8 Simple Steps to Healthy Crop Soil

by Larry Cooper

Decline in soil health is one of the most potentially devastating world-wide crises of the 21st century, but the average person who does not farm probably never gives farm soil a second's thought: The supermarkets are fully stocked—everything must be okay, right?

It's not. A Reuters news headline from 2014 stated, "Only 60 Years of Farming Left If Soil Degradation Continues." The article quoted the United Nations Food and Agriculture Organization (FAO) as saying that about a third of the world's soil has already been degraded from chemical-heavy farming techniques, deforestation, and global warming. It was predicted that in 2050 the amount of agricultural land, in particular, would be only a quarter of the amount available in 1960—yet we will have 2 billion more people to feed.

What can be done about it? Quite a bit, actually; though reversing soil degradation and improving soil health is going to require changes in thinking and changes in some very hard-wired cultural practices. The *8 Simple Steps to Healthy Crop Soil* that we're about to discuss are culled from a variety of farming philosophies, some as old as time itself. You can find them in modern-era discussions of Sustainable Agriculture, Regenerative Agriculture, Restoration Agriculture, and Conservation Agriculture, but they also draw from many aspects of "conventional" farming that were in place long before the concept of "conventional" included chemical fertilizers and pesticides. Most important, these steps are modeled on the practices followed by Nature itself in every undisturbed forest floor, unplowed prairie, and pristine mountain meadow.

The very best thing about the *8 Simple Steps to Healthy Crop Soil* is that these practices can be profitably applied with good results by commercial farmers (conventional *and* organic), hobby farmers, community gardeners, even the "square-foot" backyard gardeners in the middle of a city. And while geography, soil type, and soil history certainly influence how the *8 Simple Steps to Healthy Crop Soil* are implemented, implementing them all (and it has to be all of them) will lead to good results in all soil-based plant-growing situations.

8 SIMPLE STEPS TO HEALTHY CROP SOIL: A PREVIEW

Of course, you'll need to read this complete article to understand how and why each of these steps is essential for creating healthy crop soil, but here's a preview:

- ***Understand that soil is a living system.***
- ***Measure and document your soil characteristics.***
- ***Disturb the soil structure as little as possible.***
- ***Bring plant diversity to the soil.***
- ***Keep soil covered at all times.***
- ***Keep living roots in the soil all year round.***
- ***Build soil organic matter.***
- ***Have a soil health plan: Review and revise it regularly.***

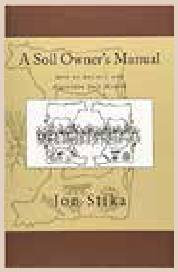
What are the benefits of healthy soil?

- *Better Yields.* Healthy soil produces more abundant crops of higher quality that are less susceptible to pests and diseases, more drought resistant, and better tolerant of wind, heavy rain, hail, heat, and all the other mayhem that keeps farmers up at night.
- *Economic Return.* In addition to better yields, crops will require less chemical input in terms of fertilizers and pesticides. This won't happen overnight, or even necessarily in the first year or two. But in the long term, growers will find their input expenditures greatly reduced.
- *A Farm for the Kids.* Restoring health to the soil in a sustainable way means that growers will leave their kids a productive, profitable farm that the kids, in turn, can also leave in good shape for the grandkids.
- *Saved Planet.* Though not necessarily our immediate goal, following the *8 Simple Steps to Healthy Crop Soil* will increase the amount of carbon sequestered in the soil and lower CO_2 levels in the atmosphere, which will help reduce global warming and give our grandkids' grandkids a decent world in which they can live and prosper.

With these impressive benefits in mind, let's dig deeper into how to create healthy crop soil.

SOIL HEALTH "MUST READS"

Many of the concepts presented in this article can be found in greater detail, with examples, in these 3 books—which are "must reads" for anyone who grows plants in soil.



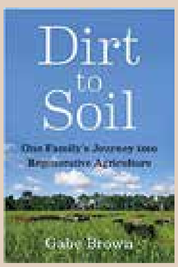
A Soil Owner's Manual: How to Restore and Maintain Soil Health

Jon Stika

CreateSpace Independent Publishing Platform; 1 edition (April 29, 2016)

ISBN: 978-1530431267

This small book (88 pages) by soil scientist Jon Stika packs in so much easy-to-understand soil science that you'll want to read it twice, just for the fun of it. This book can provide a solid knowledge foundation for all of your DIY soil-related farming and gardening projects.



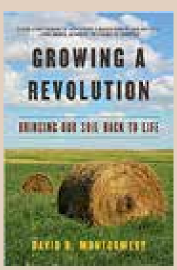
Dirt to Soil: One Family's Journey Into Regenerative Agriculture

Gabe Brown

Chelsea Green Publishing; 1 edition (October 11, 2018)

ISBN: 978-1603587631

Gabe Brown takes us on his fascinating yet ultimately very practical journey of discovering how a focus on soil health can lead to economic success for a working farmer and rancher.



Growing a Revolution: Bringing Our Soil Back to Life

David R. Montgomery

W. W. Norton & Company; 1 edition (July 10, 2018)

ISBN: 978-0393356090

Geologist David Montgomery gives us a historical perspective on soil health, then takes us around the world to show us how specific soil practices can restore fertility, feed the world, improve the environment, and help individual farmers return to profitability. For a deeper dive into understanding soil microorganisms, read another of Montgomery's books, *The Hidden Half of Nature: The Microbial Roots of Life and Health*.

