21

Practitioner's Perspective

Building Resilient Cropping Systems with Soil Health Management

Barry Fisher

Why Now?

Rebuilding soil health and function are the keys to achieving optimum productivity during extreme weather patterns, addressing environmental concerns, and narrowing profit margins. As agriculture technology, scale, and specialization have increased, production has also risen to levels unimaginable just a generation ago. However, costs of production have in many cases outpaced the gains in production, thereby reducing real income. Current production systems that are typical, across the United States and other countries, include limited crop diversity; extended fallow periods that leave soil bare and without living roots; and heavy reliance on physical, chemical, and biological disturbance. The unintended consequence of these activities has been reduced soil health and associated soil functions. Most farmers have grown accustomed to decreased soil function. For example, when we get an inch of rain overnight and see ponded fields or considerable runoff, we chalk it up to "crazy weather." Actually, most soils should be able to infiltrate an inch of rain water if soil aggregates were stable in water. Among farmers and research scientists there is typically consensus that soil function and soil health indicators such as water infiltration, water availability, nutrient and carbon (C) cycling, stability and support, aggregate stability, biodiversity, bulk density, and soil organic matter are important for yield as well as economic and environmental stability. We possess adequate knowledge and skill to improve soil function.

Barry Fisher is soil health specialist and central region team leader for the Soil Health Division of the USDA Natural Resources Conservation Service, Indianapolis, Indiana. He also operates a cash grain and livestock farm in west-central Indiana.

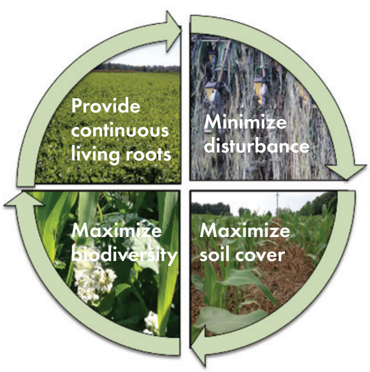
The question facing agriculture is whether the will exists to make the management changes necessary to achieve it.

Soil Health—Are We All Talking about the Same Thing?

The US Department of Agriculture Natural Resources Conservation Service defines soil health as "the *continued capacity* of a soil to *function* as a vital, *living ecosystem* that sustains plants, animals, and humans." This definition contains some key words that carry important meaning. *Continued capacity* refers to the importance of resilience through time and extreme events. *Functions* inherent to soils are extremely important for production, environmental services, and habitat for soil life. Within the *living ecosystem*, billions of diverse organisms, when they have adequate habitat, are developing the foundation of a healthy, functioning soil.

Figure 1

Soil health management principles. Image by Indiana Conservation Cropping Systems Initiative.



Soil Health Management Principles

Production systems that are managed to improve habitat for soil organisms will be necessary to capitalize on the benefits obtained from the living ecosystem. Such production systems will require consideration of how each activity may affect the soil ecosystem. Remembering four principles will help with managing to improve soil health: minimize disturbance, maximize cover, maximize biodiversity, and maximize continuous living roots (figure 1). Minimizing disturbance and maximizing cover provide protection for soil aggregates and soil organisms from degradation by wind, rain, and extreme temperature. No-till farming can be effective for implementing these two principles and can significantly slow soil health degradation. However, to rebuild soil function, C capture needs to be maximized. Maximizing system biodiversity and the presence of living roots increase the quality and quantity of C entering and being stored in the soil to serve as energy for soil organisms. Biodiversity begins with the plants and animals that live on and in the soil. Plants capture the energy from the sun through photosynthesis. Some of that energy in the form

Figure 2

Developing rhizosphere with continuous living roots. Photo by Barry Fisher.

of carbohydrates is transferred to the animals that eat plant biomass and soil organisms that congregate along the living roots to feed on exudates that leak into the rhizosphere (figure 2).

