume for months or years, was historically a common method of rebuilding soil health. Some farmers used fields in ley farming for hay production or livestock grazing. With the development of low-cost synthetic fertilizers in the early 20th century, ley farming was largely abandoned in favor of continuous cropping.

Despite its decline, ley farming continues to be occasionally used in rotation with crop production. In Australia, researchers have tracked the use of ley farming across more than 50 million acres, where wheat has been rotated with legume-based pasture for sheep over multiple decades. In published research findings, this system demonstrated a natural increase in soil nitrogen and water-stable aggregates, as well as 50% yield increases of wheat (when compared to continuous wheat cultivation). Similarly, case studies from Argentina have demonstrated the successful elimination of synthetic fertilizers from grain fields where rotational ley farming is practiced. Despite the fact that rotational ley farming has been used for centuries, contemporary research on the practice remains limited, especially research related to ley farming and soil biodiversity. However, one study

Figure 41—One way that an Indiana farm integrates livestock into annual crop rotations is to graze cattle on the cover crop (wheat) prior to termination.

of rotational ley farming, led by K. Y. Chan, found the highest numbers of earthworms occurring during the second year of grass-legume ley farming, while the populations dropped to their lowest levels during active cash crop production.

Support for Soil Health Practices

The NRCS and the USDA Farm Service Agency (FSA) provide technical and financial assistance to support conservation efforts for soil health and wildlife on working agricultural lands. Agricultural producers can use conservation programs such as the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), and Conservation Reserve Program (CRP) to help establish soil health practices that support soil organisms, such as cover cropping or planting permanent ground cover. The NRCS also provides free technical assistance to landowners and managers through the Conservation Technical Assistance (CTA) program, and can help develop conservation plans to address resource or habitat concerns. Table 1 includes conservation practices available through the NRCS that can support soil organisms and other conservation goals. For information on conservation programs or technical assistance, contact your local NRCS, FSA, or conservation district office. The office nearest you can be located at **http://offices.sc.egov.usda.gov/locator/app**.

FIGURE 42—NRCS staff provide technical assistance to producers, including creating custom plans to conserve soil and address other resource concerns.

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Chapter 24

PUTTING IT ALL TOGETHER

... generally, the type of soil management that gives the greatest immediate return leads to a deterioration of soil productivity, whereas the type that provides the highest income over the period of a generation leads to the maintenance or improvement of productivity.

—CHARLES KELLOGG, 1936

In this chapter, we'll provide some guidance on promoting high-quality soils through practices that maintain or increase organic matter, develop and maintain optimal physical and biological conditions, and promote top-notch nutrient management. In Part 3, we discussed many different ways to manage soils, crops and residues, but we looked at each one as a separate strategy. In the real world, you need to combine a number of these approaches and use them together. In fact, each practice is related to, or affects, other practices that promote soil health. The key is to modify and combine them in ways that make sense for your farm. In our discussion of the topics, we generally focused on farms, but the same principles apply to gardens large and small.

We hope that you don't feel as confused as the person on the left in Figure 24.1. If the thought of making changes on your farm is overwhelming, you can start with just one or two practices that improve soil health. Not all of the suggestions in this book are meant to be used in every situation. Also, a learning period is probably needed to make new management practices work. Experiment on one or two selected fields and permit yourself to make a few mistakes.

Ultimately your decisions need to support the bottom line. Research shows that the practices that improve soil health generally also improve the economics of the farm, in some cases dramatically. Higher soil health tends to provide higher yields and more yield stability, while allowing for reduced crop inputs. However, you need to consider the fact that the increased returns may not be immediate. After you implement new practices, soil health may improve slowly, and it may take a few years to see improved yields or changes in the soil itself. Similarly for other businesses like landscaping, your initial investments in soil health may be more expensive but will result in better outcomes for your clients in the long run, like more aesthetic parks and gardens that are more resilient and less expensive to maintain.

The bottom line therefore may not improve immediately. Changing management practices may involve an

Photo by Abram Kaplan

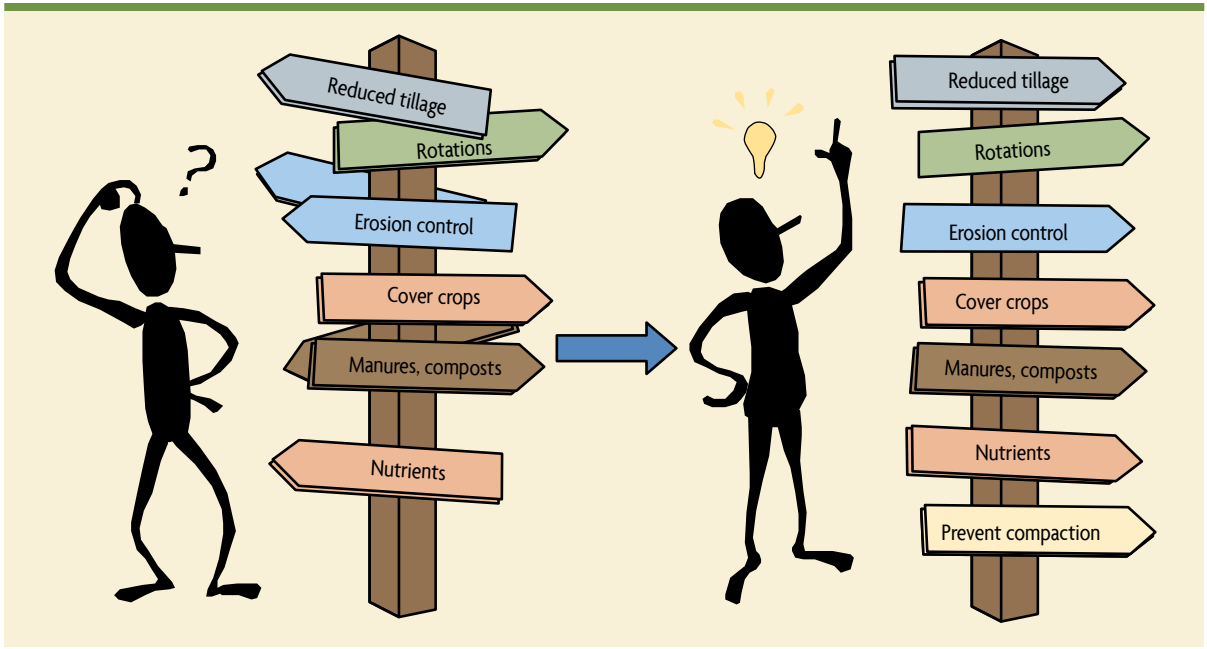

Figure 24.1. Are all the practices discussed in this book just confusing? Solutions can be found by matching them with the needs and opportunities of your farm.

investment in new equipment; for example, changing tillage systems requires new tillage tools and planters. For many farmers, these short-term limitations may keep them from making changes, even though they are hurting the long-term viability of the farm. Big changes are probably best implemented at strategic times. For example, when you are ready to buy a new planter, consider a whole new approach to tillage as well. Also, take advantage of flush times—for example, when you receive high prices for products—to invest in new management approaches. However, don't wait until that time to make decisions. Plan ahead, so you are ready to make the move at the right time. If you establish a new orchard, vineyard or landscaped area, it's best to do whatever is possible to improve the soil before you put your plants into the ground. When switching to no-till it likewise makes sense to try to add extra organic matter, take care of subsoil compaction and correct any nutrient deficiencies. Remember that soil health management is a long-term commitment. There are no silver bullets or snake oils that will work to build soil health; it requires integrating the concepts of physical, biological and chemical processes we have discussed in this book.

GENERAL APPROACHES

The ultimate purpose of ecological soil management is to create a healthy habitat belowground, with good soil structure, thriving and diverse soil organisms, and nutrients in sufficient supply for high crop yields while not in excess and, as a result, causing off-site pollution. When this is combined with healthy above ground habitat, in the field and around its perimeter, plants are provided with optimal conditions for their growth and protection against pests. Soil health can be improved through six main approaches:

- reducing tillage
- avoiding soil compaction
- growing cover crops

- using better crop rotations
- applying organic amendments in appropriate quantities
- applying inorganic amendments in appropriate quantities, timing and locations

There are many options for making soil management changes in different types of farming systems. We have discussed these in the previous chapters with respect to helping remedy specific problems. A good analogy is to think of your soil as a bank account with credits and debits. The credits are management practices that improve soil health, like manure additions, reduced tillage and cover crops. The debits are the ones that degrade the soil, like compaction from field traffic and intensive tillage (Table 24.1). One farming system may result in a different balance sheet than another due to specific constraints. For example, a daily harvest schedule means that you cannot avoid traffic on wet soils, and small-seeded crops require intensive tillage (at least in the planting row) in order to prepare a seedbed. Still, strive to optimize the system: If a "bad" practice, such as harvesting in a wet field that contains spoilable crops, is unavoidable, try to balance it with a "good" practice, thereby making your soil health account flush. Also, you may have options to reduce the impacts of a bad practice, like controlling traffic to certain lanes to reduce unavoidable soil compaction.