What Is Healthy Soil?

One of the great misperceptions about soil is that it is simply an inert medium that provides structural support for plant roots and serves as a reservoir for holding water and fertilizers. Those functions are certainly important, but it is a very passive view of what soil actively does for growing plants. Maybe part of the perception problem is that in recent years we've become so used to working with degraded soils that we no longer have an appreciation of what healthy soil can be.

From a wide perspective, a farmer's main job is to harvest energy from sunlight and convert it to food for humans and animals. We use plants to do that, but we often overlook the fact that plants evolved over millions of years before farmers were around, and they have developed a lot of non-farmer partnerships to conduct their sunlight-harvesting business. In the next section we'll discuss the symbiotic partnerships plants have with many essential soil microorganisms, but let's begin with a discussion of plants' physical soil habitat.

We're all familiar with the soil physical characteristics of sand, silt, and clay—which have different particle sizes. Soils made up of different combinations of those three components have different capacities for holding water and air, holding and releasing mineral nutrients, and allowing water infused with nutrients to travel through it to plant roots. Healthy soils are typically composed of 50% minerals (sand, silt, and clay), 25% water, 15% air, and less than 10% organic matter.

Soil organic matter is formed from the residues of decayed plants, roots, and animals (including microorganisms, which can make up 80% of soil organic matter). Soil organic matter holds water and nutrients, prevents soil-surface crusting (which impedes water infiltration), and helps soil to resist compaction (which destroys air pockets and those channels through which water, nutrients, and microorganisms flow). It is estimated that soil organic matter controls up to 90% of soil functions for plant growth, which is why percentage of soil organic matter is often used as a proxy measurement of soil health. As soil organic matter increases from 1% by weight to 3% by weight, the water-holding capacity of the soil doubles. North American farmland soil organic matter percentages have dropped from a pre-farming high of about 6% to current levels of 3% or less, sometimes much less.

Important to many soil functions are soil aggregates—those irregularly shaped, (hopefully) water-stable, sticky clumps and crumbs of soil that, when congregated, provide the channels through which roots, microorganisms, water, and nutrients move. Without soil aggregates—which, as we will discuss in more detail later, are formed by plants and microorganisms and are destroyed by tillage—water will not infiltrate, nutrients will not move, microorganisms will not travel, roots will have reduced capacity to seek out nourishment, and there will be no spaces to hold the oxygen that microorganisms require. It is the aggregates that hold most of the soil organic matter and provide a habitat for essential soil microorganisms.

When managing soil as a biological system, it is important to understand that carbon is much more important than nitrogen, phosphorus, or potassium. It is often said that carbon is the energy currency of soil because carbon feeds the soil food web. Through the process of photosynthesis, plants exude carbon through their roots to feed supportive microorganisms. Carbon is also supplied through plant and animal decay and is present in humic substances that are formed from plant and animal decay. When soil contains enough carbon, well-fed soil organisms cycle nutrients and efficiently supply them to plants with little "leakage" to the atmosphere, surface water, or groundwater.

Step 1. Understand That Soil Is a Living System

Good farmers farm crops, great farmers farm the soil. What this means is that soil is a living system and has to be managed as a living system in order to grow great crops. Soil is alive with organisms that have evolved symbiotic relationships with plants over millions of years. It's estimated that 95% of all life on land resides in the soil. Crop soil can be a particularly good home for these microorganisms and, though largely unseen and unsee-able by the naked eye, they congregate there in almost unimaginable numbers. A handful of crop soil can contain more microorganisms (microbes) than there are people on earth. An acre of farm soil has a microorganism biomass of over 2,000 pounds! That is a whole lot of extra hands (or to be more bluntly precise, mouths and digestive systems, acids, and enzymes) that a farmer can put to work on a crop if they are properly managed. In the business of agriculture, understanding how the microbial community of a crop field (the "microbiome") works and leveraging that understanding into practical application will often mean the difference between success and failure, between profit and loss.

Soil microbes largely consist of bacteria, fungi, protozoa, and nematodes, plus an assortment of yeasts, algae, archaea, and others. While in the past these little critters were globally associated with "germs and pests that should be killed," in recent years we've come to realize that the majority of them (perhaps as high as 98%) have helpful jobs to do and positive, interconnected roles to play in crop and soil health; they should be allowed—even encouraged—to exist. Killing off the microbiome, as is often the practice with soil fumigation before growing some specialty crops, simply reduces available plant nutrients and other benefits the microorganisms provide—and makes the plants more susceptible to pathogens when they come back to the soil (and they will come back) without healthy competition.

