Resources Conservation Practices

Tillage Management and Soil Organic Matter

Conservation Quiz

1. What are the two classes of soil organic matter?

2. How does soil disturbance by tillage decrease soil organic matter?

3. What are the benefits of soil organic matter to the soil?

Answers on page 5.

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Tillage systems play a significant role in agricultural production throughout Iowa and the Midwest. It has been well documented that increased tillage intensities can reduce soil organic matter in the topsoil due to increased microbial activity and carbon (C) oxidation. The potential loss of soil organic matter due to tillage operations is much higher for high organic matter soils than low organic matter soils. Tillage effects on soil organic matter can be magnified through soil erosion and loss of soil productivity. Soil organic matter is a natural reservoir for nutrients, buffers against soil erosion, and improves the soil environment to sustain soil productivity. Maintaining soil productivity requires an agriculture management system that maintains or improves soil organic matter content. Combining cropping systems and conservation tillage practices, such as no-tillage, strip-tillage, or ridge-tillage, are proven to be very effective in improving soil organic matter and soil quality.

Importance of Surface Residue in Building Soil Organic Matter

Soil organic carbon (SOC) content is enhanced by reductions in carbon dioxide emission, but the reduction in inorganic nitrogen results in decreased residue production and lower organic carbon storage in soils. There is a strong relationship between surface residue and SOC (Fig. 1). Greater quantities of annual residue additions can positively contribute to soil organic matter (Robinson et al., 1996). Management of crop residue and soil organic matter is important to maintaining soil productivity and minimizing agricultural impacts on the environment. Conservation systems use tillage practices that are defined by the percent of residue cover left on the soil surface, such as ridge-tillage, strip-tillage, and no-tillage. Fragile crop residue contributes less to SOC and decomposes much faster than non-fragile residue (i.e. soybean vs. corn residue). The removal of crop residue for various purposes (i.e. baling or grazing) can result in accelerated soil erosion and consequently will lead to soil organic matter and nutrient losses.

What is Soil Organic Matter?

Soil organic matter consists of a wide range of carbon compounds that reside in the soil. Soil organic matter includes above and below ground plant material, animal remains that are in various stages of decomposition, and wide range of soil organisms (bacteria, fungi, yeast).

Soil organic matter can be classified as
1) active organic matter that is partially decomposed, which includes components of living plants, animals, and soil organisms.

2) stable organic matter which represent the forms of organic matter that are fully decomposed and less susceptible to losses. Therefore, the objective of managing soil organic matter is to increase the stable portion of organic matter.

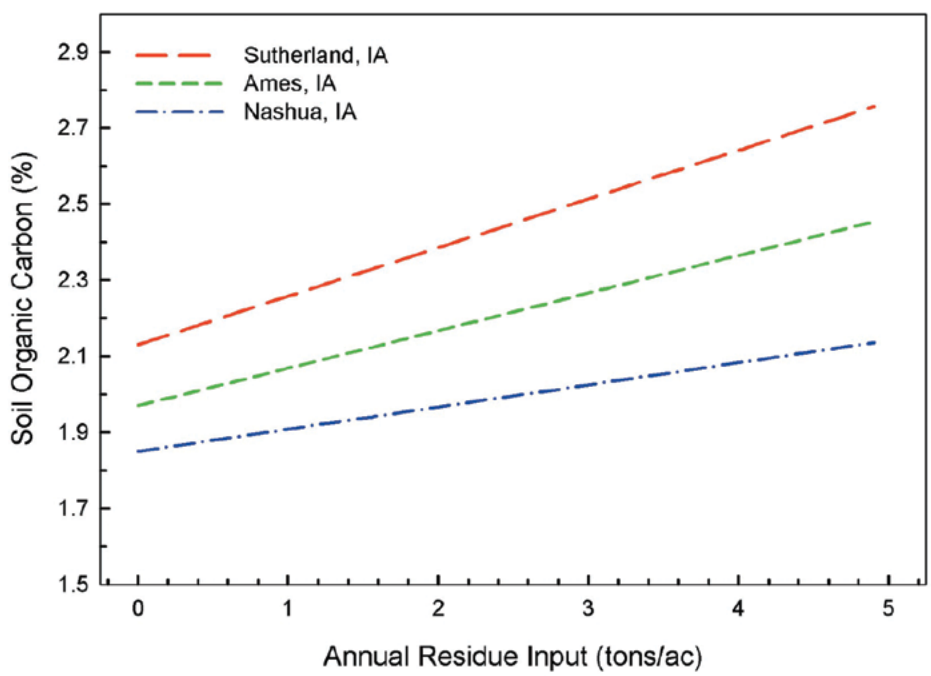

Figure 1. Relationship between soil organic carbon and annual residue additions (Robinson et al., 1996).