If at all possible, use rotations that use grass or legume forage crops (or a combination of the two), or crops with large amounts of residue as important parts of the system. Leave residues from annual crops in the field, or, if you remove them for feed, composting or bedding, return them to the soil as manure or compost. Use cover crops when soils would otherwise be bare to add organic matter and maintain soil biological health, capture residual plant nutrients, keep the soil protected and reduce erosion. Cover crops also help maintain soil organic matter in resource-scarce regions that lack possible substitutes for using crop residues for fuel or building materials.

Raising animals or having access to animal wastes from nearby farms gives you a wider choice of economically sound rotations. Those that include perennial forages make hay or pasture available to dairy and beef cows, sheep and goats—and nowadays even poultry. In addition, on mixed crop-livestock farms, animal manures can be applied to cropland. It's easier to maintain organic matter on a diversified crop-and-livestock farm, where sod crops are fed to animals and manures are returned to the soil. Compared to crop farms, fewer nutrients leave farms when livestock products are the

Table 24.1
Balance Sheet for Soil Health Management*

Practice or Condition	Improves Soil Health	Reduces Soil Health
Tillage		
moldboard plowing		XX
chisel plowing		X
disking		X
harrowing		X
conservation tillage	X	
Compaction		
light		X
severe		XX
Organic matter additions		
bedded manure	XX	
liquid manure	X	
compost	XX	
mulch	XX	
Cover crops		
winter grain	XX	
winter legume	X	
summer grain	XX	
summer legume	XX	
Rotation crops		
3-year sod	XX	
1-year sod	X	

*X = a moderate effect; XX = a greater effect.

main economic output. However, growing crops with high quantities of residues, plus frequent use of green manures and composts, helps maintain soil organic matter and soil health even without animals. In many situations you may have opportunities to bring in organic resources. Perhaps there is a lot of municipal compost available in your area, or maybe a nearby dairy farm sells well-composted manure that can help you grow vegetables or improve an orchard or landscaped area.

You can maintain or increase soil organic matter more easily when you use reduced-tillage systems, especially no-till and strip-till. The decreased soil disturbance keeps biological activity and organic matter decomposition near the surface and helps maintain a soil structure that allows rainfall to infiltrate rapidly. Leaving residue on the surface, or applying mulches, has a dramatic impact on soil biological activity. It encourages the development of earthworm populations, maintains soil moisture and moderates temperature extremes. Adding mulch can be very helpful after you plant perennial trees to control weeds and conserve soil moisture.

Compared with conventional tillage, soil erosion is greatly reduced under minimum-tillage systems, which help keep organic matter and rich topsoil in place. Any other practices that reduce soil erosion, such as contour tillage, strip cropping along the contours and terracing, also help maintain soil organic matter. Even if you use minimum-tillage systems, you also should use sound crop rotations. In fact, it may be more important to rotate crops when large amounts of residue remain on the surface, as they may harbor insect and disease organisms. These problems may be worse in monoculture with no-till practices than with conventional tillage.

WHAT MAKES SENSE FOR *YOUR* SITUATION?

We strongly advocate a holistic management approach designed to prevent problems from developing, as preventive medicine approaches do. And, as with human health, we have the ability to diagnose problems through observations and testing. If problems are identified, the patient and physician develop strategies to address them. This may include a change in diet, exercise, a pill or even surgery. There are often multiple ways and combinations to reach the same goal, depending on personal preferences and circumstances. Similarly for soil health, what makes sense for any individual operation depends on the soils, the climate, the nature of the enterprise, the surrounding region, potential markets and your goals. The tests and observations provide useful guidance to help target constraints, but there is rarely a simple recipe. We wish it was that easy. Holistic soil health management based on ecological principles requires an integrative understanding of the processes, which is basically the purpose behind this book.

Start with regularly testing your soils, preferably using comprehensive soil health analyses, and applying amendments only when they are needed. Testing soils on each field every two to three years is one of the best investments you can make. If you keep the report forms, or record the results, you will be able to follow soil health changes over the years. Monitoring soil test changes will help you fine-tune your practices. Also, maintaining your pest scouting efforts and keeping records of those over the years will allow you to evaluate improvements in that area.

PRACTICES TO HELP REMEDY SPECIFIC CONSTRAINTS

Building soil health can help prevent problems from affecting the environment and plant growth. However, as good a job as you might do, specific problems may arise that require some sort of remedial action. The choice of a practice or combination of practices depends largely on specific soil health problems and possible constraints imposed by the farming system. We discussed in Chapter 21 how traditional (chemical) soil tests are used to provide quantitative nutrient and lime recommendations. As discussed in Chapter 23, newly

Table 24.2
Linking Some Soil Health Measurements to General Management Solutions

	Suggested Management Practices	
Physical Concerns	**Short Term or Intermittent**	**Long Term**
Low aggregate stability	Fresh organic materials (shallow-rooted cover/rotation crops, manure, green clippings)	Reduced tillage, surface mulch, rotation with sod crops
Low available water capacity	Stable organic materials (compost, crop residues high in lignin, biochar)	Reduced tillage, rotation with sod crops
High surface density	Limited mechanical soil loosening (e.g., strip tillage, aerators), shallow-rooted cover crops, bio-drilling cover crops, fresh organic matter	Shallow-rooted cover/rotation crops, avoiding traffic on wet soils, controlled traffic, physical decompaction—loosening
High subsurface density	Targeted deep tillage (zone building, etc.), deep-rooted cover crops	Avoiding plows/disks that create pans, reducing equipment loads and traffic on wet soils, deep tillage
Biological Concerns		
Low organic matter content	Stable organic matter (compost, crop residues with high lignin, biochar), cover and rotation crops	Reduced tillage, rotation with sod crops, mulch
Low active carbon	Fresh organic matter (shallow-rooted cover/rotation crops, manure, green clippings)	Reduced tillage, rotation
Low organic forms of nitrogen	N-rich organic matter (leguminous cover crops, manure, green clippings)	Cover crops, manure, rotations with forage legume crop, reduced tillage
High root-rot rating	Disease-suppressive cover crops, disease-breaking rotations	Disease-suppressive cover crops, disease-breaking rotations, IPM practices
Chemical Concerns		
Low CEC	Stable organic matter (compost, lignaceous/cellulosic crop residues, biochar), cover and rotation crops	Reduced tillage, rotation
Unfavorable pH	Liming materials or acidifier (such as sulfur)	Repeated applications based on soil tests
Low P, K	Fertilizer, manure, compost, P-mining cover crops, mycorrhizae promotion	Repeated application of P, K materials based on soil tests; increased application of sources of organic matter; reduced tillage
High salinity	Subsurface drainage and leaching	Reduced irrigation rates, low-salinity water source, water table management
High sodium	Gypsum, subsurface drainage, leaching	Reduced irrigation rates, water table management

available soil health tests, as well as careful attention to your soils and crops, can help target management practices related to specific limitations. We cannot be quite as precise for making recommendations regarding physical and biological constraints as we can be for nutrient problems because these systems are more complex and we don't have as strong a research base.

General management guidelines for specific constraints that may have been identified from soil health tests or field observations are presented in Table 24.2. They are listed in terms of two timelines: short term or intermittent, and long term. The short-term recommendations provide relatively quick responses to soil health problems, and they may need to be repeated to prevent recurrence of the problem. The long-term approaches focus on management practices that don't provide quick fixes but that address the concern more sustainably. You will probably note that the same practices are often recommended for different constraints because they address multiple concerns at the same time.

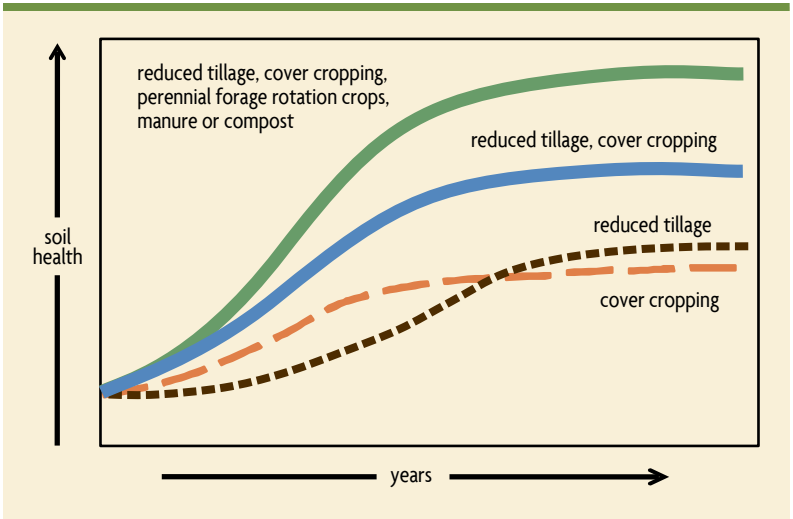

Figure 24.2. Combining practices that promote soil health has an additive effect.