The complete list of benefits provided by soil microbes is too large to fully describe in this article, but here are some of the major examples:

- Breaking down plant and animal matter into humus and releasing minerals in soluble forms that are easier for plants to absorb.
- Bringing nutrients into the soil from the atmosphere (nitrogen fixation) and from locked up mineral reserves that are already in the soil.
- Enhancing nutrient transport, drought tolerance, and resistance to disease and other stressors through the production of antibiotics and antifungal metabolites.
- Protecting plant roots from pathogens and parasites.
- Creating conditions that improve seed germination, transplant survival, and root growth.
- Stimulating plant growth through the production of hormones.
- Holding soil aggregates together while increasing porosity, creating channels through which roots can

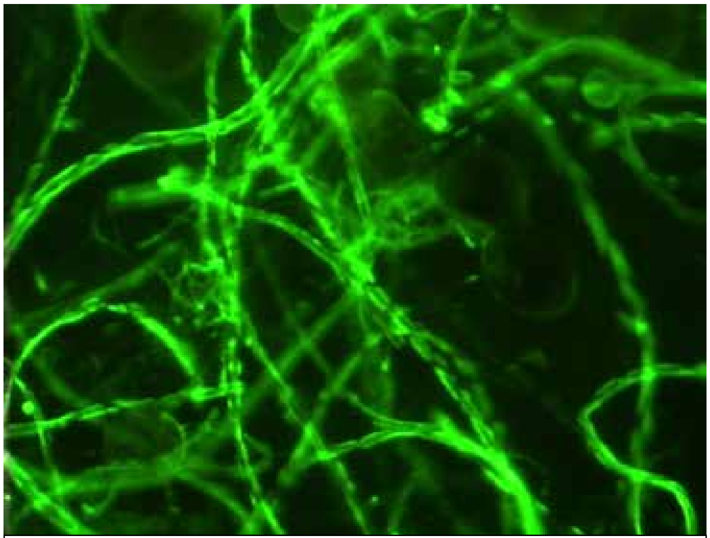
grow and water can flow—increasing infiltration and reducing runoff.

- Degrading soil pollutants.

Why are microbes so helpful to plants? They work for food. Through millions of years of evolution, plants have learned to feed supportive soil microorganisms by producing root exudates (substances secreted by roots) of carbon—created through photosynthesis—in the form of carbohydrates: a typical plant can give up 25%–45% of its total carbohydrate reserves to feed its microbes. In return, microbes provide plants with all of the benefits listed earlier, and more. This symbiotic relationship can be fragile, though, easily disrupted by common farming practices such as tillage, soil compaction, and heavy use of chemical pesticides and fertilizers.

Soil bacteria, in particular, play many important roles in soil health. They decompose organic matter, consume carbon compounds, improve soil structure and soil micro-aggregates, recycle soil nutrients and convert atmospheric nitrogen into plant-available nitrogen, and can alter soils to benefit certain plant communities as soil conditions change.

Another category of microorganism that deserves special attention in any discussion about crop soil is mycorrhizal fungi. These fungi colonize plant roots and send out their very long, very thin strands of hyphae (threadlike branches) that actively function as root extenders. These thin strands can travel through much smaller soil openings than plant roots can, well beyond the nutrient-depletion zones that normally develop around plant roots. In exchange for plant carbohydrates, mycorrhizal fungi can explore up to 100 times the volume of soil that plant roots can. A single hyphae can be several meters (yards) long, and a teaspoon of soil can contain up to 0.8 kilometers (½ mile) of fungal hyphae, bringing back water and mineral nutrients that the plant by itself would not have been able to access with its shorter, thicker roots. Not only that, mycorrhizal fungi create a network of connections with other plants and other fungi.



Mycorrhizal Fungi—*Thin, threadlike strands of mycorrhizal hyphae from pot cultures have an abundant amount of glomalin, seen on their surface as bright green spots here after a laboratory procedure.*
—Photo by Kristine Nichols, courtesy of USDA ARS

In addition to outreach and transport, mycorrhizal fungi produce compounds that can break the chemical bonds of inorganic nutrients that are bound up in organic matter and clay, releasing them for plant use. Perhaps their greatest contribution, though, is their production of glomalin. Glomalin is a kind of carbon-holding glue, a sugar protein, that mycorrhizal fungi produce to coat and seal their hyphae so that water and liquid nutrients don't leak out during transport back to plant roots. A very important side benefit of glomalin is that it's the stuff that helps bind soil particles into those important, essential soil aggregates discussed earlier. Its wax-like property helps the aggregates to remain stable when water flows around and through them. Glomalin allows air to pass through, an essential function that reduces air pressure in the voids and helps keep aggregates from breaking up. As old hyphae die off, the carbon in the glomalin coating eventually returns to the soil, providing another carbon source for the plant-soil-microbe food web.

Microbes are not the only essential organisms in healthy soil. Another biological indicator of healthy soil is the presence of earthworms. Earthworms eat bacteria—along with fungi, other microbes, and the organic matter they live in. Earthworms are not typically attracted to unhealthy soil (Why go there if there is nothing good to eat?), so an increase in a soil's earthworm population is usually an indication of improving soil health. Earthworms themselves contribute to soil health in a number of ways. Of course, there are the tunnels they create as they eat their way through the soil—which aerates the soil, helps water to infiltrate, and helps nutrients to move with that water infiltration. But even more important are the castings they leave behind (vermicastings, also known as worm poop), which can be 50% higher in organic matter than the surrounding soil. The earthworm digestive process (which relies on bacteria) also unlocks many of the chemical bonds that normally keep nutrients tied up in the soil. Vermicastings are rich in plant-available nitrogen, phosphorus, potassium, magnesium, and calcium, making earthworms free fertilizer-dispersing machines. Though earthworms will burrow down as much as 12 feet (4 meters) if the soil temperatures are too warm, they prefer to spend their time in the top 6 inches (15 cm) of soil, putting fertilizer exactly in the root zone.