Tillage Effect on Soil Organic Matter

Soil texture, climate, landscape position, native vegetation, and management have an impact on soil organic matter content. Tillage management has a negative effect on soil organic matter due to human influence. Different tillage systems cause different levels of soil carbon losses depending on the intensity of the tillage. Figure 2 illustrates that for a Clarion-Nicollet-Webster soil after three years, no-tillage had a higher soil carbon content compared to other tillage systems with different intensity at the top 6 inches of the soil. Intensive tillage systems accelerate the degradation of soil organic matter compared to native or permanent vegetation, which allows organic carbon to accumulate (Fig. 3). However, when modern agriculture introduced clean tillage systems there was a dramatic decline in soil organic matter as the transition from native vegetation to cropland took place. Therefore, selecting a low intensity tillage system is one of the critical components for minimizing negative tillage effects on soil organic matter. Recently, a significant effort has been made to encourage the adoption of conservation tillage systems through research and agricultural programs. Research supports the role of conservation systems in improving soil organic matter and indicates that the accumulation of soil organic matter content to the original level is very slow and requires significant amounts of time. Tillage system intensity plays a significant role in determining soil organic matter by affecting both soil disturbance and surface residue. Soil aeration oxidizes soil organic matter causing carbon loss as carbon dioxide. In the same action, plant residue is incorporated into the soil creating an ideal environment for rapid organic matter decomposition. Excess decomposition of soil organic matter leads to a loss of the nutrient holding capacity and degradation of soil quality. Conservation tillage systems reduce the rate of organic matter oxidation compared with the conventional tillage systems, balancing microbial activity and slowing down decomposition of root biomass and below ground organic matter. Residue left on the soil surface slows decay, thereby maximizing residue carbon input. It has been shown in various studies that no-tillage can increase soil organic matter by as much as 1 ton/acre/year. In a recent study, it was shown that the loss of soil carbon as carbon dioxide-carbon equivalent reached 1.9 pounds C/acre in the first hour and 125 pounds C/acre in the first three weeks following moldboard plowing compared to no-tillage with residue losses of 0.60 pounds C/acre in the first hour and 73 pounds C/acre in the first three weeks (Fig. 4) (Al-Kaisi and Yin, 2005).

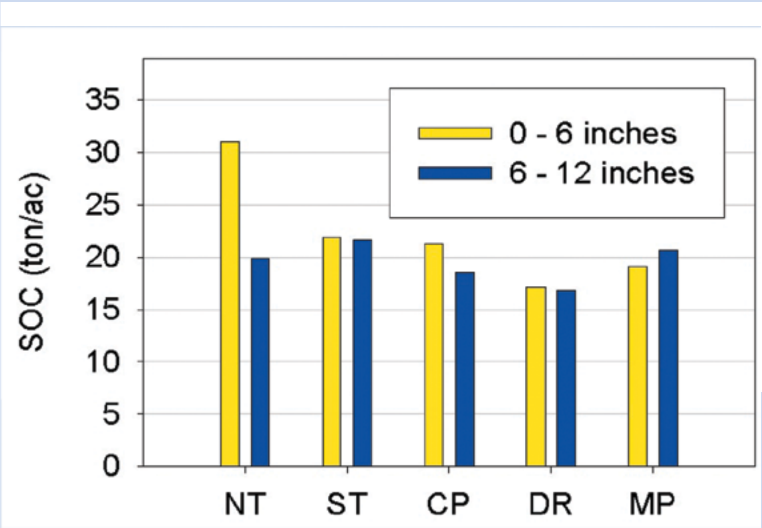

Figure 2. Soil organic carbon (SOC) for no-tillage (NT), strip-tillage (ST), chisel plow (CP), deep rip (DR), and moldboard plow (MP) at two depth increments (Al-Kaisi et al., 2004).