Note that many of the management solutions listed in Table 24.2 involve improving organic matter. As you probably realize at this stage of the book, we believe that improved organic matter management is key to sustainable soil management. But keep in mind that simply bringing in any type of organic material in any amount is not necessarily the solution. For one thing, organic additions that are too large may create problems with nutrient surpluses. Second, some organic materials reduce disease levels, but others can increase them (see Chapter 11 on rotations and Chapter 13 on composting). Third, some constraints like acidity, sodicity and extremely low nutrient levels are often more effectively approached with chemical amendments. Fourth, there are important considerations relating to the type of organic materials that are used. In chapters 9, 10 and 12 we discussed different organic residues and manures, and their effects on soil health. One important distinction is whether the material is mostly "fresh" and easily decomposable or contains more stable compounds. Fresh materials like manure, cover crops and green clippings are high in sugars, cellulose and proteins, and have relatively high N content (low C:N ratios). They immediately stimulate soil biological activity, especially bacteria, and provide a lot of available N for crops. The organic materials that are dominated by stable materials high in lignin, like the residues of mature crops, and those that contain humic material, like composts, are critical to building soil health in the long term. Biochar and other heat-treated organic materials decompose slowly and are much more stable materials, sometimes remaining for hundreds of years. If, for example, aggregate stability or active carbon levels are low, the application of easily decomposable materials will be beneficial in the short term. However, these materials disappear quickly and need to be added regularly to maintain good aggregation. For longer-term effects it is recommended to include more stable organic compounds and use reduced tillage.

What is the role of fertilizers? The emphasis on organic matter should not be interpreted as a complete condemnation of synthetic fertilizers. It is true that the sole dependence on synthetic chemicals without consideration of organic matter and biology in the soil is a primary source of soil health degradation. But not supplying adequate nutrients where they are needed will make matters more dire. There are situations where organic crop production is possible and makes sense, but for better or worse, the current structure of agriculture leaves many areas without adequate options for carbon and nutrient cycling. There the emphasis should be on using conservation practices and supplemental fertilizer to reduce nutrient losses, maintain crop yields and enhance biomass cycling. Otherwise, soil health will deteriorate further and yield reductions will result in food shortages or will necessitate more agricultural expansion into natural areas.

Grain Crop Farms

Most grain crop farms export a lot of nutrients and are managed with a net loss of organic matter. Nevertheless, these farms provide a great deal of flexibility in adopting alternative soil management systems because a wide range of equipment is available for grain production systems. You can promote soil health easily with reduced-tillage systems, especially no-till and strip-till. Well-drained, coarse-textured soils are especially well adapted to no-till systems, and finer-textured soils do well with strip-till or zone-till systems. Regardless of the tillage system that is used, travel on soils only when they're dry enough to resist compaction. However, managing no-till cropping on soils that are easily compacted is quite a challenge because there are few options to relieve compaction once it occurs. Controlled-traffic farming is a very promising approach, especially for such situations, although it may require adjustments of equipment and investment in a GPS guidance system. Incorporating these innovations into a conventional grain farm often requires an investment in new equipment and creatively looking for new markets for your products. There also are many opportunities to use cover crops on grain farms, even in reduced-tillage systems.

Even if you use minimum-tillage systems that leave significant quantities of residue on the surface and decrease the severity of erosion, you also should use sound crop rotations. Consider ones that use grass or legume perennial forage crops, or a combination of the two. Even bringing small grains into a row crop system (like corn and soybeans) can improve soil health and open up opportunities for cover crops. Raising animals on what previously were exclusively crop farms, cooperating on rotations and manure management with a nearby livestock farm, or growing forage crops for sale gives you a wider choice of economically sound rotations and at the same time helps to cycle nutrients better.

Organic grain crop farms do not have the flexibility in soil management that conventional farms have. Their main challenges are providing adequate nitrogen and controlling weeds. Tillage choices are limited because of the reliance on mechanical methods, instead of herbicides, to control weeds. On the positive side, organic farms already rely heavily on organic inputs through green or animal manures and composts to provide adequate nutrients to their crops. So their balance sheet (Table 24.1) is often very good despite the tillage. A well-managed organic farm usually uses many aspects of ecological soil management. However, erosion may remain a concern when you use clean and intensive tillage. It is important to think about reducing tillage intensity; using strips, ridges or beds; controlling traffic; and perhaps investing in a good planter. New mechanical cultivators can generally handle higher residue and mulch levels, and may still provide adequate weed control. Look into ways to increase surface cover, although this is a challenge without the use of chemical weed control. Alternatively, consider more traditional erosion control practices, such as strip cropping, as they work well with rotations involving sod and cover crops.

Crop-Livestock Farms

Diversified crop-and-livestock farms have an inherent advantage for improving soil health. Crops can be fed to animals, and manures can be returned to the soil, thereby providing a continuous supply of organic materials. For many livestock operations, perennial forage crops and management intensive grazing are an integral part of the cropping system, thereby reducing erosion potential and improving soil physical and biological properties. Nevertheless, integrated crop-livestock farms have challenges. Corn silage harvests do not leave much crop residue, which needs to be compensated for with manure applications or cover crops. Minimizing tillage is also important and can be done by injecting the manure or gently incorporating it with aerators, disks or harrows rather than plowing it under. Soil pulverization can be minimized by

reducing secondary tillage, using strip or zone tillage, and establishing the crops with no-tillage planters and seeders.

Preventing soil compaction is important on many livestock-based farms. Manure spreaders are typically heavy and frequently go over the land at unfavorable times, doing a lot of compaction damage. Think about ways to minimize this. Livestock farms require special attention to nutrient management, including making sure that organic nutrient sources are optimally used around the farm and that no negative environmental impacts occur. This requires a comprehensive look at all nutrient flows on the farm, finding ways to most efficiently use them, and preventing problems with excesses. Finally, management-intensive grazing systems are very efficient and are similar to how herds of wild animals naturally graze. Harvesting and fertilizing are done by the animals, but be aware that it is important to match stocking rates to the productivity of pastures.

Vegetable Farms

Soil health management is especially challenging on vegetable farms. Many vegetable crops are sensitive to soil compaction and often pose greater challenges in pest management. Vegetable lands have generally been worked hard over many years and have a long way to go toward improved soil health. Most vegetable farms are not integrated with livestock production, and it is difficult to maintain a continuous supply of fresh organic matter. Bringing manure, compost or other locally available sources of organic materials to the farm should be seriously considered. In some cases, vegetable farms can economically use manure from nearby livestock operations or swap land with them in a rotation. Farms near urban areas may benefit from leaves and grass clippings, and municipal or food waste composts, which are increasingly available. In such cases, care should be taken to ensure that the compost does not contain contaminants. Contrary to large commercial vegetable operations, we found that many smaller organic vegetable farms are often on the other end of the spectrum for soil health. They typically use good rotations and cover crops to provide nitrogen and to reduce pest problems, and they import manure or compost to maintain fertility.

Vegetable cropping systems are often well adapted to the use of cover crops because the main cropping season is generally shorter than those for grain and forage crops. There is usually sufficient time for the growth of cover crops in the pre-, mid- or post-season to gain real benefits, even in colder climates, and vegetable growers often have a multitude of cover cropping options. Using them as a mulch (or importing mulch materials from off the farm) appears to be a good system for certain fresh market vegetables, as it keeps the crop from direct contact with the ground, thereby reducing the potential for rot or disease.

But many vegetable crops are highly susceptible to diseases, and selection of the right cover or rotation crop is critical. For example, according to Cornell plant

FINDING CREATIVE SOLUTIONS

Dairy farmers in Vermont were concerned about soil health on their corn fields. The state's colder continental climate limits the time window for cover crop establishment before winter dormancy sets in. Working together with University of Vermont specialists, the farmers experimented with two shorter-season corn varieties that mature seven to 10 days earlier and increase the time window for cover crop establishment equivalently. They found that their corn yields were generally unaffected by the shorter growing season, but their ability to establish cover crops was greatly enhanced.

pathologist George Abawi, bean root rot is suppressed by rapeseed, crown vetch, wheat and rye but is actually enhanced by white clover. Sudan grass can effectively remediate compaction, control pathogenic nematodes and allelopathically control weeds, but it requires a long time window for sufficient growth.