Step 2. Measure and Document Your Soil Characteristics

One of the well-worn mantras of many college business classes is, "What gets measured, gets managed." This is also becoming increasingly true in the farming business, and measuring soil characteristics should be right at the top of every farmer's measurement list. If you are a commercial farmer, you will definitely want to work with a professional laboratory to have your soil analyzed, but—commercial or not—there are also some simple tests that you should periodically conduct and document yourself to establish a more personal connection to the soil changes you are trying to influence.

Commercial Lab Soil Tests

Standard commercial lab soil tests are going to report on a soil's texture, pH, electrical conductivity (EC), and some measure of sodium (salt). These tests will also give percentages of macronutrients such as nitrate-nitrogen, phosphorus, potassium, calcium, and magnesium. These are helpful things to know about farm soil, but they don't offer much information about soil health.

If available, you'll want to request that your lab conduct some advanced testing such as a Solvita or Haney Soil Health Test (or something similar) that determines total soil organic carbon (SOC) and total organic nitrogen (to determine a C:N ratio), along with a 24-hour CO_2 soil respiration test to estimate microbial biomass. Tracking changes in SOC and microbial biomass over time are great indicators of soil health improvement (or decline).

Do-It-Yourself Soil Tests

To really develop a personal relationship with your soil and understand changes that are (or should be) taking place, you're going to have to get your hands dirty. A couple of times a year, every year, you should go out into each of your fields and conduct (and document) the following activities:

- The Grab, Examine, and Squeeze Test—Reach your hand down and push it into the soil. Can you? If not, why not? Is the soil too hard, too compacted, too dry, too rocky? If you can't push your hand into crop or garden soil, you already know you have soil health problems because healthy soil is going to be soft enough and resilient enough to allow you to push your hand in. If you need to use a spade (and some force) to get a handful of soil, do so. What color is the soil: black (great!), brown, tan, gray? Can you see bits of decomposing organic matter? Now, with soil in your hand, squeeze your hand into a fist and then open it. What happened to the soil? Did the soil crumbs hold together (good), or did the structure shatter into loose particles?


Soil Probe

- The Smell Test—With that soil still in your hand, bring it up and cup your hand under your nose: What does the soil smell like? If it has no smell at all there are probably very few living microorganisms in it. A healthy soil should smell slightly sweet with a distinct, earthy aroma (caused by bacteria known as actinomycetes) or perhaps have a mushroom/compost smell (from fungi). A soil that smells like rotten eggs (hydrogen sulfide) is out of balance with too many anaerobic organisms. A soil that smells metallic or like kitchen cleanser is out of balance with too many bacteria. If your soil just smells of pesticides or other agrochemicals—or has no smell at all—your microorganisms are probably dead or dying.
- The Water Infiltration Tests—There are 3 approaches here:
  - *Soil probe*: Everyone who grows in soil should have a soil probe. This is typically a 3–4-foot metal rod (like rebar) with a 1/4" to 5/16" diameter and a

T-handle at the top. About 30 minutes after a good rain or irrigation, press the tip of the probe into your soil and lean your weight into it: don't hammer it in. How far into the soil does the probe go? It will go as far as the water has infiltrated. If the soil is crusty and water is just running off the top, you may not even get the probe in an inch. Ideal is for the probe to penetrate at least past the root depth of whatever you are planting. For shrubs, you want at least 2 feet of penetration; for mature trees you want at least 3 feet of penetration.

– *Bottomless-can*: Take a large coffee or similar can and cut the bottom out of it. If your soil is soft enough, push the bottomless can down into the soil at least 3 inches. Add an inch of water and measure how long it takes the water to completely infiltrate into the soil. When the first inch is gone, add another inch of water and time it also. This second inch will tell you how well water infiltrates after the soil surface is wet. If the second inch of water takes more than 30 minutes to infiltrate, then you have a problem.

– *Dug-hole*: If your soil is not soft enough for the can method above or you don't have access to a large can, dig a hole of a set depth and width (such as a foot square, so you can replicate it next time). Add a measured amount of water to the hole and record the time it takes for all the water to infiltrate. If all the water goes into the soil immediately, the soil may be too sandy for growing. If, after an hour or so, most of the water is still standing, then you probably have a water infiltration problem. Note that this test does not give information about permeability of the soil surface as the previous "can" test does.

– Remember, it's not how much rain you get or how much irrigation you provide, it's how much water goes into the soil and stays available for your plants. As you build up the organic matter in your soil, water will move into it more easily and stay there.

SOIL TILTH: WHAT'S IN A PHRASE?

"Soil tilth" is a generic phrase that is used to describe how good a soil is for growing plants. The phrase originally evolved to describe a soil quality in terms of how easily it could be tilled (plowed). These days of "no-till" farming doesn't mean we throw the phrase out, we just need to adapt it to describe a soil quality in which biological tillage (by our microorganism helpers) is easily accomplished.

