



Build soil organic matter to improve your crop production system

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Improving soil quality is an important consideration for every producer, not only to maintain yield, but to build resilience to the potential impacts of climate change, such as heavy downpours and extreme weather variability. However, Midwestern crop production practices have shifted from diversified cropping systems traditionally part of animal-based farming systems to commodity crop-based systems that require external inputs. Increased row cropping with tillage will impact soil quality by reducing soil organic matter content and increasing soil erosion. Researchers with the Sustainable Corn Project¹ are finding that adopting practices which increase soil organic matter also build resilience, fortifying it against degradation and erosion, and improving soil quality.

The interpretation of “improved” or “good” soil quality has been highly subjective and is often associated with the intended use of a particular soil. For example, the coarse-textured soils found in portions of many Midwestern states may not have high

What defines and influences soil quality?



Soil quality is a reflection of both inherent soil properties such as drainage, slope, and texture; and the effects of management practices such as crop rotation, tillage, fertilization, and crop residue management.

apparent quality; but with irrigation, fertilization, and proper management they can be very productive and are often used to grow high value crops.

In 2014, researchers Nakajimi and Lal developed a Soil Quality Index (SQI) to provide a numerical value for soil quality for an Ohio soil that included the measurement and weighting of factors including bulk density, texture, available water content, saturated conductivity, pH, and soil organic carbon. Soil organic carbon had the highest weighting value and the calculated SQI based on these factors was correlated with grain yield. They concluded that a SQI assessment is a useful tool for assessing potential productivity.

¹The Sustainable Corn Project (officially referred to as the Climate and Corn-based Cropping Systems Coordinated Agricultural Project) is a transdisciplinary partnership among 11 institutions: Iowa State University; Lincoln University; Michigan State University; The Ohio State University; Purdue University; South Dakota State University; University of Illinois; University of Minnesota; University of Missouri; University of Wisconsin; USDA Agricultural Research Service – Columbus, Ohio; and USDA National Institute of Food and Agriculture (USDA-NIFA). Project website: sustainablecorn.org.

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Source: Available at sustainablecorn.org and online extension store at Iowa State University

Farmers Rate “Organic Matter” Top Contributor to Soil Quality

Farmers know what makes their soil productive. They recognize the relationship between soil organic matter management and the processes that maintain and improve soil structure. It is well known that soils with good structure (aggregate stability) have better infiltration and water holding capacity, are less easily compacted, allow unrestricted root growth, and are more resistant to erosion.

Wisconsin farmers were polled about what factors they believed contributed most to soil quality on their farms. They were given a list of 40 soil quality indicators from the Wisconsin Soil Health Scorecard (UW Center for Integrated Agricultural Systems). Their “Top Ten” list is shown in the graphic at the right. The Wisconsin farmers listed soil organic matter as the number one factor.



What is soil organic matter?

Soil organic matter is the stable fraction of roots and crop residue, soil organisms, and added organic residues such as manure that have accumulated in the soil.

Soil organic matter content is a relatively constant soil property assuming management practice and environmental conditions are consistent. Soil organic matter is categorized as being either active or stable. Examples of active materials include fresh crop residue, manure, or simple organic molecules secreted by plants or soil organisms, and recently

Top 10 Soil Health Scorecard

Based on a survey of Wisconsin farmers

1. Organic matter 
2. Crop appearance 
3. Earthworms 
4. Erosion 
5. Ease of tillage 
6. Drainage 
7. Soil structure 
8. Soil pH 
9. Soil test phosphorus (P) and potassium (K) 
10. Yield 

dead organisms. Stable materials have undergone considerable decomposition. The latter material, which is also known as humus, is very finely-divided and contributes to the development and maintenance of soil structure and cation exchange capacity. It enhances the soil’s ability to hold onto essential nutrients and buffer against soil acidification.

Humus affects the fate of many processes in the soil. It is the material measured by most routine soil tests. It is difficult to quickly change, but it is possible to monitor changes in its content over time.

Medium and fine textured soils develop structure, or the binding of microscopic individual particles into aggregates that are visible to the human eye. Within these structural aggregates there are pores – spaces where water can be held, oxygen and other gasses can be exchanged, and roots can grow.

Well aggregated soils are productive soils. A simple test that demonstrates aggregate stability is the “slake test.” This is done by simply placing a small amount of a similar soil collected from different management settings (e.g. plowed field and the adjacent undisturbed fence row) in separate plastic cups containing distilled water and gently swirling for a few seconds. Soils that have poor aggregate stability will break apart and the water will quickly become cloudy, whereas a soil with good aggregate stability will remain intact and the water will be relatively clear.



FIGURE 1 | Demonstration of aggregate stability using the slake test at a Wisconsin Soil Quality field day.



What builds organic matter?

Practices that build organic matter include the addition of organic residues such as manure and other by-products, leaving crop residues in the field, reducing tillage intensity, and diversifying rotations to include forages or cereal crops.



What effect does tillage have?