The immediate need to harvest crops during a very short period before quality declines, often a concern with vegetables, can result in severe compaction problems on vegetable farms. Controlled-traffic systems, including permanent beds, should be given serious consideration. Limiting compaction to narrow lanes and using other soil-building practices between them is the best way to avoid compaction damage under those conditions.

Fruit Farms and Landscaping

Many fruit crops, such as brambles, citrus, grapes, apples and stone fruits, are perennials that take several years to establish and may be harvested for 20 or more years. Similarly, landscaped areas in parks and gardens are intended to remain attractive for many years with minimal maintenance. This makes it especially important to address soil health concerns up front and to avoid mistakes during the establishment years, which can have negative impacts long into the future. Comprehensive soil health analyses and field surveys are worthwhile investments, considering the already high costs of establishing the crops. For tree and vine crops, these evaluative steps should pay attention to deeper soil layers, especially the presence of hard pans, subsoil acidity and shallow water tables, because the quality of the fruits is often strongly influenced by deep roots. It is often worthwhile to make one-time investments like drainage installation, in-row deep ripping and deep lime and compost incorporations, as these are difficult to perform after planting. For landscaped areas, future maintenance costs and watering are concerns that can be addressed by building up the soil before transplanting. Post-establishment, the emphasis should be on managing the surface layer. Avoiding compaction is important, and maintaining good surface mulches is generally also beneficial, depending on the crop type.

SOME FINAL THOUGHTS

The old folk saying, "The farmer's footprint is the best fertilizer" could be modified to "The farmer's footprint is the best path to improved soil health." If you don't

MORE IS NOT ALWAYS BETTER WITH GRAPEVINES

A good soil is needed in the early years in order to establish healthy grapevines. But the best wines generally come from soils that are not overly fertile and that allow for some water stress during the season. High organic matter and nitrogen contents in vineyard soils create overly abundant vegetative growth in grapevines, reducing fruit set and requiring repeated pruning. Also, important traits of wines are enhanced by the presence of the grapes' anthocyanin pigments, which contribute to both the taste and to the color of wine. Mild water stress and reduced root growth during the early summer (between bloom and the beginning of the ripening stage) increase the content of these pigments. Poor drainage and aeration are bad for wine quality. Some of the world's best wines are grown on soils that allow for deep rooting; are calcareous, sandy or gravelly; and are low in organic matter. The best climates experience water deficits during the growing season, which can be supplemented by irrigation if needed. This complex interaction between soil, climate and vine is referred to as *terroir*.

already do so, begin to regularly observe and record the variability in plant growth and yield across your fields. Take the time to track production from the various sections of your fields that seem different. Compare your observations with the results of your soil tests, so you can be sure that the various areas within a field are receiving optimum management. Each of the farming systems discussed above has its limitations and opportunities for building better soils, although the approaches and details may differ. Whatever crops you grow, when you creatively combine a reasonable number of practices that promote high-quality soils, most of your soil health problems should be solved along the way, and the yield and quality of your crops should improve. By concentrating on the practices that build high-quality soils, you also will leave a legacy of land stewardship for the next generations to inherit and follow.

Regenerative Agriculture

Cows graze at Nice Farms Creamery in Federalsburg, Maryland.

Definition of Regenerative Agriculture

Regenerative agriculture is farming in synchrony with nature to repair, rebuild, restore, and revitalize ecosystem function, starting with all life in the soil and expanding to all life above the soil. Regenerative agriculture describes holistic farming systems that, among other benefits, improve soil, water, and air quality; enhance ecosystem biodiversity; produces nutrient-dense food; and stores carbon to help mitigate the effects of climate change. These farm systems are designed to work in harmony with nature, while also maintaining and improving economic viability.

Diversifying farming systems is an essential component in today's regenerative agriculture movement, but this concept is not new. Indigenous communities farmed with the Three Sisters system of planting corn, squash, and beans together. Corn provided the support for the beans, which provided the nitrogen fertilizer, and squash provided cover, suppressing weeds, while helping maintain soil moisture. George Washington Carver's research on crop rotation to reduce pests and planting peanuts, a legume which fixes nitrogen from the atmosphere, to restore soils depleted after years of growing cotton is another example of regenerative agriculture. Regenerative agriculture's deep roots in farming culture and history provide a strong foundation for th future of food production in the Chesapeake Bay watershed.

Clover used as a cover crop provides nitrogen to the soil and is healthier than applying chemical fertilizer.

Regenerative agriculture focuses on working with soil biolog as there are over six billion microorganisms in a teaspoon of healthy soils. There is a symbiotic relation between soil microbes and plants where plants provide the liquid-carbon food to microbes through photosynthesis and the microbes in return provide the plants with essential nutrients and micronutrients for plant and human health. Soil microbes als create a microbial glue to form soil aggregates, which allow water to infiltrate and air spaces for roots to grow. To have healthy soils there are five principles that are critical and all impact soil biology.

The Top Five Principles of Regenerative Agriculture:

- Minimize negative disturbance—tillage, pesticides, and herbicides impact soil biology and structure.
- Keep the soil always covered—prevents erosion, maintains moisture and soil temperature, and reduces weeds.
- Plant diversity—diversity of plants results in diversity of soil microbes and reduced fertilizer needs.
- Keep roots living as long possible—maintains photosynthesis, sequesters carbon, and feeds soil biology, a symbiotic relationship.
- Add livestock/rotational grazing—good soil disturbance, manure is probiotic, cattle graze grass, encouraging root to grow deeper in soil.

enefits of Regenerative Agriculture:

Ecological	Social	Economic
Improve soil health, biology, and fertility.	Produce nutrient-dense foods that are free from chemical contaminants.	Increased farm productivity.
Increase the land's ability to filter, infiltrate, and retain water.	Make farms and communities more resilient to drought and floods.	Improved crop yields and forage quality.
Reduce erosion and polluted runoff.	Maintain baseflow to streams during dry periods as the soil's sponge releases water, extending periods for recreational use and sustaining drinking water supply.	Reduced risk due to increased resiliency.
Improve wildlife habitat and ecosystem biodiversity and resilience.	Restoring soils for the next generation of farmers.	Cost savings from reduced irrigation needs and inputs: synthetic fertilizers, herbicides, and feed purchase.
Capture substantial amounts of carbon from the air and store it in the soil while reducing nitrous oxide emissions, a potent greenhouse gas.		

egenerative agriculture can include a suite of practices catered to fit the unique aspects of each farm.
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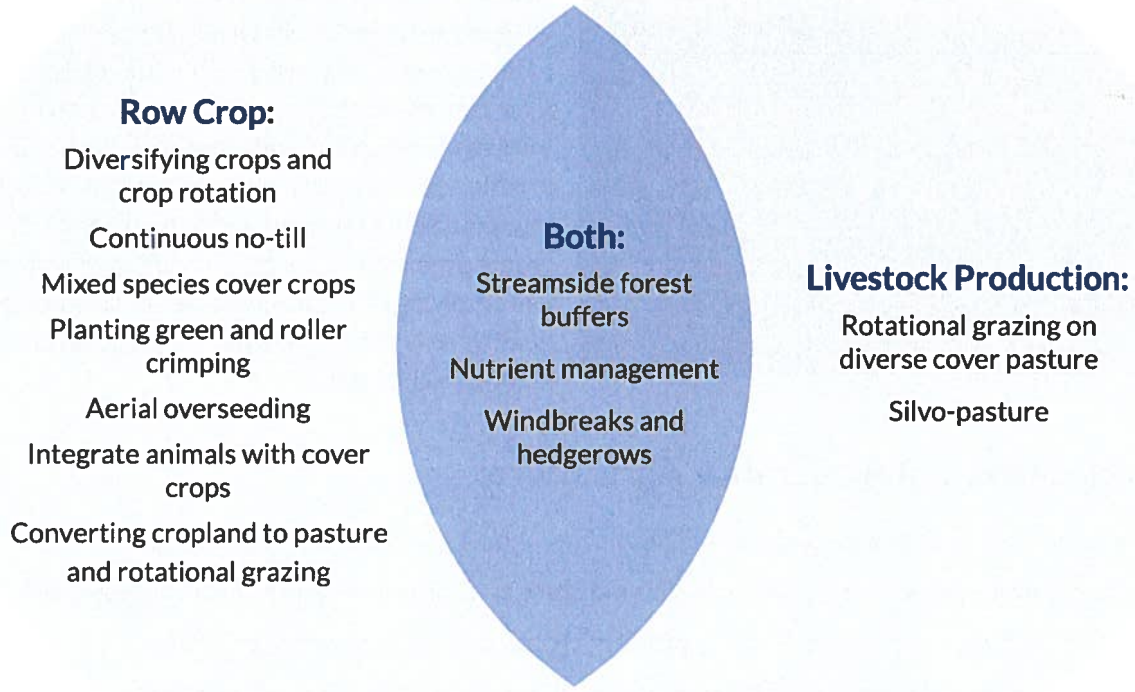