- The Aggregate-Holding-Together (Slake) Test—In earlier sections of this article, soil aggregates, how they are formed, and their importance to soil health were discussed. Take a clump of soil from a field and set it aside in the sun to air dry for a day or so. You can conduct a simple slake test by filling a see-through container with water and then dropping in the dried soil clump. If your soil has good water-stable aggregates held together with fungi-produced glomalin (typical of high-organic-matter, no-till soil), the aggregate will hold together even after an hour in the water. If it doesn't have water-stable aggregates (typical of low-organic-matter, tilled soil), the soil clump will rapidly disintegrate. (A good video example of USDA-NRCD Agronomist Ray Archuleta conducting a slake test and a rainfall infiltration test is at https://youtu.be/CEOyC_tGH64.)
- The Earthworm and Macroorganism Test—(Note: Earthworms are most active in top soil in the spring and fall.) Dig up a square foot or so of soil and set it in a box. Break it apart. Are there earthworms? How many and what kind? What other kinds of life do you see? It was mentioned earlier in this article that the presence of worms is, in itself, a proxy measure for good soil health because they won't stay if the soil is not healthy for them (and healthy for them means healthy for crops).

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Services (NRCS) offers a Soil Quality Test Kit that describes 12 on-farm tests with procedures, interpretations, and data collection sheets.

Important with both the laboratory soil tests and the DIY soil tests is to conduct them in a consistent way at the same time of year and crop stage and to document them in a way that allows you to compare changes over time. This will be a key component of developing and implementing a Soil Health Plan, which we'll discuss later in Step 8.

Step 3. Disturb the Soil Structure as Little as Possible

Tillage, soil compaction, and heavy use of chemical pesticides and fertilizers are common practices that are the most destructive of soil biology and soil structure, so let's examine each one in some detail.

Tillage

Mechanical tillage, or plowing, has been seen as an essential agricultural practice for over 7 thousand years. Plowing is so much a part of the popular farming ideal (there's a plow depicted on the seal of the United States Department of Agriculture, for heaven's sake—see illustration at right) that people are often surprised to learn that there is no scientifically proven farming benefit to be gained from it.

USDA Seal

Mostly, farmers plow because farmers have always plowed. When pressed, they will say that they plow to open up the soil for water infiltration (false: it can actually result in a soil crust or hard pan that prevents water infiltration, leading to runoff and soil erosion), to control weeds (false: it creates more opportunities and better conditions for weeds to grow, exposing weed seed to light and water, spreading them around by machine, and providing weed seed with additional soluble forms of nitrate nitrogen as microbes die), or because it breaks up the soil so crop seeds have an easier time getting established (true: it breaks up the soil—which is actually a bad thing, but false: it does not make germination or initial plant growth easier). Plowing at the same depth year after year can also create a hard pan at that plow-depth that will interfere with root growth and water movement. (Sometimes plowing is necessary to rip up the hard pan that previous plowing created.)

The most destructive thing about plowing is that it destroys soil aggregates. With a little wind, unprotected organic matter and the soil itself can simply blow away (e.g., the Southern Plains Dust Bowl of the 1930s). A further complication is that with the soil aggregates broken, the next rain or irrigation will flow small soil particles into position to plug up the aggregate-created soil channels that previously allowed water to infiltrate, and the water will run off the top of the soil and not into the soil. With the soil channels plugged, soil can also become anaerobic, which disturbs the healthy microbial balance and breeds microorganism types that are not beneficial for growth and may even be pathogenic to crops.

If all that isn't bad enough, plowing also rips apart all those mycorrhizal hyphae networks that were described earlier as important root extenders that provide more water and nutrients to plants.

In short, plowing is a wrecking ball that destroys a soil's microbial habitat and disrupts the symbiotic plant/microbe relationships that have evolved over millions of years. For no benefit.

Without plowing, how can farmers get seeds into the ground? As more farmers discover the benefit of a no-till approach, the agricultural implement and machinery industry has responded by producing no-till seed drills that literally slice a shallow groove into the soil at a set depth to insert and then cover up seeds with very little soil disturbance. Soil structure is left intact and the microorganism plant-assistance factory remains open for business.

Soil Compaction

Tractors, plows, and other farming equipment are heavy—heavy enough to compress the soil under their tires and collapse air pockets and water infiltration channels. The fewer the passes a farmer makes over a field with heavy equipment, the more functional and the healthier the soil will be. This may not seem like a big deal, but tractor paths through fields can often be easily identified by the sparse vegetation that grows there later. If it is necessary to bring heavy equipment into a field, don't drive over the same tracks year after year: vary the tracks and direction (e.g., horizontal one year, vertical the next).

Chemical Disruption

Chemical fertilizers originally became so widely used because they could increase yields on depleted soils. What is not widely understood is that heavy use of chemical fertilizers will further degrade soils by disrupting symbiotic plant-microbial relationships. With nutrients immediately available, plants no longer need to put out carbon root exudates to attract microbes. When the exudates stop coming, microbes die out or go looking for food elsewhere and stop producing all those plant benefits described earlier. When the microbial population declines, soil structure declines—which leads to less water and fewer soil nutrients for plants, creating a situation in which farmers have to apply even more chemical fertilizers to keep yields up. As this cycle of diminishing returns continues, farmers are forced to spend more and more money on inputs to get acceptable yields—which reduces the economic value of the farm.