Tillage has a major effect on soil organic matter content. Tillage aerates the soil, increasing the rate of microbial decomposition of crop residues and reducing the soil organic matter content. Tillage also mechanically decreases the size of aggregates.

Tillage Effect on Soil Organic Matter

Tillage has a major effect on soil organic matter content. Tillage aerates the soil, increasing the rate of microbial decomposition of crop residues and reducing the soil organic matter content. Al-Kaisi and Yin (2005) noted that the loss of carbon as CO₂ occurs rapidly after tillage. They compared several tillage systems and found that three weeks after tillage practices that included chisel plowing, deep ripping, and strip-till each lost nearly 40% more CO₂/a than no-till, with moldboard plowing losing more than 70% more CO₂/a than no-till. Low disturbance systems, such as no-till, have generally resulted in improved soil quality characteristics as they preserve soil C. Surface soil samples collected from no-till

systems have had higher aggregate stability, total carbon, microbial activity, and earthworm populations (Karlen et al. 1994).

Tillage Effect on Soil Erosion

Erosion is a significant factor affecting the long-term productivity of Midwestern soils. In addition to reducing soil organic matter and the loss of nutrients; tillage reduces the consolidation of the soil at the surface and mechanically reduces aggregate size. The relationship between erosion and yield response is dependent on the soil type and the soil water holding capacity. In one study, Arriaga and Lowery (2005) found significantly less organic carbon in eroded soils versus slightly eroded soils (see Figure 2). Average yield was 4% lower in eroded areas compared to areas that had slight erosion. Yield reduction was greater in drier years.

Tillage buries crop residue and increases the potential for soil erosion. Residue intercepts the energy contained in raindrop impact, which displaces individual soil particles from aggregates. Residue also protects the soil from sealing, helps maintain infiltration through macropores from earthworms and roots, and creates a physical impediment to overland flow. When a soil is tilled these benefits are lost and the potential for erosion increases.

The USDA periodically estimates soil loss by state. Results are published in a Natural Resources Inventory Survey. As shown in Figure 3, survey results for several Midwestern states show a wide range of soil loss resulting from water processes (sheet and rill erosion) on cropland. Trends over a nearly 30-year period show that some states such as Minnesota and North Dakota have relatively low levels of soil erosion by water processes because of their lower total precipitation and flatter landscape. It should be noted that these states have much higher soil erosion by wind than states further to the east. States that have large areas of sloping soils; such as Wisconsin, Missouri, and Iowa, and also produce a lot of row crops, have much higher soil loss.

In general, soil loss has decreased in the Midwest over the past 35 years; however water erosion rates appear to be increasing in both Iowa and Wisconsin. Soil loss in the 4 to 5 ton/a range, while perhaps considered “tolerable,” still greatly exceeds the rate of soil formation and is not sustainable over decades of crop production. Twenty continuous years of soil loss at 5 ton/a would equal a soil loss of 100 ton/a...or about 10% of the plow layer.

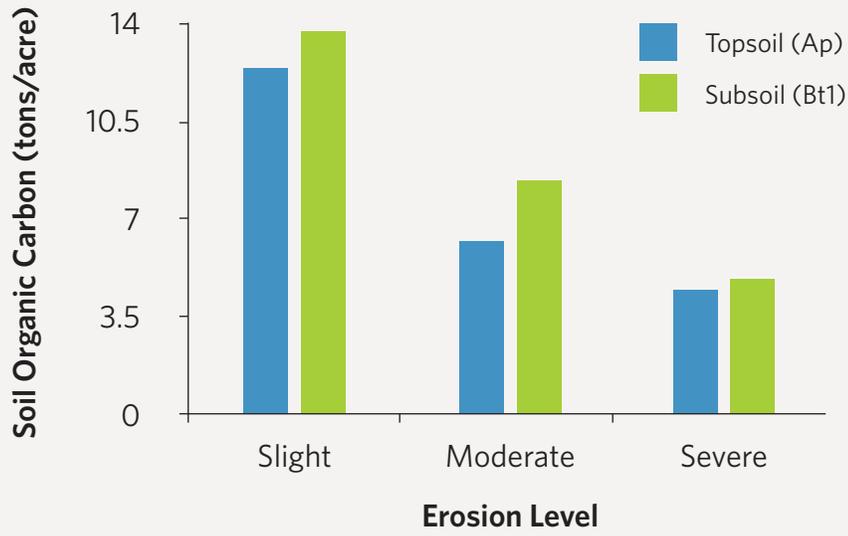


FIGURE 2 | Relationship between erosion level and soil organic carbon (Arriaga and Lowery, 2005).

