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SOIL HEALTH: THE FOUNDATION FOR CONSERVATION MANAGEMENT AND ASSESSMENT

The Issue

Worldwide demand for food, feed, fiber, and fuel from U.S. farms is increasing as the global population pushes towards 9 billion by 2050. The pressures on agricultural soils and related natural resources continue to mount as American farmers and ranchers strive to meet the growing demand without damaging the environment. At the same time, though conservation investments increased substantially in the last two farm bills, the current budget environment mandates reductions across the entire Federal Government, including conservation funding. Achieving agricultural sustainability in the face of the burgeoning global population is imperative. Maintaining soil health is the foundation for the sustainability of farm and ranch production and for environmental protection.

What Is Soil Health, and Why Is It a Fundamental Component of Sustainability?

Soil health has been defined variously as "the capacity to function" (Karlen et al. 1997) and "fitness for use" (Larson and Pierce 1991). Soil health can thus be regarded as the capacity of the soil to perform the functions necessary for its intended use while continuing to provide important ecosystem services. More than just a medium for plant growth, healthy soils cycle and retain nutrients, partition water and soluble materials, buffer and break down contaminants, and support agricultural production and biodiversity. High-functioning, healthy soils resist the erosive forces of water and wind and maintain good structure and aggregate stability, which allows water to infiltrate, improves soil water-holding capacity, and reduces flood damage. They retain nutrients and break down contaminants, keeping them out of surface and ground water. When soils are functioning well, they support diverse and productive plant communities, providing habitat for wildlife and increasing carrying capacity for livestock. These critical relationships between soil function and the quality of other natural resources ultimately leads to the view of soils as the foundation resource.

How Does Managing Disturbance Help Maintain Soil Health?

Some soil disturbance is natural. Wildlife, treefalls, droughts, fires, and floods are among the many factors that disturb the soil. Some of these disturbances help maintain soil functions, while others degrade them. Healthy soils are able to resist or recover from natural disturbances. These soils are *resistant to* and/or *resilient from* degradation. Resistance is the ability of the ecosystem to continue to function without change when stressed by disturbance, and resilience is the ability of the ecosystem to recover after disturbance (Herrick and Wander 1998; Seybold et al. 1999). A resistant and resilient ecosystem is essential for sustainability.

Response to disturbance depends on soil properties and the frequency, intensity, and type of disturbance. For example, a soil with high resistance to compaction could lose this resistance when subjected to repeated disturbances. Many small events, such as repeated tillage, can lead to decreased resilience with each event until the soil is compacted to the point where air, water, and the roots of many plants cannot penetrate it. The reduced function associated with soil disturbance is assumed to lead to lower soil stability (Carter et al. 2004), less stable production, increased soil erosion, and other problems.

By definition, agricultural ecosystems are subject to large disturbances because they are highly managed systems. Agricultural practices, including tillage, pesticide applications and livestock grazing, can disturb the soil in ways that overwhelm the soil's resistance and resilience. There are three main types of disturbance: physical, chemical, and biological. Many options exist to manage agroecosystem disturbances:

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- For physical disturbances such as tillage, conservation tillage or no-till practices are effective alternatives. Livestock-related disturbance can be reduced with proper grazing management.

- For chemical disturbances such as pesticide inputs, precision or spot application can reduce losses of chemicals to the environment and limit deleterious impacts to agricultural soils.

- For biological disturbances such as monoculture crops, diversity can be achieved through rotations, cover crops, intercrops, field borders, filter strips, and buffer strips. Prescribed grazing on rangeland or pasture can not only reduce soil compaction and streambank sloughing but also enhance desired species whose root systems can repair historical disturbances throughout the soil profile.

Why Go Beyond T to Manage for C?

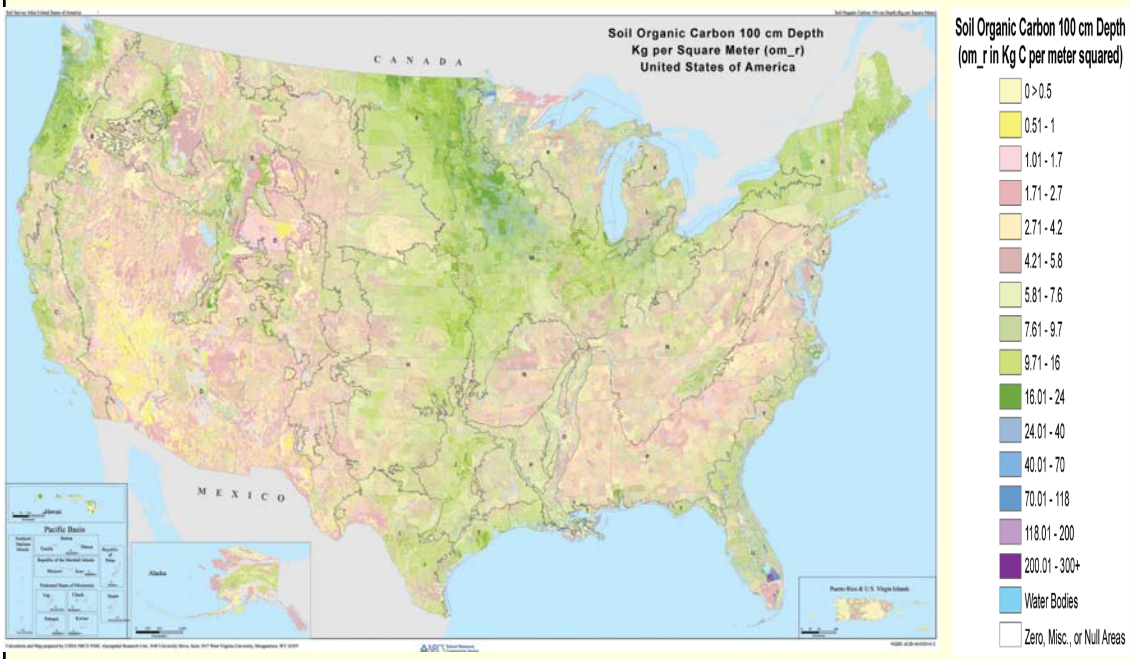
Concern for preserving agricultural productivity resulted in development of the concept of tolerable soil loss and the creation of the soil loss tolerance, or T factor, which is the maximum annual soil loss that can occur on a particular soil while sustaining long-term agricultural productivity. Soil formation is a slow process. The development of a favorable rooting zone by the weathering of parent material occurs much more slowly than development of the surface layer. As a result, most soils cannot renew themselves while their surfaces continue to degrade and erode away.