Adapting Systems for Soil Health Management

Building a soil health management system that is practical and successful for a specific region and enterprise requires understanding the adaptations necessary to achieve the soil health principles, while maintaining a profitable outcome. As tillage is reduced or eliminated, and soil cover, plant diversity, and the time live roots are present all increase, there will likely be a significant shift in the C, water, and nutrient cycles. Some of the management shifts needed to capitalize on these changes in cycling may not be intuitive to a producer moving from a full width tillage system. A step-in strategy will be needed to sustain production while building soil health. An example of a significant nutrient management adaptation involves the relationship between C and nitrogen (N). Studies have shown (Das et al. 1993) that plants obtain over half of their N from biological cycling in the soil rather than fertilizer-derived N. Under a full width tillage system, the tillage injects a dose of oxygen and exposes soil organic matter. The bacteria population explodes, respires carbon dioxide, and dies quickly, so the soil-supplied N releases in an early burst. Changing from spring full width tillage to no-till changes soil populations high in bacteria to more organisms with longer life cycles. These organisms, as well as cover crops, can tie up (immobilize) most of the available soil N early in the growing season. As soil disturbance decreases and organic matter pools stabilize, less N is available early in the season but more available later as organisms live and respire longer into the season resulting in gradual N release. This is a major change in the delivery of over half of the total N that a corn crop will use. It can have a significant effect on corn yield if timing, placement, and source of N aren't adapted to complement this transition. Some early work in the 1990s by Martens (2001) and adaptations common to successful early adopting farmers suggest that applying a higher portion of the planned N at planting time (usually as starter fertilizer injected 5 to 10 cm [2 to 4 in] beside the seed row) and using a source with nitrate, such as urea ammonium nitrate (UAN), is important to complement the changes in N and C cycles.

As cover crops are integrated into these systems, knowledge of biology and chemistry becomes necessary. Cover crop species have inherent differences in the amount of N that is stored in the tissues and thus differences in the ratio of C to N (C:N). Understanding these differences helps to optimize selection and management of cover crop species to complement the cash crop rotation. The higher the C:N, the more likely soil N will be immobilized. Therefore, a high C:N cover crop such as cereal rye is a better fit preceding a legume cash crop like soybeans. Managing for seeding windows that allow for earlier establishment of cover crop species with lower C:N ratios, such as legumes, annual ryegrass, or vegetative-stage terminated cover crop mixes, is a useful strategy ahead of grass crops like corn. By using insights like these, we can find more logical starting points and practices to initiate soil improvement.

A Farmer Transition Scenario

The following is an abbreviated example of a "step-in" scenario for a simple corn–soybean (C–SB) rotation, summarized from successful operations across the Midwest and the scientific logic from above. Start by guarding against compaction and effectively spreading crop residues evenly during corn harvest. No-till (NT) plant a cereal rye cover crop (CC) into corn stalks. It's easy to establish and easy to kill. This is the first NT operation. Next spring, NT a relatively early maturity soybean into the cereal rye; try to plant these beans early in the planting season. Early group soybeans benefit from early planting and provide a wider window to seed a favorable CC mix next fall. This is the second NT operation, and soybeans do well in higher C:N cover crops like cereal rye. Next, plant a low C:N CC mix after SB. Cover crops prior to corn should trap or produce N in the fall and early spring but release N at the optimum time in the spring/summer. Corn does well into a mix such as oats/daikon radish that winter kills or annual ryegrass/crimson clover that release the N closer to the time of greatest need. This becomes the third NT operation. Finally, NT corn into the low C:N mix the following spring. This is the fourth NT operation. By now, diverse soil biological populations and processes are well on their way. Soil aggregates are stabilizing, and pores are opening. Water infiltration and holding capacity are on the rise. Nutrients are cycling and accessible from alternate pathways. By now, you've had a full season to update your planter and attend some good soil health workshops. The result is great production potential!

Certainly, this isn't the only scenario for steps to transition, and management will need to be adaptive to seasonal conditions; however, it shows

Figure 3

Four principles of soil health supporting a living ecosystem. Photo by Barry Fisher.

the importance of having a logical process. Transition is possible without a production penalty. Numerous farmer case studies offer evidence on many soil health management systems with sound principles that provide production efficiency and higher profitability (figure 3).

This is just one scenario, compiled from practical strategies that are employed by successful farmers who use soil health management systems to continually improve soil function. Across the country, these soil health strategists are forming and joining networks with like-minded farmers, specialists, and researchers. They meet or talk regularly in farmer shops or on social media to accelerate the understanding of soil ecosystems and share breakthroughs, new practices, and technologies for soil improvement. Most are utilizing new soil health tests to monitor progress. The technology available to today's farmer makes them a very viable partner for research projects. The opportunity for the research community is to continually reset the foundation for soil health research on the management plane where top soil health farmers have already landed. Researching these dynamically managed systems won't be easy, but necessary, to help solve problems, quantify benefits, and assist with broader adoption. The time is now to capture the potential of soil health!

References

Das, S.K., G.S. Reddy, K.L. Sharma, K.P.R. Vittal, B. Venkateswarlu, M.N. Reddy, and Y.V.R. Reddy. 1993. Prediction of nitrogen availability in soil after crop residue incorporation. Fertilizer Research 34(3):209-215.

Martens, D.A. 2001. Nitrogen cycling under different soil management systems. Advances in Agronomy 70:143-192.