Understanding Soil Health

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Soils are composed of air, water, minerals, organic matter, living plant material, and organisms that support our everyday lives in ways that often go unnoticed. Soils have many functions, including a medium for plant growth, a key component of the water cycle, a habitat for organisms, and an engineering medium. These functions allow soils to provide multiple ecosystem services, particularly in agriculture where we typically think of soil as being a medium for plant growth to produce food, fuel and fiber. It provides income for millions of people.

It takes an estimated 500 to 1,000 years to form one inch of topsoil. For this reason, soil is not considered a renewable resource. On a global basis, soils are being lost due to erosion, with estimates of 20 to 30 billion tons of soil lost per year due to water erosion and at least two billion tons of soil lost per year due to wind erosion. U.S. growers lose an estimated $100 million in farm income each year due to soil erosion.

In Arkansas, estimates of soil erosion in the delta region range from one to five tons of soil lost per acre per year due to water erosion. A dime's thickness of soil eroded from an acre equals roughly 10 tons. This represents a significant loss of nutrients and our most fertile soil layer. When we take a step back and realize how much humans rely on the soil as the foundation of our lives, families, communities and livelihoods, we begin to appreciate measures to protect this valuable resource.

What is Soil Health?

According to the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS), soil health is the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans. To function properly, the soil's properties — categorized as biological, chemical or physical — must be sufficient to promote the soil-health concept.

Methods to improve soil health are not "organic" farming or "low input" farming but rather farming systems that recognize the need to view soils in a holistic manner. This means considering management practices that not only seek to optimize soil chemical/fertility properties, but soil physical and biological properties as well. While soil health means different things to different people, the act of improving soil health uses agronomic principles that most people can agree upon.

Soil health, in an agricultural setting, refers to a soil's capacity for production of food, fuel, or fiber. Increases in soil health should lead to increases in productivity or profitability of our crop production systems. The chemical, biological, and physical properties that make up soil can be divided into two distinct groups: inherent soil properties and dynamic soil properties.

Inherent soil properties are the characteristics of a soil that form over hundreds to thousands of years and are typically not influenced by land use and management. Examples of inherent soil properties include soil texture, clay type, depth to bedrock, and drainage classification.

Dynamic soil properties are chemical, biological, and physical characteristics that change with land management and cultural practices. Typical dynamic soil properties that are used to measure changes in soil health include soil organic matter, soil structure, biological activity, water-holding capacity, nutrient concentrations and bulk density. Measurements of dynamic soil properties are indicators of soil function and overall soil health. In general, increasing organic matter will increase soil health, as organic matter impacts or is related to many of the dynamic soil properties that promote soil functions and increase overall soil productivity.

Soil health is a new and emerging area of soil science that requires research and data to define how cultural management practices impact soil functionality, crop productivity and producer profitability. Key components of increasing soil organic matter and increasing soil health are improvements to soil water infiltration and soil water-holding capacity, which can lead to significant yield gains in rainfed/dryland production systems.

How will increases in organic matter impact yield in irrigated systems? Since water is not often limiting in irrigated systems, we may not see big yield increases in our Arkansas production systems. However, improved soil health that leads to increased water infiltration and water retention can mean greater water use efficiency and a reduction in input costs, leading to increases in producer profitability. Improved soil health may not always lead to greater yields but will almost always result in greater profitability.

There are three primary ways that soil health can benefit the people of Arkansas: increased productivity, increased profitability, and protection of natural resources, including air, soils, and ecosystems, as well as surface and groundwater resources.

The Arkansas Soil Health Partnership is working to answer the many remaining questions related to soil health in Arkansas. The partnership is a collaborative effort of several organizations (Table 1) to better define soil health and refine conservation practices in order to realize the potential benefits of improved soil health.

Why is Soil Health a Growing Trend in Agriculture?

Protecting the soil we have now is key to maintaining agricultural production into the future. The Soil Health Institute was formed in 2015 through a private endowment. This organization promotes national research on soil health and defining soil health metrics for a wide variety of crop production systems in the United States. The USDA-NRCS has launched a major soil health initiative, "Unlock the Secrets in the Soil," which provides financial assistance to growers to implement healthy soil practices.

Agricultural supply chains concerned with sustainability of natural resources have adopted soil health as a consideration in documenting continuous improvement. For example, the U.S. Cotton trust protocol employs metrics, many of which are directly influenced by soil health, to help farmers document and ensure sustainable cotton production.

Table 1. Organizations of the Arkansas Soil Health Partnership that are working together to define, protect and improve soil health for agriculture.