CHESAPEAKE BAY FOUNDATION
SAVE THE BAY

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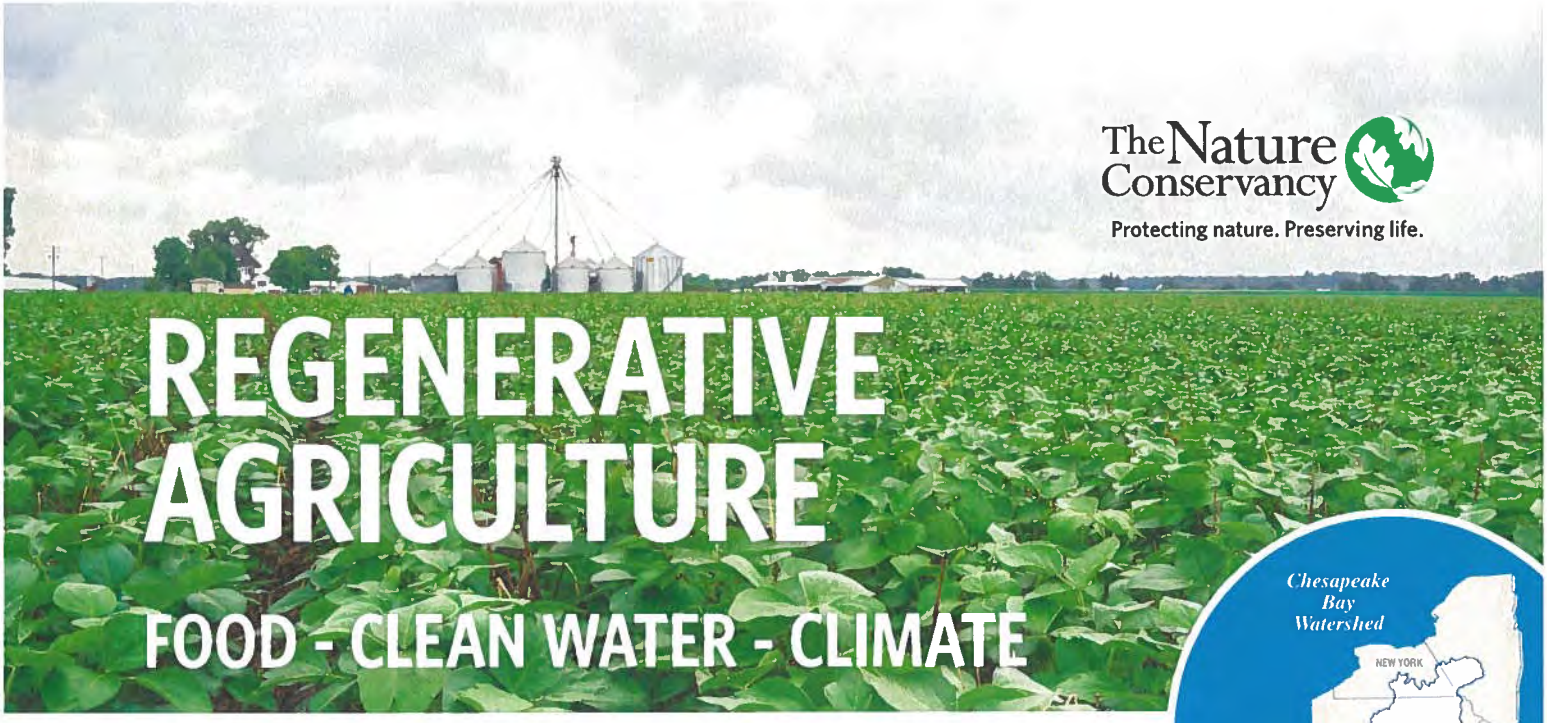


The Nature Conservancy
Protecting nature. Preserving life.

REGENERATIVE AGRICULTURE

FOOD - CLEAN WATER - CLIMATE

NUTRIENT AND SOIL MANAGEMENT IN FIELDS

The health of the Chesapeake Bay is intricately linked to the health of more than 83,000 farms that operate in its watershed. Agriculture contributes the largest amount of nutrients to the Bay, which in excess quantities degrades aquatic habitat for fish, oysters, crabs, and submerged plants.

In the past 30 years, farmers have more than doubled the amount of corn produced on every acre while also reducing the amount of nitrogen making it to the Chesapeake Bay by 37%. Despite these successes, more farmers will need to adopt advanced nutrient management practices (i.e., precision use of fertilizer) to restore the Bay, especially now that increasing temperatures and precipitation due to climate change continue to make our water quality goals even harder to meet.

In 2018, The Nature Conservancy co-founded the MidAtlantic 4R Nutrient Stewardship Association — a collaboration of agribusinesses, government agencies, researchers, and conservation groups — to increase the adoption of these practices while also improving the economic sustainability of farms. **Our goal is to see 2 million acres of cropland in the Bay watershed adopt climate-smart nutrient management and soil health practices.**

WETLAND AND FLOODPLAIN RESTORATION AT THE EDGES OF FIELDS AND DOWNSTREAM

The Chesapeake Bay watershed is made up of more than 150 rivers and 100,000 streams carrying water across the landscape and eventually to the Bay. As the population across the watershed has grown, however, many of those waterways have been greatly impaired and wetlands have been converted to other land uses; primarily agriculture and development.

Restoring the Chesapeake will require restoring this network of streams, wetlands, forest buffers and floodplains to slow and clean the water before it reaches the Bay. As we experience greater impacts of climate change — including rising temperatures and more frequent large storms — the water filtration and storage provided by wetlands and floodplains is even more critical.

Using cutting-edge science, The Nature Conservancy is identifying key areas where wetland and floodplain restoration can have the greatest benefit to water quality. To complete restoration projects on a larger scale, the Conservancy is also helping to build new coalitions and partnerships with landowners, federal and state agencies, NGOs, and others. **Our goal is to restore and enhance 235,000 acres of wetlands and floodplains across the Chesapeake Bay watershed along with the benefits they provide.**