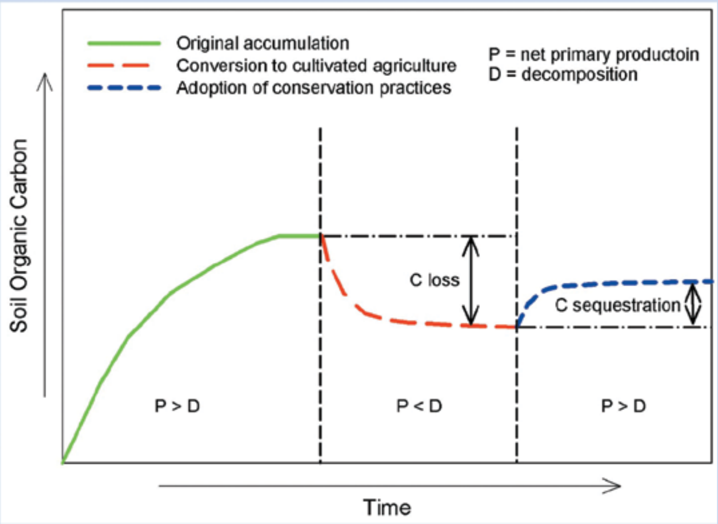

Figure 3. Schematic illustration of soil organic C in relationship to time as affected by different agricultural systems and practices.

Benefits of Organic Matter for Improving Soil Quality

No tillage soybeans (NRCS)

Soil organic matter is beneficial to soil quality, water quality, and crop production (Fig. 5). Soil organic matter contains a pool of nutrients that become available for plants under proper soil and weather conditions. Soil organic matter contains a wide range of macro and micronutrients in organic forms that are released slowly to the soil system. This function keeps nutrients in a more stable form that can be used better and reduces losses into the environment.

Higher levels of soil organic matter improve soil water dynamics. Soil organic matter acts like a sponge and can absorb many times its own weight in water. In addition to increased water holding capacity, soil organic matter helps create soil conditions that improve water infiltration and reduce surface runoff.

Soil aggregates are held together by soil microbes, their exudates, and other components of soil organic matter. Soils containing stable aggregates aid in control of soil erosion, reduce soil crusting, decrease soil compaction, and encourage root development. Overall, soil organic matter is a necessary component for improved soil and water quality.

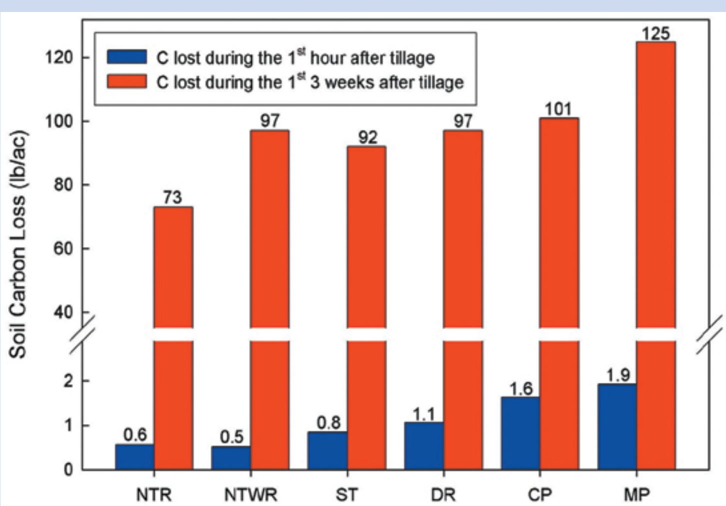

Figure 4. Soil carbon (C) lost during the first hour and three weeks following different tillage operations. NTR, no-tillage with residue; NTWR, no-tillage without residue; ST, strip-tillage; DR, deep rip; CP, chisel plow; and MP, moldboard plow (Al-Kaisi and Yin, 2005).

