In Defense of Soil Health

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Soil health is a hot topic today in sustainable agriculture circles and is even becoming more popular in conventional agriculture. However, the term is often thrown around loosely and sometimes the meaning gets muddled. I give a lot of presentations at conferences relative to soil health and conduct workshops around the country on soil health practices. What we are finding is that, even with a lot of attention thrown its way, less than 10% of farmers and grazers around the U.S. have adopted sound soil health principles and practices. Most are still somewhat skeptical and have a hard time grasping the benefits derived from building true health in the soil.

The most common objections I hear from farmers and grazers on shifting practices to promote soil health are: If this works so well why isn't everyone doing it? What will it cost me? I'm too busy to implement any of those practices. But the biggest question I get is, "Where is the scientific data supporting all these claims of benefits?" In today's article, I will attempt to address these questions and comments through showing results of soil health practices and principles with peer-reviewed published data.

Benefits of Soil Health Practices

There are many benefits that have been attributed to soil health practices and the building of the soil. To understand these benefits we first have to understand that all plant growth is highly correlated to life in the soil.

Research conducted at New Mexico State University revealed that the soil microbial community structure relative to the fungi to bacteria population ratio has a greater influence on plant biomass production and yield than inorganic Nitrogen (N) or Phosphorus (P) applications (Johnson, et. al., 2012). Johnson and co-workers also found that when farmers planted highly diverse cover crops between plantings of cash crops they were able to produce similar or even higher yields, even with reduced reliance on synthetic fertilizers. Their results showed that soil essential minerals and trace elements increased as cover crop diversity increased due to carbon inputs from the living plants stimulating microbial activity which, in turn, increased soil macro- and micronutrient availability, increased soil aggregation, and improved soil water-holding capacity. This creates a positive feedback loop similar to the endocrine system feedback loop found in the body of animals and humans. Interestingly, Johnson and co-workers discovered that as cover crop diversity and biomass production increased, the effects in the soil were quadratic, not just linear. This is due to the ever increasing synergies between the soil microbial population and the plants they serve.

Dr. Christine Jones (WANTFA New Frontiers in Agriculture, Sept. 2013) found that the more closely we mimic the structure and function of year-round ground cover, the more productive our farms are. Her work indicates that the more species included in the ground cover the better. Multi-species cover crops helped restore below-ground diversity and soil biological function. This included increases in atmospheric N fixation and the solubilization of bound Phosphorus (P). These effects improved overall plant productivity and yields. Her work showed that the increases in nutrient sourcing and soil moisture retention through planting of diverse cover crops builds soil nutrients in successive years.

Similarly, research has shown that grassland ecosystems need year round cover to protect from soil loss and facilitate soil microorganism function. Plant and litter cover provide numerous documented benefits such as enhanced soil microbial activity, soil aggregate stability, increased soil organic matter, improvements in water infiltration rates, decreased soil water evaporation and soil temperature buffering. These benefits result in enhanced plant nutrient status and nutrient availability, improved plant growing conditions, and increases in soil organic matter (Thurow,1991; Rietkerk, et. al., 2000; Bardgett, 2005).

Results of Poor Management Practices

Researchers have found that poor management and excessive practices can inhibit soil-building processes and even cause soil degradation. Poor grazing management practices that result in excessive plant leaf and tissue removal and excessive trampling create conditions conducive to soil loss. In addition, these same researchers found that frequent use of fire (Patch burning, pasture burning) inhibited soil building, as did excessive drought conditions (Thurow, 1991; Wright & Bailey, 1982). Thurow (1991) found that as the amount of bare ground increased due to poor management practices, proper soil function decreased and erosion risk increased substantially.

One of the biggest mistakes we make in agriculture is creating bare ground. It has been documented that bare ground experiences a significant decrease in soil microbial activity, a loss in soil organic matter, and subsequent increase in erosion. Simply the energy of raindrops falling from the sky and striking the soil unimpeded creates conditions conducive to rapid soil erosion. Plant diversity and density dissipates the energy of raindrops before they contact the soil (Blackburn, 1975; Blackburn, et. al., 1986).