Organization	Description	Role
Arkansas Soil Health Alliance (ASHA)	A non-profit organization consisting only of agricultural producers whose aim is to educate other producers on the benefits of improving soil health.	Provides Farmer to Farmer Education utilizing their experiences in improving soil health on their farms; Leads teams of scientists and professionals in identifying soil health benefits and challenges on their particular farm.
Arkansas Association of Conservation Districts (AACD)	A non-profit organization consisting of member conservation districts who provide local leadership for soil and water conservation.	Provides coordination and planning of educational efforts for soil health in Arkansas as well as coordination of the Arkansas Soil Health Partnership.
USDA Natural Resources Conservation Service	The Conservation Agency of the United States Department of Agriculture with locations in most Counties at the USDA Service Center.	Provide Technical Assistance to agricultural producers and landowners on soil and water conservation practices. Administers financial assistance programs such EQIP and CSP for practices that improve or build soil health.
University of Arkansas Division of Agriculture	The agricultural research (Experiment Station) and technology transfer arm (Extension) of the Land-Grant University in Arkansas with local County Extension offices in each County.	Conduct research on how to characterize soil health and how soil health practices affect selected soil parameters in terms of crop production, water use and water quality. Provide unbiased, research-based information on crops, soils and the environment with respect to soil health practices.
Arkansas State University	A state funded University that provides teaching and research in agriculture.	Conduct research on how to characterize soil health and how soil health practices affect selected soil parameters in terms of crop production, water use and water quality.

In Arkansas, the Arkansas Soil Health Alliance (ASHA) has led the effort to develop and use healthy soil concepts to improve profitability amid low commodity prices and the ever-increasing cost of agronomic inputs. Members have observed changes in their soil, reduced irrigation and other inputs, and increased profitability over several years of implementing soil-health-building practices including the use of cover crops and reducing tillage.

How do I Improve the Health of My Soil?

There are five basic principles for protecting and improving soil health as shown in table 2.

Table 2. The 5 Principles to Build Soil Health
1. Reduce or minimize soil disturbance.
2. Keep the soil covered.
3. Keep living roots growing during as much of the year as possible.
4. Promote biodiversity above and below the soil surface.
5. Integration of livestock through grazing (optional).

Management practices that address one or all of these principles will increase the function of soil over time. In an ideal scenario, we would implement practices that address all factors, but even the adoption of one or two practices can lead to improvement in soil health. In the following sections we will break down each of the components for improving soil health.

Reducing or Minimizing Soil Disturbance

Tillage has been a routine practice for generations of row crop producers. At one time, tillage was needed to prepare the seedbed, control weeds, manage residue and repair a field's surface. Minimum tillage is now widely used in Arkansas and is certainly feasible in modern agriculture.

The main detriments of tillage to soil health are the reduction of soil organic matter, loss of top-soil due to increased erosion potential, release of greenhouse gasses, and the destruction of soil structure. Anything we can do to reduce or eliminate tillage in our production systems will improve soil structure, overall soil health, increase soil organic matter, and reduce erosion.

Reducing tillage also reduces input costs, leading to increased profitability. For example, soybean growers who switch from using stale seedbed or conventional tillage systems to no-tillage production practices save an estimated $30 to $50 per acre per year. In rice, and other more traditionally tillage-intensive crops, the savings could be much greater.

Keep the Soil Covered

Under most sub-humid environments, such as present in Arkansas, nature works to try to keep soils covered throughout the year. In most undisturbed soil settings, even with low inherent soil fertility, nature will provide vegetation. The vegetation is often diverse even if it is comprised of undesired species, such as weeds.

In modern agriculture, fields are often left fallow during the non-crop-growing season, yet nature will still try to cover soils with winter weeds that often have to be controlled near planting. The benefits of keeping soil covered year-round include a reduction in soil erosion, preservation of the seedbeds and rows, providing live plant stock to promote soil biology, preservation of soil structure, prevention of unwanted weeds and reduction of soil crusting for spring planted cash crops.

Cover crops provide a flexible option of vegetative cover that can be planted in the typically fallow windows of the year. Cover crops were routinely used before the advent of modern weed control and commercial fertilizers, primarily to control weeds and to promote nutrient cycling by using cover crops as green manures.

In addition to reducing tillage, residue management can have a profound impact on soil health. Burning or removing crop residues removes valuable nutrients from the field, and most of the organic material that could be used to increase soil organic matter is either lost as carbon dioxide or transported elsewhere.

Slight changes to fall residue-management practices can significantly benefit soil health through additional soil protection and soil organic matter. Allowing crop residues to remain on the soil surface will provide a barrier and help keep the soil covered. The breakdown and decomposition of this residue will be the foundation of the soil organic matter pool.

Figure 1. Photo of a split field demonstration comparing a cover crop and no-till to a conventionally tilled field, courtesy of Dr. Bill Robertson, University of Arkansas Cooperative Extension Cotton Agronomist.