Keeping soil in place is only the beginning of soil conservation, and erosion should not be considered the only indicator of soil health. Soil also has to hold nitrogen, phosphorus, and pesticides in place and keep them out of surface water. Soil must recycle and deliver nutrients and water to plants

Determining soil organic carbon content

Soil organic carbon stocks are highest in the upper Midwest, an area dominated by cropland on deep soils, and in the heavily forested Pacific Northwest and Northeast. Soil organic matter also depends on climate—lower average temperatures and higher average annual precipitation lead to higher soil organic matter content. Finer textured soils also tend to retain organic matter longer than do coarser textured soils.

Soil organic carbon values are based on soil properties estimated from laboratory data from more than 25,000 sites analyzed for the National Cooperative Soil Survey. Although the data set is large, it represents a limited number of the soils in the United States, and land cover and agricultural management were not considered in site selection. Thus, estimates of soil organic carbon stocks for specific soil and land cover combinations have considerable uncertainty. The Rapid Assessment of U.S. Soil Carbon for Climate Change and Conservation Planning currently underway will help reduce this uncertainty. This one-time inventory, however, is addressing only broad soil and land cover groups and is not designed to address rates of change in soil organic carbon stocks.



Source: USDA-NRCS

as they need them. Healthy soil can help minimize the effects of floods and droughts.

Many soil properties impact soil health, but soil organic matter deserves special attention. Organic matter content affects several critical soil functions, can be manipulated by land use and management practices, and is important in most agricultural settings across the country. Increased organic matter promotes better soil structure, which in turn improves stability and makes soils less prone to crusting and erosion. As soil structure and pore continuity improves, water infiltration increases and runoff decreases; compaction pans are ameliorated; nutrient storage and water-holding capacity increase; and beneficial soil organisms become more diverse, numerous, and active.

The most practical way to improve soil health today is to promote better management of soil organic matter, or carbon, its main component (SWCS 2008). Organic matter helps soil perform all of its vital functions and contributes to resistance and resilience to degradation. Managing for carbon (C), thereby increasing soil organic matter content and thus enhancing soil health, improves soil far more than does erosion control alone. Managing for soil carbon can enhance productivity and environmental quality; reduce the severity and costs of natural phenomena such as drought and flood; and reduce or eliminate offsite impacts such as those associated with surface water eutrophication, airborne particulates, and human disease. In addition, increasing soil organic matter content sequesters carbon and reduces atmospheric carbon dioxide levels that contribute to climate change. In short, we should *"Go beyond T, Manage for C."*

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How Can We Manage for Improved Soil Health?

Addressing soil health shifts the conservation focus from managing for tolerable degradation to enhancing soil function for long-term sustainability. This management philosophy exploits the full potential of cover crops, crop rotations, reduced tillage, prescribed grazing, and other practices and systems to address resource concerns. Moreover, managing for carbon can provide additional onsite benefits and incentives for the landowner or operator, such as reduced fertilizer costs, improved productivity, and potentially, ecosystem market credits.

Soils can be managed to maximize their resistance and resilience, and thus minimize loss of function, by addressing diversity and disturbance. However, no individual practice or combination of practices will have the same effect on all land. Conservation practices and systems must be designed according to need and site-specific indicators of function and resilience.

Sustaining agricultural production capability will require making informed choices that strengthen productive agricultural soils and protect our most vulnerable soils. These include highly erodible shallow soils, soils with inherently low organic matter accumulation rates, soils on which management practices are causing loss of organic matter, and soils susceptible to salinization when hydrology is modified. Strategic investments are needed to generate scientific knowledge about the effects of different conservation practices on both resistance to and resilience from degradation of soil function for various climates and soil types.

Change will not happen overnight or at the same pace everywhere. Land managers can expect a transition period and learning curve associated with management changes. Soil biological and physical properties will improve before increased soil organic matter is noticeable. One action that could be taken immediately is to develop a new land capability classification system that can help match production systems to the capacity of the soil to resist and recover from degradation. This requires an understanding of the resistance and resilience of different soils to all potential production systems within a region. A resilience-based land capability classification system would help managers by providing them with the information necessary to select and develop new systems that sustain and increase soil health and productivity.

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