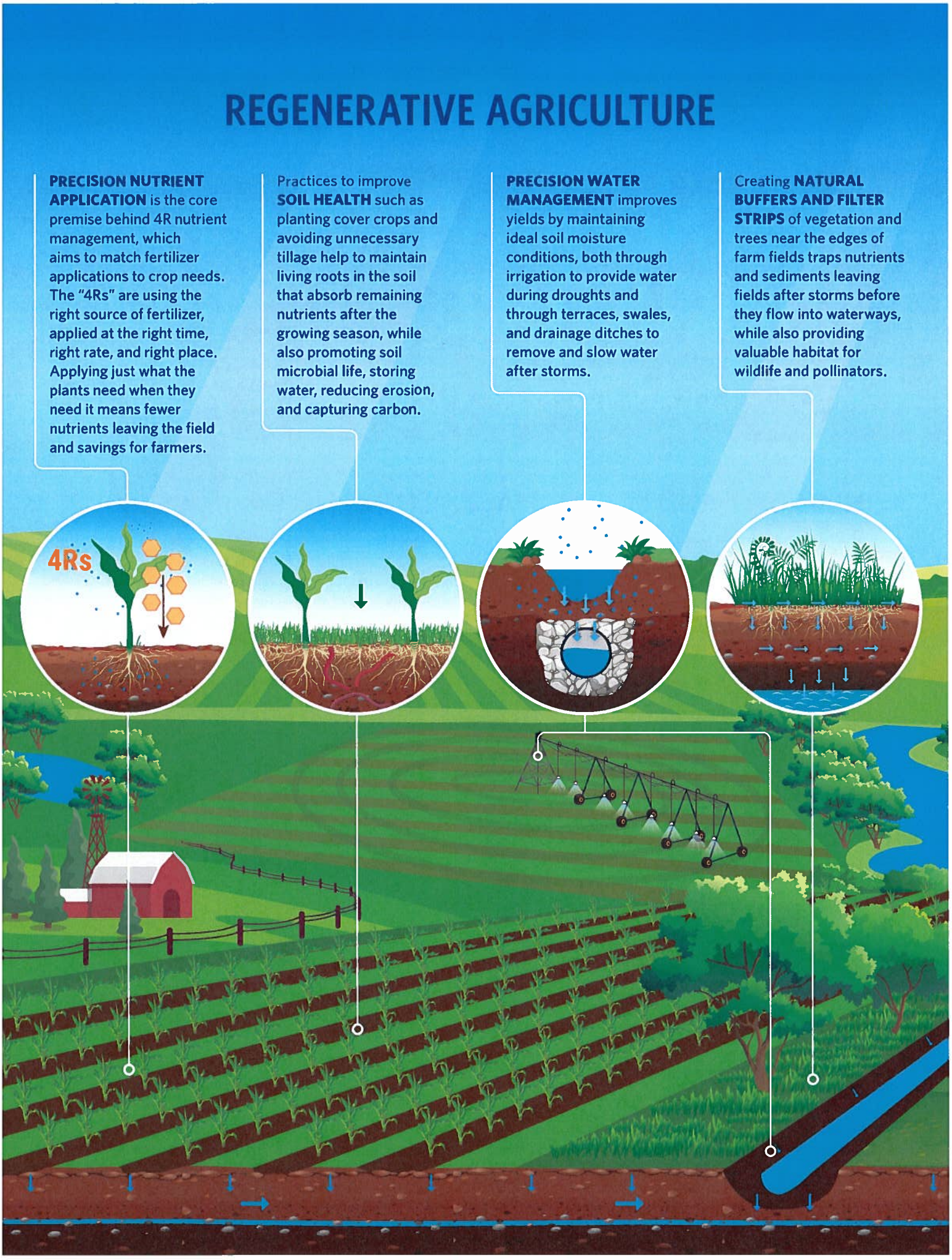
REGENERATIVE AGRICULTURE

PRECISION NUTRIENT APPLICATION is the core premise behind 4R nutrient management, which aims to match fertilizer applications to crop needs. The "4Rs" are using the right source of fertilizer, applied at the right time, right rate, and right place. Applying just what the plants need when they need it means fewer nutrients leaving the field and savings for farmers.

Practices to improve **SOIL HEALTH** such as planting cover crops and avoiding unnecessary tillage help to maintain living roots in the soil that absorb remaining nutrients after the growing season, while also promoting soil microbial life, storing water, reducing erosion, and capturing carbon.

PRECISION WATER MANAGEMENT improves yields by maintaining ideal soil moisture conditions, both through irrigation to provide water during droughts and through terraces, swales, and drainage ditches to remove and slow water after storms.

Creating **NATURAL BUFFERS AND FILTER STRIPS** of vegetation and trees near the edges of farm fields traps nutrients and sediments leaving fields after storms before they flow into waterways, while also providing valuable habitat for wildlife and pollinators.

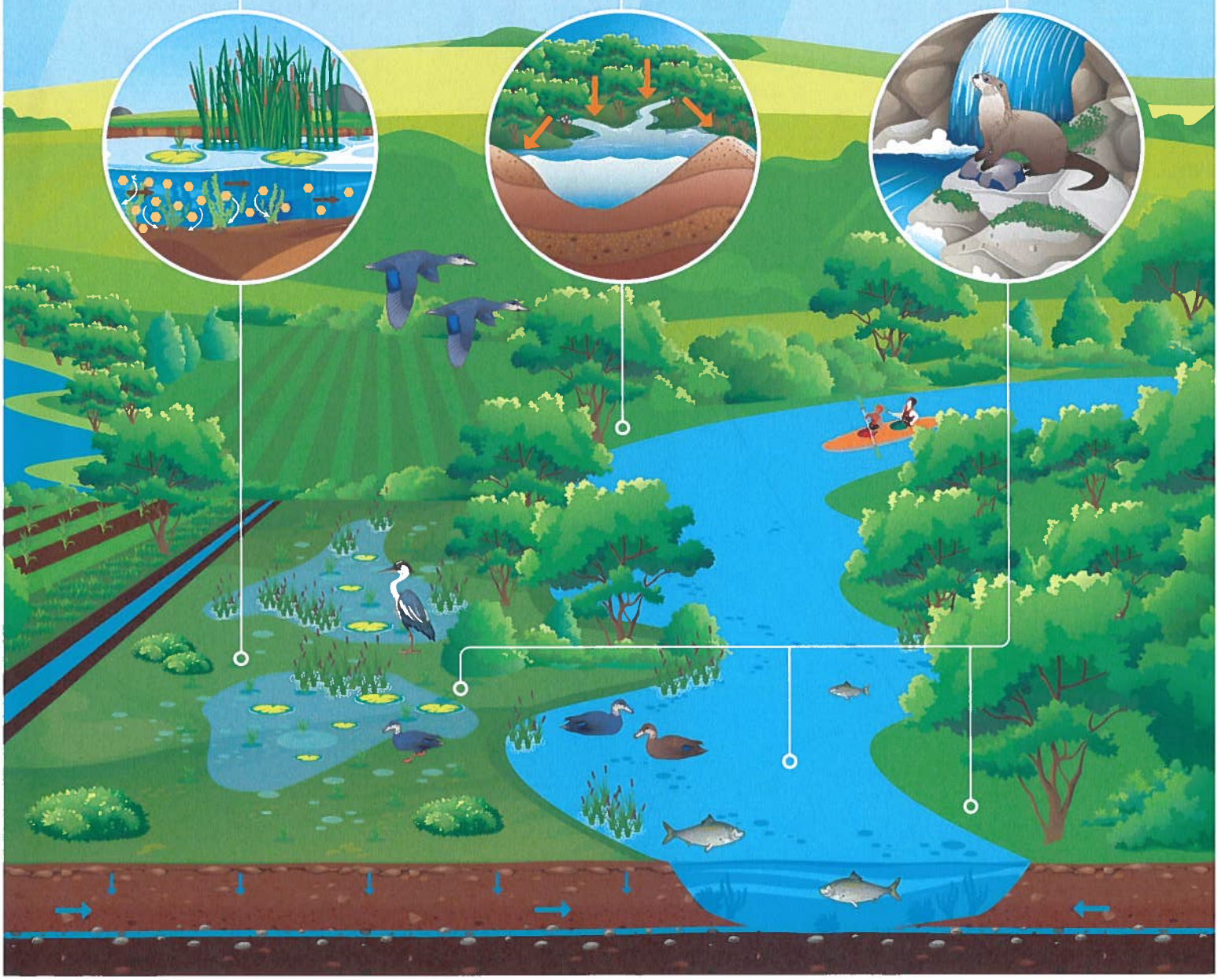


WETLANDS AND FLOODPLAINS

Wetlands perform critical function throughout different parts of the watershed. **WETLANDS ADJACENT TO FARM FIELDS CAN CAPTURE** nutrients and sediment carried away by rainwater during storms by slowing down runoff and allowing natural processes to filter the water before it continues downstream.

Large-scale storm events can impair water quality by moving high volumes of water very quickly across the land. Restoring streams and degraded **FLOODPLAINS** helps to slow and store flood water to allow nutrients and sediment to be removed. In some areas, it can also reduce flooding to communities downstream

Humans aren't the only ones who benefit from wetland restoration. A huge array of wildlife depend on wetlands for everything from food to shelter to a place to rear young. Wetland and **STREAM RESTORATION** can be particularly beneficial for animals like fish, birds, small mammals, reptiles and amphibians. Around the Chesapeake Bay watershed, that includes species like black ducks, river otters, salamanders, and trout.



Why Canadian Farmers and Ranchers Need a National Soil Health Strategy

Tanya Craddock

Oct 7, 2025

Why Canada Needs a National Soil Health Strategy Now More Than Ever

Healthy soil is the foundation of every successful farm and ranch. Whether you're growing crops or managing pasture, soil health directly impacts yields, forage quality, water retention, grazing resilience, and long-term farm profitability.

Across Canada, experts, industry leaders, and producers are now calling for a **National Soil Health Strategy**, a coordinated, country-wide commitment to conserving and improving soil for future generations. For farmers and ranchers, this strategy isn't just policy talk. It's a practical path to more resilient and profitable operations.

The Challenge: Canada's Farmland Is Under Increasing Pressure

Canada's soil is a non-renewable natural resource, and today it faces multiple threats:

1. Soil Erosion and Loss of Organic Matter

Wind and water erosion continue to remove valuable topsoil. Once organic matter declines, productivity drops and inputs must rise to compensate.

2. Soil Compaction and Degradation

Heavy equipment, intensive cropping, and overgrazing can restrict root growth, and limit the movement of water and nutrients.

3. Extreme Weather and Climate Change

Drought, flooding, and unpredictable weather are becoming more common. Soil with good structure and organic matter handles these extremes far better.

4. Lack of Consistent National Soil Monitoring

Canada has no unified approach to tracking soil health, making it difficult to identify risks early or measure long-term progress.

These pressures mean that without action, soil health declines, and so does long-term farm profitability.

Why a National Soil Health Strategy Matters to Farmers and Ranchers

The goal of a National Soil Health Strategy (NSHS) is to create a coordinated, science-based, farmer-informed plan to protect soil across the country. Here's how that benefits producers directly:

1. Consistent, Practical Soil Health Guidelines

A national framework ensures farmers and ranchers have clear, region-specific guidance for improving soil health without guesswork.