Figure 2. Photo of a roller crimper flattening the standing cover crop into a mat prior to cash crop planting, courtesy of Dr. Bill Robertson, University of Arkansas Cooperative Extension Cotton Agronomist.

Keep Living Roots Growing as Much as Possible

Maintaining ground cover with vegetation also helps promote the third principal of soil health, keeping roots alive and growing as long as possible throughout the year. While the biomass above the ground is important, the biomass below ground is just as important to the function of soils. Soils can be covered with plant residue, mulch, and water to protect soil from erosion, but these options don't provide living roots in the soil throughout the year. Having a living cover, such as cover crops, provides a food supply for soil microbes and other ecological features that promote nutrient cycling.

As roots grow and senesce, they often provide the soil biota with carbon, the functional building block of life on earth. Soil biota — particularly, bacteria and fungi — are the foundational layer of the soil food pyramid and allow for a diverse assortment of micro- and macro-organisms. Living roots in the soil aid in the protection of soil structure and development of channels and larger pores in the soil to promote greater rooting of a cash crop and greater air and water movement down the soil profile.

As living roots within the soil grow, die and decay, they can have a profound impact on the physical characteristics of the soil. Living roots associate with mycorrhizal fungi that produce a chemical called glomalin that facilitates increased soil aggregation and overall soil organic matter. Furthermore, the symbiotic relationship between plant roots and soil fungi populations may offer increased survival rate for plants under environmental stress. While winter weeds can cover the soil and provide living roots, weeds in general are often shallow rooted and do not provide the below-ground biomass that cover crops can provide.

Promote Biodiversity Above and Below the Soil Surface

"Plant diversity," as it relates to soil health, is the concept that a diverse mix of plants, mimicking what one would naturally find on undisturbed, non-agricultural land, is essential to soil health.

Generally speaking, plants photosynthesize sunlight, absorb carbon from carbon dioxide in the atmosphere, and form symbiotic interactions with the soil. The plant carbon is then transferred into the soil through root exudates, which feed soil microorganisms and help build organic matter and soil structure. In return, the soil microbial populations help cycle soil nutrients, such as carbon, nitrogen, and phosphorus, making them available for plant uptake.

Each plant species releases different exudates, so roots interact with multiple types of soil life. Diversity above ground equals diversity below ground, leading to a more complete and functional soil food web. Diversity among soil microbial populations may bring "functional redundancy," as many different species can perform the same functions. This redundancy in functions may lead to a more resilient soil ecosystem, especially against sudden environmental stress such as drought or freezing temperatures.

Figure 3. Photo of terminated cereal rye cover crop with visible roots and soil surface residue courtesy of Jan Yingling, University of Arkansas Cooperative Extension agent, White County.

Most plants are in one of four primary groups: warm-season grasses, cool-season grasses, warm-season broadleaves or cool-season broadleaves. Ideally, all plant groups will be included somewhere in your crop rotation or as a cover crop because, again, a diverse mix of plants mimics nature. It's even better if more than one plant group is growing at the same time. While it's often impractical to grow more than one cash crop in a field at the same time, crop rotation aided by cover crop blends can optimize plant diversity and ensure a more consistent energy source for soil microbes.

Livestock Integration Through Grazing (Optional)

Another practice to build and protect soil is livestock integration through grazing, which promotes nutrient recycling. While some may consider this practice optional, it greatly enhances the holistic approach of integrating all four basic principles toward building soil health.

Before modern meat production turned to animal confinement for increased production efficiency, livestock were raised primarily by grazing grasslands and cover crops. Many believe this creates greater symbiosis with plants and soils that provides benefits — but it's often easier to see potential benefits than to measure and differentiate actual changes in individual soil properties with respect to different soil management practices.

Figure 4. Photo of wide-row cotton with a terminated cover crop mat dominated by winter annual grasses and brassicas, courtesy of Adam Chappell, Woodruff County farmer.

While the impact of livestock integration on soil health isn't clearly defined, research has shown that grazing livestock on cover crops in a row crop situation can be more profitable than just cultivating row crops alone. However, in row crop-producing regions of Arkansas, where soils are often poorly drained, grazing cover crops may be detrimental to soil health unless internal soil drainage has been improved through several years of cover crops or other means.

Summary

Improvements in soil health can bolster ecosystem services and protect our natural resources, benefiting all Arkansans.

Improving soil health begins with holistically enhancing the natural function of soils in terms of their chemical, physical and biological properties. Improving those interactions will optimize ecological services including crop production, soil carbon sequestration, and greenhouse gas mitigation.

However, soil health implies different things to different people. Careful planning and proper management of cover crops are necessary to effectively alter the soil's dynamic properties and improve soil health and resiliency. Commitment to these practices is needed to fully realize the possible benefits.

Committing to improving soil health can not only impact your productivity and economic well-being, but can also improve the world around you through the protection of natural resources.

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