Our understanding of soil health has evolved over the years. No longer just about fertility, attributes such as organic matter, soil aggregation, tilth, porosity, and bulk density are considered key components of healthy soil. This article describes how CCAs can help their farmer clients build and maintain healthy soils.

Soil health has been receiving a lot of attention recently, particularly with USDA-NRCS’s new soil health awareness and education effort that is widely supported by numerous groups involved in agriculture, including the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) (see sidebar on page 7). It is an ever-evolving concept that is no longer focused just on reducing soil compaction or increasing fertility. Soil scientists today are digging deeper and uncovering the secrets of high-performance soil. But what does soil health mean for CCAs and their farmer clients?

ASA and SSSA member Susan Andrews, the national leader for soil quality and ecosystems at the NRCS in Lincoln, NE, says soil health is simply the capacity of the soil to do what it is intended to do. In the context of crop production, she says, soil health falls into five key functions: Productivity, nutrient cycling to prevent nitrogen leaching, holding water for plant use, filtering contaminants, and withstanding erosion.

Those basic concepts, adds ASA and SSSA member Gary Steinhardt, a veteran soil agronomist at Purdue University, are an evolution from the old way of thinking in years past. “Traditionally, when we thought about soil quality, we would have thought about it in terms of fertility. That is, if we measured the chemical components of phosphorus, potassium, and pH levels,” Steinhardt says. “That’s still true to an extent. But there’s so much more involved in the soil. There’s something profoundly more important about what soil does in the environment than just a provision of nutrients.”

Central to today’s new concept of soil health, Steinhardt adds, is organic matter and the role it plays in creating better soil aggregation. Organic matter, comprised of decomposed plant and animal residue and other organic compounds synthesized by soil microbes, is the natural glue that holds soil particles together. That grouping of sand, silt, and clay particles into larger particles, Steinhardt explains, allows water and air to move through the soil pores while at the same time acting like a sponge to store plant-available water for later use.

CCA Norm Widman, the national agronomist for NRCS in Washington, DC, agrees organic matter is the primary ingredient for improving and maintaining soil functionality. According to NRCS, a 1% increase in organic matter equates to a 0.5 acre-inch increase of available soil water capacity, or 13,577 gal/ac of water. Widman, who is also an ASA and CSSA member, says that increased availability of water can make a huge difference—especially during exceptional drought years like 2012.

“Organic matter helps the soil function at its full potential, and I think this summer was a prime example with this drought that we went through,” Widman says. “Those soils that were in better shape were able to store and hold more available water for the crop.”

Well-aggregated soil with good tilth, porosity, and bulk density also

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allows for a more active root system that can achieve deeper penetration, adds ASA and SSSA member Mark Coyne, soil microbiologist at University of Kentucky. Plants with deeper root penetration, Coyne says, ultimately will have better access to water deeper in the soil profile and make better use of the available moisture and nutrients.

“The roots are going to grow deeper. They’re going to be more profuse, so they’ll have a better opportunity to take up those nutrients,” Coyne says. “The microbial community associated with the plant roots is also going to be able to grow better and be more extensive in terms of their distribution. Nutrients, therefore, that are added as fertilizer are going to be better used and won’t escape the rooting environment.”

As for sheer yield response? Quantifying the relationship between crop yield and organic matter has been somewhat elusive, Steinhardt says. A crop’s yield response to an increase in soil organic matter is more difficult to measure than other relationships, such as yield to fertilizer. But, Steinhardt stresses there are still clear benefits from increased organic matter with reduced erosion, greater nutrient utilization, reduced nitrogen leaching, and better water quality.

And, not every soil has the same potential as another soil, adds Widman. Getting each soil type to achieve its best potential depends on a number of environmental factors that can affect a crop’s overall performance and the economic return to the farmer.

“I don’t think we’re able to come up with that correlation yet where we can directly say that a given percentage increase in organic matter will lead to an increase of ‘x’ bushels per acre, or a reduced amount of nutrient. It’s really going to be still very climate and crop specific,” Widman says. “But, I think we will find as we start doing those things that improve organic matter and soil quality that you’re going to see better crop response with the inputs that you’re putting in there as far as nutrients.”

**Testing soil health**

What’s the best measure for soil health? A routine lab test for soil organic matter or carbon content is the surest way to gauge the quality of the soil, Coyne says. But scouting a farmer’s field will also reveal much to the physical senses when trying to determine a soil’s health. The most basic diagnostic is to simply poke the soil with your finger.

“If the soil is really, really hard or you’ve got a crusty soil that’s tough to put your finger in, that’s a bad sign. That means that you’ve got poor soil,” Coyne says. Soil that breaks apart easily in your fingers, though, will likely open up and have enough pore space for plant roots to grow through, he adds.