When poor soil management practices are employed, either through poor grazing management or conventional farming, soil degradation increases due to increased soil compaction and bulk density, resulting in elevated water penetration resistance and reduced soil aggregate stability (Herrick et. al., 1999; Herrick & Jones, 2002). Neary and co-workers (1999) and Wright & Bailey (1982) found that conditions that allow for elevated soil temperatures and soil loss negatively affect water infiltration rates, nutrient retention, and biological function, and increase the rate of water evaporation from the soil.

Researchers in Australia discovered that the hot and dry southern half of the continent supported significantly more warm season (C4) grasses and forbs at the time of European settlement than it does today. Even with temperatures routinely climbing above 100o F and little rain, the original groundcover remained green throughout the summer season due to greater water holding capacity of the soil. Poor grazing practices after European settlement devastated the forb population and reduced the number of grass species, resulting in reduced plant populations and increased soil exposure (Presland, 1977).

Similarly, in the U.S., poor grazing practices and excessive tillage from farming have significantly reduced soil water holding capacity and reduced broadleaved plants (forbs). The original groundcover across the Great Plains of North America contained far more broadleaf plants than grasses, with numerous summer-active legumes and forbs. Broadleaf plants stimulate far greater nutrient cycling and microbial diversity than grasses alone. Scientists found that poorly managed grazing and excess tillage have significantly reduced the broadleaf plant population across much of the Great Plains. With unmanaged grazing, ruminants selected the broadleaf plants, which were the most palatable and nutrient dense, and grazed them out of existence in much of the landscape (Lunt, et. al., 1998).

Realizing Benefits From Soil Health Management

Studies have shown that the amount and type of vegetation covering the soil significantly influences all soil physical parameters and hydrological properties. Benefits increase as you progress from bare soil to short grasses to bunch grasses and forbs interspersed with woody plants. A mixed plant population of bunch grasses, broadleafs, and woody plants produce significantly greater amounts of foliage and root biomass (especially when compared to monocultures, short grasses, annuals, and improved cultivars) resulting in greater soil organic matter and microbial species diversity and density (Blackburn, 1975; Milne & Haynes, 2004; Pluhar et. al., 1987; Thurow, 1991; Thurow, et. al., 1986, 1987).

Devi and Yavada (2006) found that above-ground plant litter and plant cover creates conditions conducive to enhanced soil moisture micro-environment and more consistent soil temperatures. These conditions favor greater soil microorganism activity. In addition, these conditions tend to enhance the formation of stable soil aggregates, which results in increased water infiltration and improved soil fertility (Herrick, et. al., 1999).

Approximately 60% of all soil organic matter (SOM) is comprised of soil organic carbon (SOC) which positively influences all chemical, physical, and biological functions of soil health (Bardgett, 2005). Increases in SOC result in increases in soil aggregate stability, water-holding capacity, and Cation Exchange Capacity (CEC). As organic matter increases the ability of the plant to take up nutrients and trace elements increase, nutrient leaching is reduced, soil pH is buffered, and plant growth is enhanced. Scientists have found that SOM profoundly impacts plant biomass production and health, water quality and availability, carbon sequestration, and overall soil health (Charman & Murphy, 2000; Lal, 2008).

Land management practices significantly affect the ability of the soil to sequester and retain organic carbon. Practices that increase plant growth on a year-round basis, lower incidence of bare or partially exposed soil, and stimulate extensive root growth and microbial growth accelerate carbon sequestration (Parton et. al., 1987).

Adaptive Grazing Practices Produce Dividends

In a direct comparison of Adaptive Multi-Paddock (AMP) grazing with Light Continuous (LC), Heavy Continuous (HC), and Non-Grazing (EX), researchers found that the highest levels of soil carbon, the greatest plant biomass production, and the lowest level of bare soil were experienced when AMP grazing practices were implemented. The LC and HC grazing practices had lower plant biomass production and greater degrees of bare soil, along with decreased soil water-holding capacity than AMP and EX (Teague, et. al., 2011; Allen, 2007; Leake, et. al., 2004). These results are consistent with prior studies that show soil C availability is regulated through plant biomass production and soil coverage (Conant, et. al., 2001: Jones & Donnelly, 2004). Similarly, earlier work conducted by Thurow (1991) demonstrated that with AMP grazing at higher stock densities, on semi-arid rangeland, there was more positive impact on soil physical properties and soil water infiltration than with continuous grazing at the same stocking rate.