Excessive use of chemical fertilizers can create deadly salt stress on sensitive microorganisms, particularly bacteria, by extracting fluid from their cells through osmosis.

Chemical pesticides are even more destructive to soil health. Poisons of any sort are going to kill or impair those tiny microorganism life forms, disrupting the plant-microbial relationships that have developed in soil over millions of years. Nature is supremely adaptable to coping with intermittent stresses, but being pounded season after season with unnatural stresses will have a lasting effect. The widely used herbicide product component glyphosate, in particular—which is also registered as a biocide and a chelator—is suspected of killing off soil microorganisms and of tying up soil nutrients so that plants can't use them.

Can commercial farmers survive without heavy chemical fertilizers and pesticides? They can, and many now are. As soil health improves, plants will be healthier and more resistant to pests, pathogens will be largely excluded through competition with beneficial microorganisms, and weeds will have less opportunity for growth as they are crowded out by cover crops. Chemical nutrients will become less needed as the soil itself becomes more plant nutritious. Nature will provide if you work within Nature's way (and don't get *in* the way).

Step 4. Bring as Much Plant Diversity as Possible to Your Soil

Plants feed soil microorganisms, and the types of plants in the soil determine the types of microorganisms that will dominate the soil microbiome. A mono-crop will severely limit the types of microbes that take up residence (and will encourage a microbial imbalance that allows pathogen populations to take hold), while a diverse array of plant types will attract a diverse array of microorganisms. Mixing in different plant functional groups (forbs [herbaceous broadleafs], grasses, and legumes) results in the production of different root exudates at different root depths that really stimulate diverse microbial populations and accelerate production of all those soil-health benefits discussed earlier. As with humans, microorganisms are just plain healthier and better able to do their work when fed a diverse diet.

Rotating two mono-crops in a field has some benefit in terms of reducing pests and nutrient depletion, especially if the crops come from different functional groups such as corn (a grass) and soybeans (a legume). But this brings nowhere near the benefit of planting a multi-species mix of plants that are all growing around each other in the same space at the same time. Some farmers are now experimenting with multispecies mixes of 6 or more—sometimes as high as 60—plants. Season-appropriate plants (think warm- and cool-season broad leaf plants and warm-and cool-season grasses) of different types with different leaf sizes and above-ground heights are going to much more efficiently harvest sunlight and, through photosynthesis, pump more carbon into the ground—creating a very attractive, super-charged environment for diverse microbial growth.

Implementing 3-year and 4-year rotations can show even greater benefits than 2-year rotations. An 8-year study at Iowa State University (Liebman, et al.) compared corn-soybean with corn-soybean-oat and corn-soybean-oat-alfalfa rotations. Researchers found that corn and soybean yields improved in the 3- and 4-year rotations, with the greatest increases (3% for corn and 17% for soybeans) in the 4-year rotations. There was reduced herbicide and N-fertilizer use, reduced disease susceptibility, reduced soil erosion, and improved soil health. Soils in extended rotations tested higher for organic matter and microbial biomass, providing crops with the highest amounts of usable nitrogen.

A very effective approach to a 3- or 4-crop rotation is to grow all the crops at once in different fields, but rotate the fields every year. This helps reduce risk from pest infestations, market-price declines for particular crops, etc.

One of the microbial benefits mentioned earlier is that microorganisms break down organic matter into humus, which is an organic carbon that has high cation-exchange and high water-holding capacity. When humus is produced over a wide range of soil depths, water and nutrients are better held in the plant-root growing region (not leached away)—which in turn protects the watershed and protects freshwater and marine areas near, and sometimes even far away from, the farm.

What happens when the multispecies cover crop season is over and it's time to plant the cash crop? Most of the time growers will either cut it down or roll it down and leave it (with roots still in the soil) as a mulch to break down into the soil as a green manure, or if the plant height allows they'll simply seed the cash crop right into it, letting the seeds take advantage of established microbial systems and fungal networks to get them up and growing.

An additional benefit of having a root microbiome that is well supplied with carbon from decaying organic matter and exudates from multispecies plant roots is that the cash crop planted in the field later will have a better and more available supply of nutrients and beneficial microbial metabolites. Other benefits for the cash crop include less need for chemical fertilizers, pesticides, weed control, and irrigation—saving money for the farmer.

Video Link: USDA NRCS—Under Cover Farmers

Step 5. Keep Living Roots In the Soil All Year Round

Farmers have been implementing crop rotations for about as long as they have been plowing their fields. One of the unfortunate crop-rotation practices adopted early on was the idea that one of the rotations should be a fallow (unplanted) period so that the soil can "rest."

This is a man-made practice that is not found anywhere in Nature. Without living roots in the soil, soil microorganisms become starved for food—which, if it doesn't kill them entirely, at least slows down all the work they do to keep the soil healthy. How can this be good for plants? It can't: there is a well-documented phenomenon called "fallow syndrome" in which the crop planted in a recently fallowed field has reduced yields.

When soil is viewed as a living system, it makes no sense to starve it for extended periods. Farmers in climates that have winter seasons that preclude a cash crop strive to get a winter cover crop planted that will keep roots living in the soil and producing exudates to feed the microbiome for as much of the winter as possible. This enables spring cash crops to be seeded into a living, healthy soil.