Looking at the soil’s color can also reveal its condition. Soils that are poorly drained will appear grayish or greenish instead of being more brown or black in color, Coyne says. And smell can also be a good indicator how well your soil is functioning.

“The soil should smell the classic earthy smell. You shouldn’t have all kinds of odors,” Coyne says. “You shouldn’t smell things that you would associate with decomposing material.”
Looking for signs of erosion and nutrient deficiency in plants is also an easy visual diagnostic that may indicate a soil in declining health, Andrews adds. But if you want a more comprehensive analysis of biological and physical measurements in addition to field observations or a routine soil test for carbon, she recommends working with the Kellogg Soil Survey Laboratory in Lincoln, NE and the soil test lab at Cornell University. Otherwise, Andrews says, a simple soil test for carbon is sufficient to measure the progress if you’re on a path to build soil organic matter.

Going so far as conducting a microbial analysis might be overdoing it, Coyne says. What’s most important is not the microbe population itself, he advises, but rather the ability of the microbe community to function.

“At the microbial scale, you’re talking on the order of tens of thousands or hundreds of millions per gram of soil. Your typical cultural test is going to give you the diversity of these organisms, but that’s not going to tell you how well the system is functioning,” he says. “So, just trying to isolate the organisms themselves is not really going to be revealing about whether or not it’s a healthy soil.”

**Building organic matter... slowly but surely**

If farmers and their CCAs have in mind a plan to increase soil organic matter, don’t expect results overnight. Building organic matter is not a quick process, says ASA and SSSA member Neil Hansen, agronomist at Colorado State University. Even increasing organic matter by a fraction of a percentage point can take years—even decades—to accomplish.

“Organic matter changes slowly,” Hansen says. “If you put a ton of fresh biomass into the soil, about half of the dry matter might be carbon, and only 10% of that carbon will end up in the long-term soil carbon pool. Most of it is going to be decomposed and go off as CO₂. So, when you compare that to the amount of carbon that was already there in that 1%, you’re adding a needle to the haystack every year.”

The biggest challenge may be for those farming in a semi-arid region where a lack of precipitation makes it difficult to produce biomass that is returned to the soil and converted to organic matter. In semi-arid environments, setting a goal to double organic matter from 1 to 2% in five years would be overly ambitious, Hansen warns.

Rather, increasing organic matter from 1 to 1.2% over the course of 5 to 10 years is much more plausible for farmers in water-stressed environments. While seemingly small, Hansen says that slight improvement shouldn’t be underestimated.

“The top six inches of an acre weighs about 2 million pounds,” Hansen says. “For a semi-arid soil with 1% organic matter, that equates to 20,000 lb of organic matter in the soil. Increasing organic matter to 1.2% is an increase of 4,000 lb of organic matter in the top 6 inches. This increase of just 0.2% represents a lot of mass.”

The ability to increase organic matter is also region specific, Andrews says. Even using the exact same system will affect organic matter over different time spans based on climate, precipitation, and soil type. In southern states in the U.S. where temperatures are warmer, for example, it may take 12 to 15 years to see a measurable difference in total soil carbon. In the northern U.S. [continued on p. 8]
Unlocking the secrets in the soil

It’s a daunting task. How do we meet the food production needs of the world’s growing population while reducing the environmental impact of production agriculture, sustaining wildlife habitat, and providing potential cost savings to producers? The key, according to the USDA-NRCS, is to improve the health of our nation’s soil.

So to help producers discover the basics and benefits of soil health—as well as ways to improve it—NRCS recently launched a soil health awareness and education effort titled “Unlock the Secrets in the Soil.” The effort is supported by fact sheets; brochures; videos; web, radio, and social media announcements; and local field days. In addition, NRCS will be making programmatic changes that will give farmers more assistance in trying the healthy soil methods on their own farms.

Soil health is achieved by disturbing the soil as little as possible, keeping it covered, growing as many different species of plants as practical, and keeping living plants in the soil as much as possible. Soil health practices, such as no-till, cover crops, buffers, etc., keep the soil in place, which improves air and water quality, reduces flooding, and enhances wildlife habitat.

“This effort will help our farmers meet current and future demands for American-grown agricultural products by encouraging good soil and natural resource practices that are beneficial to their operations,” says NRCS Chief Dave White. “We understand that soils and farms vary a great deal across the country, so our job is to provide farmers the very best information available to meet their unique needs and help their businesses thrive,” he says.

NRCS’ focus on soil health has garnered the support of farmers, businesses, and partnering agencies and organizations from communities across the country, including the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

For more information, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health.
Midwest, however, it may take only three years to experience the same increase due to differences in temperature and decomposition rates.

Whichever region you are in, the surest way to build and maintain organic matter involves two main steps: (1) reducing or eliminating tillage and (2) increasing residue.