Teague and Co-Workers (2010), in earlier work, found that AMP Grazing produced greater forage biomass production, maintained adequate ground cover with far less exposed soil, increased soil aggregate stability, lowered soil temperatures, and sequestered higher soil C than other methods of grazing or non-grazing.

In addition, soil chemistry parameters were improved with AMP grazing. Soil Cation Exchange Capacity (CEC) was higher when AMP grazing was employed vs. Light Continuous, Heavy Continuous, or non-grazing, which is consistent with differences in soil C increases. As soil CEC increases, the ability of the soil to retain nutrients and water increases. Soil pH was buffered when soil microbial responses were increased with AMP grazing. In addition, levels of Magnesium and Sodium in the soil were improved with AMP grazing, as was the rate of nutrient cycling. One primary factor in these nutrient cycling improvements was the fact that AMP grazing encouraged deeper root penetration allowing the roots and the associated mycorrhizal fungi to reach mineral stores deeper in the soil (Teague, et. al., 2011).

AMP grazing practices produced the greatest fungi:bacteria ratio when compared to other grazing methods or non-grazing (Teague, et. al., 2010; Teague, et. al., 2011). Soil bacteria and fungi perform much of the decomposition of organic matter at the soil surface. This provides significant nutrients for growth health and growth. Researchers have found that fungi are simply more efficient at decomposing and storing nutrients than bacteria (Bardgett & McAlister, 1999; De Vries, et.al., 2006). It has been demonstrated that higher fungal populations in the soil increase the soil's ability to hold C, to create a readily available nutrient pool, and to buffer against low pH conditions. This makes the soil fungi:bacteria ratio a reliable measure of overall soil health improvement and soil C sequestration (Beare et al., 1992; Yeates et. al., 1997; Bailey et al., 2002).

Better soil management practices, which include AMP grazing, create favorable species changes in the plant community. This, in turn, creates more favorable soil microbial compositions and enhances soil biota function which triggers natural feedback mechanisms (Coleman & Crossley, 1996). Bardgett (2005) found that enhancing the interactions between plants and soil biota drives ecosystem function and productivity, as well as providing pivotal structuring forces in the plant community. Bardgett's work showed that the plant-soil biota interactions increased the microbial breakdown of plants making nutrients more readily available, enhanced plant root exudate production, increased fungal associations with plant roots, and positively altered the physical structure of the soil to allow for increased water and nutrient movement.

Roundup Toxic to Soil Fungus

A recently released study published in Environmental Science and Pollution Research found that Roundup is toxic to soil fungus, even at application rates that are well below recommended dilution rates. The study discovered that at application rates diluted 100 times less than those typically used in agriculture caused a 50% mortality in the soil filamentous fungus, Aspergillus nidulans. What is critical about this is that Aspergillus nidulans is frequently used as a marker of soil health (Nicolas, et. al., 2016).

Even more disturbing is the finding that the commercial formulation of Roundup appears to have even greater toxicity than glyphosate alone. This indicates that the additives are not necessarily inert. The published research found that Roundup impaired soil fungi growth, increased cellular disturbances, and interfered with cellular energy and respiratory metabolism. The research findings went on to note that soil microorganism energy metabolism and respiratory function disturbance were detected at doses producing no visible effect to the naked eye. They reasoned that this implies that even residues in GM herbicide-tolerant crops may be causing detrimental effects.

Since soil microorganisms are critical to soil health and Roundup is the most frequently used herbicide worldwide, soil fungi populations in many countries and across broad landscapes have been damaged. This is very relevant to farmers trying to improve their soil health.

Conclusions

Soil health management practices and principles have numerous benefits that produce not just linear positive effects but exponential effects. I often state during my presentations that nothing we do in agriculture has a singular effect. Every decision we make in our management practices has compounding and cascading effects, whether for the good or for the bad. The practices we implement on a day to day basis will have an impact. It is up to us as to whether those effects are beneficial or not.