Fallowed fields are also notoriously susceptible to wind and water erosion, which brings us to Step 6.

Step 6. Keep the Soil Covered at All Times

To ensure soil health, a primary goal for farm soil is that you should never see it bare. Whether through live plants, crop stubble, or mulch, keeping the soil covered is essential for soil health.

Uncovered soil quickly dries out from the wind and heats up from the sun, causing soil water evaporation that can also leave behind salt on the soil surface that will later be

Multispecies Cover Crop

detrimental to germinating seeds. The force of raindrops or hail on uncovered soil can break up soil aggregates, leaving the soil more vulnerable to water and wind erosion. If the soil gets too hot, microorganisms and even some macroorganisms (earthworms) will go dormant or even burrow deeper into the soil, disrupting their normal soil-health-enhancing work.

Keeping a protective layer of plants or plant residues on the soil also suppresses weed growth and provides a habitat for important members of soil biology that thrive on the soil surface. These arthropod "shredders" will chew up dead plant material along with bacteria and fungi, excreting valuable soil nutrients and speeding up nutrient cycling by as much as 25%.

Think of soil cover as armor that protects soil and keeps it healthy, intact, and functioning during periods between cash-crop plantings. Living plants all year round provide the best cover, but in areas that freeze in winter, a mulch of frost-killed cover crop will do the job. Even the stubble of a harvested cash crop can provide beneficial soil protection.

Step 7. Build Soil Organic Matter

Following all of the previous steps described in this article will gradually reverse soil degradation and build soil organic matter, which is probably the most important requisite for soil health. But doing it gradually can take years, even decades. What if a farm needs to speed up the process? Can it be done? Taking decades to restore soil health seems a reasonable amount of time given that the soil in a particular field may have been degrading due to farming practices implemented for a hundred years or more. But yes, there are some options to speed up the process.

Two of the most common methods used for rapidly increasing soil organic matter and improving soil biology are to add compost or to add humic substances. There are pros and cons with each.

Compost that is created on or near the farm from local source materials and using local microorganisms for the composting process is always the very best approach, when possible and practical. However, though home-made compost is rich in organic material, it is labor intensive and requires very large amounts (up to 5 tons/acre). A benefit is that the microorganisms responsible for composting the source material can travel along with the compost into the field. If compost is purchased rather than made on the farm, it can be difficult to know exactly what went into the making of it. If manures were incorporated, there may be undigested weed seeds and harmful bacteria present. Grass clippings may contain herbicides. Carbon and nutrient content will vary quite a bit depending on the source of the composted materials. Compost is bulky and can be difficult to transport and apply—and it can only be applied during times when crops are not growing in the field. Once applied, it may take further years to decompose before it fully adds to the soil humus. At an average cost of $60/ton, it can cost about $300/acre to apply (before transportation charges, if any).

Humic substances on the other hand (technically humic and fulvic acids) must be mined and purchased. As a residue of plant and animal matter that has been created over millions of years (from heat and pressure, much like coal), humic substances contain high amounts of carbon and nutrients and will add directly to soil humus. Liquid versions can be applied at any time during the crop season, and liquid or dry material will be relatively sterile in terms of bringing along additional microorganisms. Research has consistently shown that humics improve root mass and growth, enhance nutrient availability and uptake, and contribute to higher crop yield and quality. Though more expensive than compost ($500/ton), much smaller amounts per acre are required (150–200 lb/acre), resulting in a much smaller cost per application of about $50/acre.

Dry Granular Humic Acid

Step 8. Have a Soil Health Plan: Review and Revise It On an Annual Basis

Earlier, it was mentioned that "What gets measured, gets managed." Developing a soil health plan is the "management" part. Every step of this *8 Simple Steps to Healthy Crop Soil* is important, and each must be carried out within the framework of treating soil as a living system AND in terms of the unique conditions of the soil being managed and the farmer doing the managing. Adapting specifically for the planned cash crop will steer all the steps: Which crop rotations will most benefit the cash crop? Which cover crops will provide diversity in a way that is most supportive of the cash crop? How degraded is the soil? How long can you afford to take to build up the soil organic matter? How much soil lab testing can you afford? What equipment do you own or can you rent or borrow to manage the fields without traditional plowing? Where can you most economically purchase the right multispecies cover-crop seed? Are there markets for the cover crops? Do you have or can you rent or borrow the right equipment to terminate the cover crop and return it to the soil? Most important, are there any local or state-based knowledge sources (university ag programs, extension agents, peer associations, etc.) that will help you make decisions and provide support as you go down this new path?

If you have livestock, make sure to read Gabe Brown's book, *From Dirt to Soil*, for suggestions on how to incorporate livestock management into your soil health program. He makes an excellent case for how proper management can benefit both the soil and the livestock and bring an economic benefit to the farmer as well.

Growers who have gone this direction will caution that it is best to take small steps at a time. Crops in degraded soils will likely be fertilizer dependent, so it is best to cut the fertilizer programs back a little at a time as you gradually build soil organic matter. Pesticides can be cut back more, but this may be determined by what your neighbors are doing. You don't want your fields to become the local "safe buffet" for all of the pests that have been chased out of surrounding fields. Give the soil some time to build up its defenses and to build up the defenses of the plants they support. Most of the growers who have followed this type of plan report that over a period of years they have been able to cut back on their chemical fertilizers and almost eliminate pesticides, but they do it after careful observation and with measured application.