2. Better Data and Soil Health Monitoring

Tracking soil organic matter, compaction, nutrient balance, carbon levels, and water-holding capacity will help producers make better management decisions.

3. Increased Resilience and Reduced Input Costs

Healthy soil:

- Holds more moisture during drought
- Drains better during heavy rains
- Stores nutrients more efficiently
- Reduces fertilizer and amendment needs over time

For ranchers, improved soil means stronger forage growth, longer grazing seasons, and better cattle performance.

4. Stronger Market Competitiveness

Global markets increasingly prefer products grown using sustainable practices. A national strategy strengthens Canada's brand and could lead to:

- Premium pricing
- Carbon market opportunities
- Sustainability certifications

5. More Support, Knowledge Exchange, and Producer-Driven Research

The strategy aims to expand extension services, field schools, producer networks, and regionally relevant research, putting practical tools into farmers' hands.

What Canadian Farmers and Ranchers Can Expect From the Strategy

1. Region-Specific Targets

From the Prairies to the Atlantic, from the North to B.C., soil conditions vary widely. The NSHS recognizes this and supports flexible, locally tailored recommendations.

2. Long-Term, Generational Benefits

Soil health isn't a quick fix, it's an investment. But the returns are powerful:

- Higher yields
- Improved grazing capacity
- Lower risk during extreme weather
- Higher land value for the next generation

3. Potential Incentives and Support Programs

As the strategy develops, producers may see:

- Grants or cost-share programs
- Incentives for carbon sequestration
- Technical support for adopting new practices

Soil Health Practices the Strategy Encourages

While every operation is unique, key soil-building practices include:

- **Reduced or zero tillage**
- **Cover crops and forage blends**
- **Rotational grazing and improved pasture management**
- **Diverse crop rotations**
- **Manure and compost applications**
- **Perennial systems and shelterbelts**

These practices aren't new; many Canadian farmers and ranchers are already leading the way. The national strategy helps scale these successes across the country.

Why the Time for a National Soil Health Strategy Is Now

Canada is at a crossroads. Soil degradation, climate pressures, and growing global sustainability requirements mean the old approach isn't enough.

A National Soil Health Strategy gives us a unified plan to:

- Protect farmland
- Support producers
- Improve climate resilience
- Strengthen Canada's agri-food economy
- Preserve the land for future generations

For every farmer and rancher, this strategy is about safeguarding the soil we depend on, and ensuring Canadian agriculture thrives in the decades to come.

Final Thoughts: Soil Is Our Future

Healthy soil is more than a resource, it's a legacy. It's what allows Canadian farms and ranches to produce safe, high-quality food while staying profitable and resilient. A National Soil Health Strategy ensures that legacy continues, building stronger soils, stronger farms, and stronger rural communities.

Soil Searching: The Hidden Crisis of Soil Health in the Asia Pacific

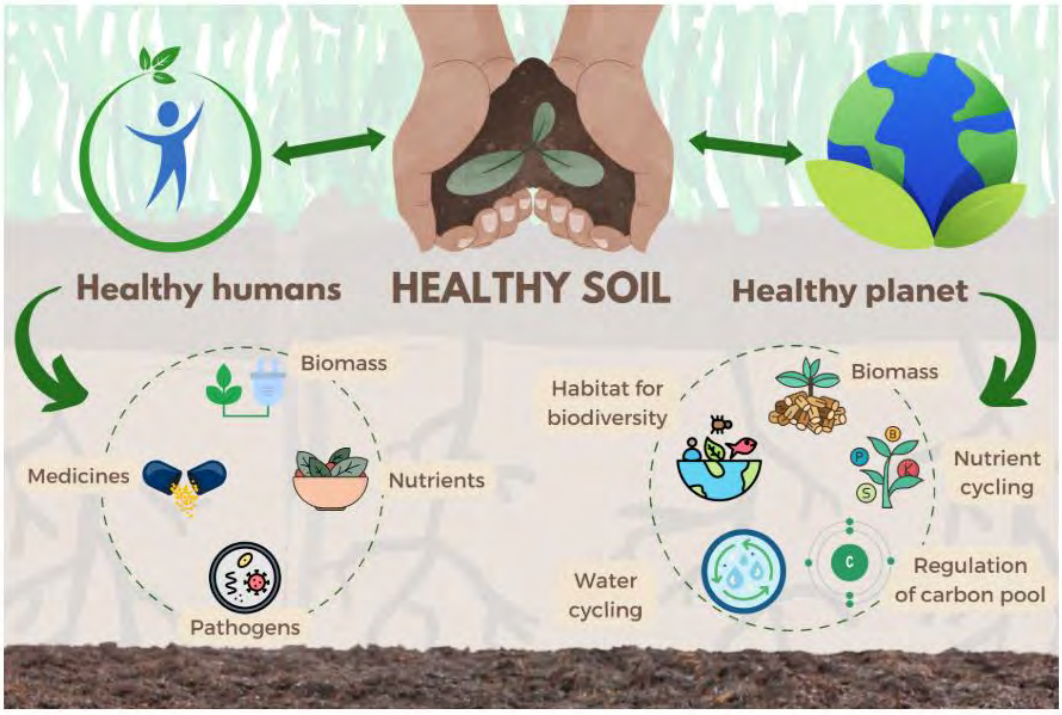
Earth Journalism Network
Sam Schramski
27 September 2024

Soil health in the Asia Pacific is under threat from climate change, pollution, and poor land management, jeopardizing food security and biodiversity. Traditional practices and innovative solutions offer hope.

An inch of land is worth its weight in gold. — Vietnamese proverb

Soil is a subject beset by cliches: It's beneath our feet. It's the world's dirty little secret. It's where everything gets muddied. But it's also the stuff of life—a substance (or collection of substances, rather) that has supported the staff of life for thousands of years. And it's in peril.

Dirt, while often overlooked and nigh-invisible, has been fundamental to humanity and its place on Earth. Grade school children are often reminded that the world is 70% water—mostly found in the ocean—but even though soil only covers about a tenth of the planet's surface area, it stores a biochemical pump that feeds billions of people and prevents harmful greenhouse gas emissions from escaping into the atmosphere. There are several other benefits of



Healthy soil is inextricably tied to healthy people and a healthy planet (graphic based on Kopittke et al. 2023) / Credit: Michael Salzwedel.

healthy soil, too, ranging from its natural medicine cabinetry (many antibiotics are earthen in origin) to flood prevention.

As the UN Food and Agriculture Organization (FAO) notes, a single gram of soil can harbor millions of tiny invertebrates and thousands of different bacterial species.

However, climate change, industrial pollution and land-use changes like mining and deforestation are disturbing dirt throughout the planet. These stresses negatively impact soil health, leading to a decline in biodiversity and essential functions like nutrient cycling, carbon storage, and water regulation—that is, processes that keep Earth thriving. And when multiplied, the consequences may be even more dramatic.

Soil degradation often tops this grim list—a third of the world's terrenity is degraded, after all, jeopardizing our ability to breathe, eat, drink, and generally be healthy. Global soil degradation is projected to increase by almost 50% by 2070, costing the world more than a projected US$600 billion. The Intergovernmental Technical Panel on Soils identifies soil erosion as the gravest threat here, impacting water quality and crop yields.

Salt-affected soils, or salinization, pose another significant challenge: up to a third of the world's irrigated lands could be affected and essentially unproductive, and climate change is intensifying the threat. (Most of these fields are found in Asia.) The economic impacts of salinization alone are substantial, with annual losses potentially reaching US$27 billion per year.

Meanwhile, soil contamination has become a notable planetary crisis, with natural ecosystems showing high levels of contaminants, including heavy metals, pesticides, chemical fertilizers, microplastics and antimicrobial resistance similar to urban environments in some places. Human activities, including industrial pollution, agriculture, mining, waste treatment and disposal, fossil fuel extraction and processing and urban development and transport, are the primary drivers of soil contamination. Heavy metals such as mercury, cadmium, lead, chromium and arsenic are particularly concerning due to their biological toxicity and potential accumulation in food webs, meaning the risk to animals and humans becomes more dangerous over time.

And then there are other soil issues sinking beneath us, in some cases literally. Subsidence, or the loss of volume and depth of soil due to the movement of microbes, water drainage, drought, sand mining, construction and excessive disturbance, means entire cities and towns face envelopment.

There are more threats to soil than you might think / Credit: Michael Salzwedel.