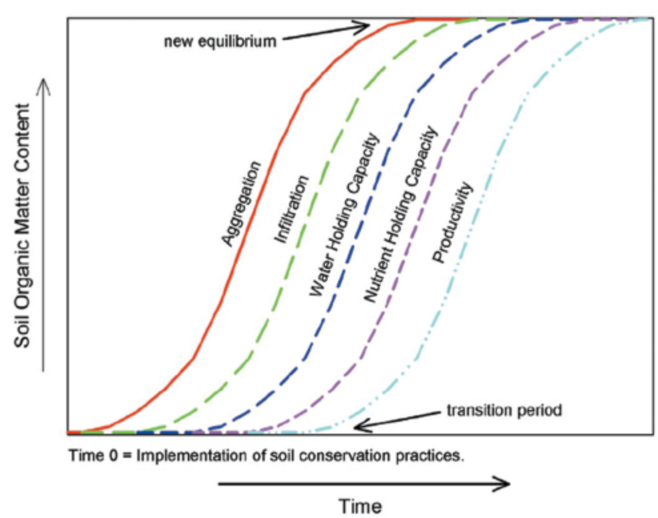

Figure 5. Effect of soil organic matter improvement over time on selected soil quality parameters and productivity (USDA, 2003).

Quality Conservation Systems and Soil Organic Matter

Conservation systems cover a wide range of tillage and cropping systems that are important to soil organic matter. No-tillage is considered the most effective conservation system for improving soil organic matter due to no soil disturbance. This characteristic of no-tillage is extremely beneficial because surface residue and soil organic matter are left undisturbed, slowing decomposition and maximizing soil organic matter gains. This lack of disturbance keeps soil organic matter from being oxidized and promotes improvements in soil quality parameters and soil tilth. The contribution of no-tillage to soil organic matter is not limited to surface residue and less soil disturbance, it is also the improvement of root biomass, microbial diversity, and more earthworms.

Other options for conservation tillage systems are strip-tillage and ridge tillage. Each system is a modified version of no-tillage that is used to improve seedbed conditions in cold and poorly drained soils. The level of disturbance to soil and crop residue with these two systems is greater than with no-tillage. With strip-tillage a narrow tilled zone is created in the fall or spring to promote soil warming and water evaporation in the seedbed while leaving undisturbed areas between rows (Al-Kaisi and Hanna, 2002). (For more information on strip-tillage see PM-1901c). In contrast, ridge tillage leaves the soil undisturbed from harvest to planting.

However, the rebuilding of the ridges after planting can cause soil organic matter loss. The effects of these two systems can be similar on soil organic matter as far as the soil disturbance and residue manipulation are concerned. In conclusion, conservation tillage systems vary in their level of impact on soil organic matter status depending on the type of tillage system, type of cropping system used, and degree of stability.

Tips for Implementing a Conservation Tillage System

1. Start out small with 40 acres in the first year and expand with knowledge and experience.

2. Interact with professionals and successful conservation tillage farmers to gain additional knowledge and solve problems as they arise.

3. Start with soils high in soil organic matter, natural fertility, and with low weed and pest pressures.

4. Use the proper planting equipment, adjusted for conservation tillage, to create a suitable seedbed that promotes seed germination.

5. Scout crops frequently for weed and pest pressures. Build a reference library to evaluate what has worked in the past based on weather conditions, etc.

6. Document surface residue levels, weather conditions, planting populations and conditions, fertilizer applications, and weed and pest control measures.

7. Implement additional conservation practices such as strip cropping, contours, terraces, waterways, and filter strips to enhance total conservation planning efforts.

8. Be patient. Conservation tillage systems can take several years to reach a new equilibrium for soil physical, chemical, and biological properties.

Answers to Conservation Quiz

1. Soil organic matter can be classified as active and stable soil organic matter pools.

2. Soil disturbance buries surface residue and aerates the soil providing ideal conditions for rapid organic matter decomposition by microbes.

3. Soil organic matter improves soil aggregation, water and nutrient holding capacity, infiltration, soil tilth, and productivity.

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Prepared by Mahdi M. Al-Kaisi, Assistant Professor, Department of Agronomy and Mark Licht, Extension Program Specialist, Department of Agronomy.

Reviewed by Mark Hanna, Extension Agricultural Engineer, Department of Agriculture and Biosystems Engineering; Rick Cruse, Professor, Department of Agronomy; and Tom Fenton, Emeritus Professor, Department of Agronomy. Edited by Jean McGuire. Layout by Micki Nelson.

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