A Soil Health Plan should be developed and written down (not just kept in your head). Identify a specific place where you are going to keep your Soil Health Plan (a ring-binder in your pickup cab or on your desk, a particular folder in your computer); determine which measures and observations you are going to document and where and when you are going to document them; and pick a specific annual date for when you are going to review the plan (for example, the day after the New Year, the day after Valentine's—any day that you will remember from year to year and that is early enough before spring planting to allow you to implement any new decisions you make).

Each year when you review the Soil Health Plan, you should have collected enough information from the past year that will call for revising the plan. Is your soil organic carbon increasing? Did the cover crop perform as you had hoped? Did the cash crop yield stay within acceptable parameters? Did you apply compost or humic acid to increase soil organic matter? How did that work out? Is it time to cut back a little on the nitrogen? Are your crops getting enough micronutrients? Has soil erosion decreased? Has water infiltration increased? Have you been able to cut back on irrigation? Write down these observations and go back and review the previous year's (and the several years before that) when it is time to write up the Soil Health Plan for the upcoming year. Do you have a trusted crop adviser that can also look over your Soil Health Plan and provide feedback and recommendations?

Most important, be patient. Implementing the *8 Simple Steps to Healthy Crop Soil* for only one year and then giving up if your soil hasn't turned around is cheating yourself and your soil. Remember how long it took for the soil to become degraded. It may take decades to bring it fully back to life, but once it's there you will have returned prosperity and value to your farm for generations to come.

Soil Health Matters

Soil health is a problem for every local farm and (whether they know it or not) for every person on the planet. It isn't something that can be ignored any longer, because the tipping point for when the problem cannot be so easily fixed is fast approaching. Where we are right now is not sustainable: food production is not growing as fast as the world's population, and, without a major change in food production capacity and distribution, humanity is at risk. Restoring crop soil health is our best hope for a sustainable solution to this problem.

This article is called *8 Simple Steps to Healthy Crop Soil*, but "simple" doesn't mean easy. Changing farming practices that have been carried out in a particular way over many generations can be very difficult. Changing these practices will require insight, courage, and patience. But the stakes are so high, not changing could be catastrophic—for each of us, for our children, and for our planet.

Bibliography

1. Arenault C. Only 60 Years of Farming Left If Soil Degradation Continues. *Scientific American.* Available at https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/.
2. Brown, Gabe (2018). *Dirt to Soil: One Family's Journey Into Regenerative Agriculture*. Chelsea Green Publishing: White River Junction, VT.
3. Jones, Christine (2015). SOS: Save our Soils. *ACRES USA; 45*:3. Available at https://www.ncat.org/wp-content/uploads/2015/08/Acres-story-for-web-posting-March15_Jones.pdf.
4. Liebman MZ, Chase CA, Johanns AM, and Sundberg DN (2013). Agronomic and Economic Performance of Thre Crop Rotation Systems in Central Iowa. *Iowa State Research Farm Progress Reports*, 1889. Available at http://lib.dr.iastate.edu/farms_reports/1889.
5. Lowenfels J, and Lewis W (2010). *Teaming With Microbes: The Organic Gardener's Guide to the Soil Food Web*. Timber Press: Portland, OR.
6. Montgomery, David R (2017). *Growing a Revolution: Bringing Our Soil Back to Life.* W. W. Norton & Company: New York, New York.
7. Montgomery, David R (2016). *The Hidden Half of Nature: The Microbial Roots of Life and Health*. W. W. Norton & Company: New York, New York.
8. Stika, Jon (2016). *A Soil Owner's Manual: How to Restore and Maintain Soil Health*. CreateSpace Independent Publishing Platform: Scotts Valley, CA.
9. USDA NRCS. *Soil Quality Test Kit*. Available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=nrcs142p2_053873.
10. What If the World's Soil Runs Out? (2012). *Time Magazine* Interview with University of Sydney professor John Crawford. Available at http://world.time.com/2012/12/14/what-if-the-worlds-soil-runs-out/.
11. Woodyard J and Kladivko E. F*our Strategies to Improve Your Field's Soil Health*. Purdue Extension, available at https://www.extension.purdue.edu/extmedia/AY/AY-363-W.pdf.

This article is brought to you by

ResponsibleAg Certified • Credentialed Auditor

BIO HUMA NETICS Incorporated

1331 W. Houston Ave. • Gilbert, AZ 85233
480-961-1220

and the BHN product brands:

HUMA GRO Plant and Soil Liquid Nutrition — **www.humagro.com**

Fertilgold Organics — **www.fertilgold.com**

MESA VERDE HUMATES — **www.humates.com**

A PDF of this White Paper may be downloaded at
https://humagro.com/8-simple-steps-to-healthy-crop-soil or
https://fertilgold.com/2019/12/05/8-simple-steps-to-healthy-crop-soil/

About the Author

Larry Cooper is the Communications Director at Bio Huma Netics, Inc., the maker of Huma Gro®, Fertilgold® Organics, and Mesa Verde Humates® crop nutrition and protection products. He is also a Certified Master Gardener.