Soil and civilization have deep roots

Healthy soils, healthy nation. — Indian proverb

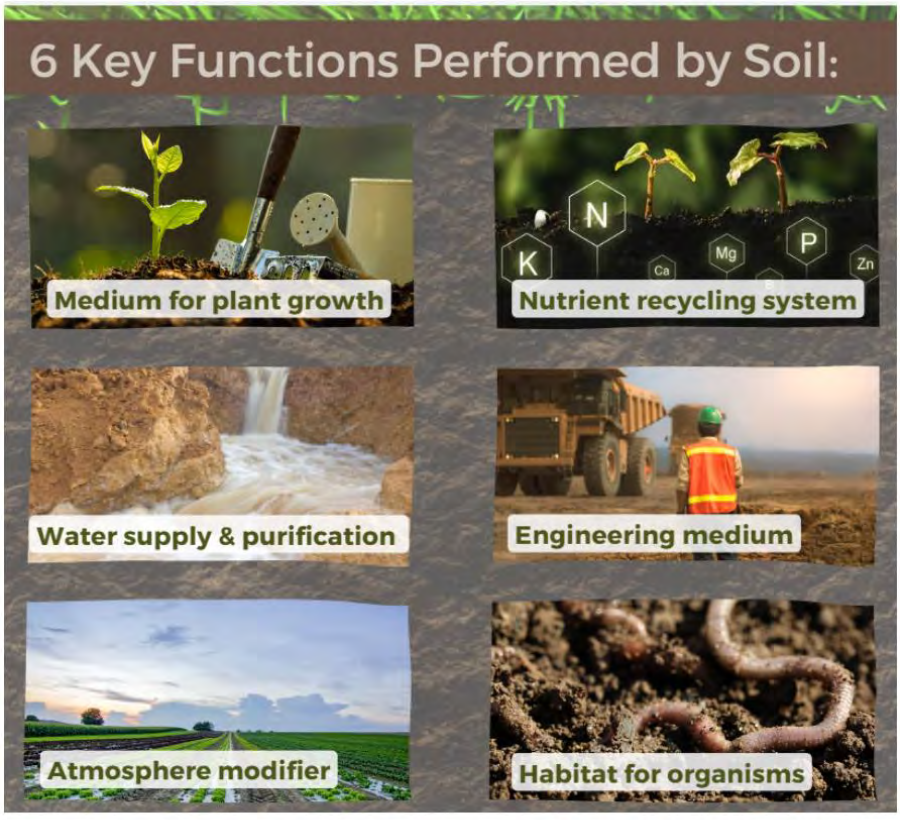
The Asia Pacific as we know it today and its neighboring regions are in many ways where the human story binds with soil. Perhaps as far back as 15,000 years ago humans domesticated cereal crops in the Fertile Crescent, which is often regarded as one of the inflection points in the development of modern civilization. And by around 9,000 BCE in modern-day China, and 7,000 BCE in the New Guinea highlands, plant domestication and the early days of the agricultural revolution were well afoot.

Our species had been building with clay and enjoying the dirt between our toes for thousands of years before these signature moments, but the wellspring of agrarian culture—and perhaps our deepest ties to soil—was a region that now boasts more than half of the world's human population and a quarter of its land area.

Soil should be on the minds of everyone in this part of the world. Agriculture represents the main source of livelihood to more than 2.2 billion people in the region, for a population that will number more than 5 billion by 2050. And yet, as recently as 2020, more than a third of a billion people in the Asia Pacific faced hunger, more than 1 billion people did not have access to adequate food, and almost 2 billion people are yet to have access to healthy diets, all according to the UN Food and Agriculture Organization.

From Nepal to Polynesia, poor soil management practices, rapid urbanization, unsustainable agriculture, deforestation, mining, and of course the climate crisis, have led to degraded soils. According to another UN study on the threats to the so-called "skin of the Earth" in Asia, roughly 21% of the total land area is estimated to have been affected by water erosion, 9% by wind erosion, 11% by chemical deterioration, and 4% by physical deterioration. Food security, biodiversity, human health and climate mitigation depend on all these figures being kept in check.

But the Asia Pacific is also a region booming with potential for solutions to heal the pedosphere (Greek for the world of soil). True, agricultural powerhouses like India and China are at increased risk from climate change and face pressure on their water and soil stocks, and to some degree both are adopting "greener" approaches to land management. But smaller countries in the region are also players. Strategies such as regenerative, climate smart and conservation agriculture are all being rolled out in the region in different ways. In South Asia, for instance, these methods include minimal tillage (that is, digging, stirring or overturning ground), increased organic amendments (substances added to soil to improve its productivity) and a more conservative application of chemical fertilizers and pesticides. These practices may increase the amount of carbon stored in the soil by almost 40%.



Soil does many things well it turns out / Credit: Michael Salzwedel.

Much of this requires rethinking the successes of the so-called “Green Revolution” —the agriculture and development initiatives rolled out in the Asia Pacific after the Second World War, which included a heavy reliance on mechanization, irrigation-dependent seed varieties and wide application of chemical fertilizers and pesticides.

However, an ideological reversal of the Green Revolution’s worst excesses may be hard to achieve for governments and farmers, even if they follow the prevailing science. Since it takes up to a thousand years for a centimeter of topsoil to form in some cases but mere seconds to destroy it, time is of the essence.

Traditional wisdom meets modern innovation

> *One’s remains decompose in the soil, but one’s good deeds are remembered.*
> — Malaysian proverb

Solutions to soil decline, which have often been overlooked by the agricultural sector, are now being revisited with urgency. Many of these originally draw upon the region’s vast repository of traditional ecological knowledge. Agricultural practices focused on increasing soil health in the Asia Pacific date back thousands of years by some accounts. Indigenous soil conservation measures in Manipur, India include the use of terrace farming with bunds, rock or tree barriers, and mulching with organic matter to prevent erosion and improve crop production. Indigenous farmers in the Sarangani uplands of the Philippines assess fertility based on visual and tactile indicators like soil color, texture, plant presence and crop growth, favoring black soils for their fertility and moisture retention, while deeming red and yellow soils less fertile.

There are many other solutions in the works in the region as well. To prevent erosion, planting specific types of vegetation has been shown to reduce the loss of quality dirt. Simple engineering proposals like contour plowing can also help conserve precious earth. Meanwhile, soil remediation is beginning to gain ground in the region, including the addition of biochar to reduce heavy metals, an uptick in phytoremediation (certain plants used to clean up contaminated sites) and the adoption of topsoil replacement techniques.

A combination of age-old techniques (see rice terraces, which have been around Asia for millennia) and modern engineering may buy some time in addressing food demands, even as human populations grow. However, the increased pressure from new mouths to feed and global commodities markets presents a significant challenge to sustainable soil management, as these techniques alone may not be sufficient to rejuvenate seemingly exhausted and unproductive land.

There are even attempts to rewrite the legal framework for soil, long-shot as they may be, which could help across the Asia Pacific. Renowned Indian-American soil scientist Rattan Lal has proposed the need for a rights-of-soil framework, not unlike much-publicized rights of Mother Nature approaches, which recognizes the role silt, sand and clay play in the lives of every living thing. “[W]e must change from the anthropocentric to soil-centric approach in developing sustainable management systems,” Lal writes, arguing that absent healthy soils, you can’t have healthy ecosystems; ergo the world can’t attain a population of healthy people. Given increased awareness of the interconnectedness of living things and landscapes in the scientific community via the concept of One Health, it certainly doesn’t seem like Dr. Lal is throwing dust in our eyes.

(There are perhaps even more optimistic efforts to assign monetary values to soil health globally as a means to show its worth in markets. But when the sums start rising to trillions of dollars, appetites for this approach begin to diminish.)

Heads out of the sand

> If you treat soil bad, soil will treat you bad.— Chinese proverb

Soil degradation, erosion, salinization and contamination—the challenges are as vast as the land itself and threaten the foundation of food systems and ecosystems. Yet, the Asia Pacific, birthplace of agriculture and staging grounds for the Green Revolution, may also be a crucible for its renewal.

Sustainable agricultural practices like minimal tillage, increased use of organic amendments and reduced dependence on chemical inputs must all be scaled up—and rapidly. Erosion control needs widespread implementation, and remediation efforts for contaminated soils should be accelerated. However, it's not just about putting the onus on overburdened farmers and other land-based people to fix the crisis. Incentives, subsidies and favorable policy environments to support these practices must be made available at scale. Perhaps most critically, the Asia Pacific requires a fundamental shift in how it views and values dirt; not as an inexhaustible resource to be exploited, but as a living system with rights that could be protected.

It's imperative that governments in the region prioritize sustainable soil management by promoting regenerative agriculture through agricultural extension programs. Policymakers in the region could increasingly develop soil-focused policies using tools like the FAO's recent Soil Atlas of Asia to combat degradation. Meanwhile, the public sector's investment in research and innovation—taking stock of what has already been successful for millennia—is essential, along with increased regional collaboration to share best practices in this dirtiest (although perhaps not messiest) of policy spheres. And, of course, public awareness campaigns should increasingly focus on the importance of soil health, ensuring food security and environmental sustainability.

After all, a region's future quite literally depends on the ground beneath its citizenry's feet.