Step 1: Reduce or eliminate tillage

Reducing tillage to the absolute minimum is the first key step CCAs need to remember when advising farmer clients on improving soil health. While not all tillage is bad, Widman acknowledges, reducing as many tillage operations as possible is always the preferred route when trying to build organic matter.

“Tillage introduces air immediately into the soil and the whole area that you tilled. That air oxidizes the carbon to CO₂, and that goes up into the atmosphere. That is carbon leaving your soil,” Widman says. “That’s not to say that you can’t do tillage. But the less tillage you do, the faster you can build organic matter.”

Coyne agrees that while some tillage may be necessary, the best way to preserve the soil’s porosity and the microbial populations needed for building organic matter is to reduce the amount of tillage. Minimizing or eliminating mechanical impact on the soil also reduces soil compaction, Coyne notes. More compaction means small pores, and smaller pores mean a greater possibility for flooding, crusting, and more difficulty in root penetration.

But tillage cannot always be completely eliminated, Hansen points out. In drier regions, some farmers have been successful with no-till while others have adopted conservation tillage that typically involves controlling weeds with chemicals during the fallow periods and doing some tillage ahead of planting to break up hardpan soils. Completely eliminating tillage when precipitation is in short supply, he warns, may increase wind erosion. When drought results in insufficient plant growth needed to anchor soil in place, high winds can remove less-dense soil constituents like organic matter, silt, and clay.

“When we get into a drought year, some of the no-till soils are a little more prone to blowing because when you have a drought failure and your residue is low, now you’ve got a flat surface and no residue. They blow a little bit,” Hansen explains, “so some farmers are managing wind erosion with some infrequent shallow tillage. To me, you’ve got to do what you can to protect against soil erosion.”

Weed resistance to herbicides can also be a barrier to adopting programs that reduce or eliminate tillage, Widman adds. Depending on the crops being grown, CCAs and their farmer clients may have a limited list of pesticides to select from to address resistant-weed issues.

“Our biggest concern is that people will turn to using excessive tillage to control the weeds,” Widman says. “And that’s going to take us down the wrong road. It may help out temporarily, but we really need to find ways to rotate crops as well as rotate modes of action of pesticides so we don’t consistently use the same mode of action and develop that resistance.”

Step 2: Increase residue

In tandem with reducing or eliminating tillage, leaving ample residue...
to protect the soil from the elements is also necessary for building and maintaining soil health. A protective layer of residue on the soil surface, Coyne says, prevents puddling during high-intensity rainfall events and shields the soil from the impact of rain drops. And, he adds, the residue will eventually be incorporated back into the soil and contribute to the building of organic matter.

“Good soil is also always going to have some sort of plant growing on top of it, whether it’s a crop or some sort of intermediate cover crop that maybe you plow in later or maybe you kill with herbicide if you’re doing no till,” Coyne says. “But the idea is that those crops are soaking up nutrients that would otherwise be lost. The residue that you would get from that cover crop is also going to eventually be turned back into organic matter, so you’re basically harvesting carbon from the atmosphere during a period when you’re not harvesting crops.”

Widman adds that incorporating high-residue crops such as corn, wheat, and rice can help increase the amount of biomass that is returned to the soil. Perennial crops such as grass and alfalfa are especially helpful in increasing residue and building organic matter, he says.

The fastest way to accelerate the rate and the amount of carbon, Andrews advises, is to rotate high-residue crops in a no-till system—and to use cover crops to keep a live root in the soil year-round to feed the soil’s food web. Recent research at the USDA-ARS National Soil Tilth Laboratory also indicates that cover crops could be used on 70 to 80% of the U.S. corn and soybean acreage to help reduce soil nitrate-N losses.

However, researchers note, cover crops have their limits. The benefits of cover crops are diminished in northern regions because of cold temperatures and frozen soils and also in drier regions west of the Mississippi River because of water limitations. Research at Kansas State University’s Southwest Research Extension Center also raises the issue of negative profitability with cover crops due to cost and reduced moisture availability for the following cash crop.

In fragile ecosystems of the semiarid western U.S. states where farmers fallow to accumulate moisture, Hansen adds that it’s a balancing act to build organic matter with cover crops and more diverse crop rotations without increasing short-term economic risk to the producer. Still, he believes cover crops have the potential to protect the soil surface, recycle nutrients, and reduce the time required to improve soil health. Finding a profitable way to incorporate them without substantially raising economic risk, he says, may require more research on termination dates and selection of species.

No matter the region, improved soil health will benefit not just the farmer, but also the long-term sustainability of the environment, according to Widman.

“In our lifetime, we only get a chance to really manage that soil and keep it healthy one time,” he says. “If we ever allow excessive erosion or compaction, we’re going to be hurt for years. So the more proactive we can be to improve and protect our soil, the more we’re going to protect the production potential of our soils. Like anything, you can screw it up really fast, but it takes a long time to fix it.”
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