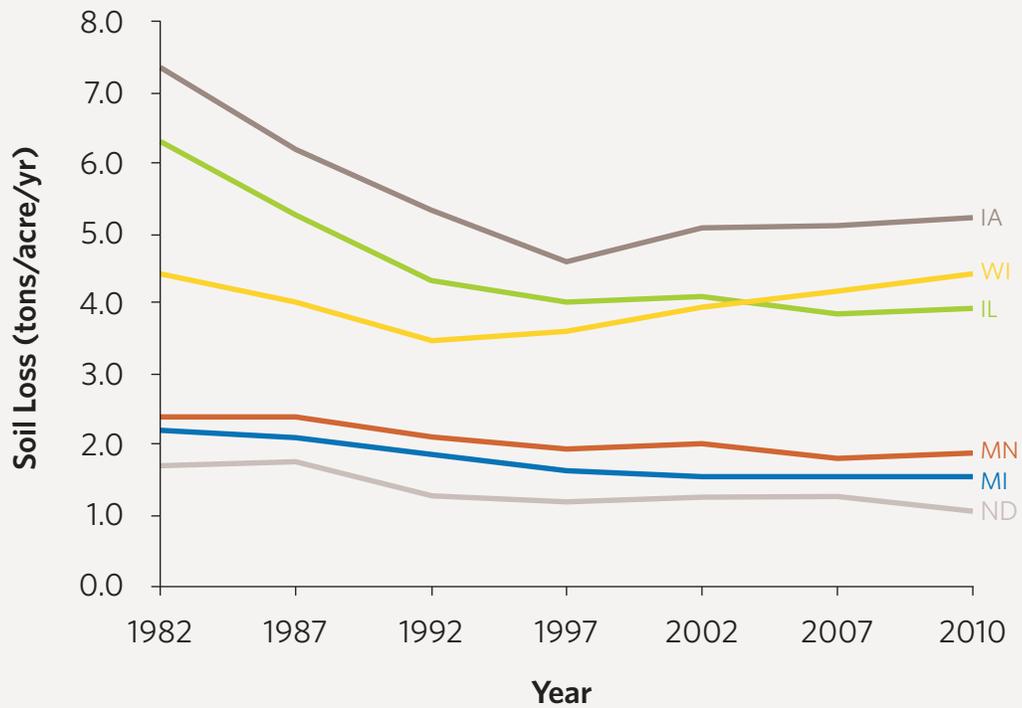


FIGURE 3 | USDA-NRI estimated soil loss caused by water processes (sheet and rill erosion) on cropland in six Midwestern states, 1982-2010.



How does crop rotation increase yield?

It is likely that several factors contribute to this response known as the “rotation effect.” These include nitrogen supplied by the preceding legume crop, improvements in the soil physical condition or tilth.



TABLE 1 | Effect of alfalfa and soybean on the yield of corn grown on a Rozetta silt loam soil, Lancaster, WI, 1995 – 2004 (Schulte et al. 2005)

Nitrogen applied	Continuous corn	Second-year corn after alfalfa	First-year corn after alfalfa	First-year corn after soybean
Pounds of nitrogen per acre (lb N/a)	Corn yield, bushels per acre (bu/a)			
0	57	96	157	102
50	88	130	167	134
100	128	145	170	157
200	141	155	173	164

Crop rotation

A practice that will build soil organic matter and improve soil quality is to adopt crop rotations that include legume forages such as alfalfa. Alfalfa and similar perennial crops develop extensive root systems that build soil organic matter. In today’s production systems there are limited use and value for forages; and many producers no longer have the specialized equipment necessary to cut and harvest the crop.

In some cases, innovative arrangements have been made between neighboring farmers, one being a grain producer and the other who has livestock, where land is swapped and managed appropriately. This type of arrangement can also include additional opportunities for the application of manure to add organic material to more acres and potentially reduces loss of nutrients to surface water.

Research conducted in Wisconsin showed that expanding the corn rotation to include alfalfa or soybean increased corn yield (Schulte et al., 2005).

Table 1 shows that yields were higher when corn was grown after either alfalfa or soybean as compared to continuous corn. Corn yields were higher following alfalfa with an optimized N fertilizer rate lower compared to corn following soybean. It is likely that several factors contribute to this response known as the “rotation effect.” These include improvements in the soil physical condition or tilth. Lauer, et al. (2014) analyzed a paired study that examined the extension of the corn/soybean rotation by adding wheat at locations in Wisconsin and Illinois. Their comparison showed that the addition of wheat increased the yield of all crops in the rotation (Table 2).

TABLE 2 | Effect of extending a corn-soybean rotation with wheat on crop yield at Arlington, Wis. (2004–2012) and Monmouth, Ill. (2002–2013). (Lauer et. al., 2014)

Rotation Sequence	Arlington, WI	Monmouth, IL
Corn yield, bushels per acre (bu/a)		
Continuous corn	190	155
CS	198	203
CSW	207	213
CWS	194	214
Soybean yield, bushels per acre (bu/a)		
Continuous soybean	52	61
SC	63	65
CSW	68	68
CWS	64	70
Wheat yield, bushels per acre (bu/a)		
Continuous wheat	32	--
CSW	74	79
CWS	62	73

C=Corn, S=Soybean, W=Wheat



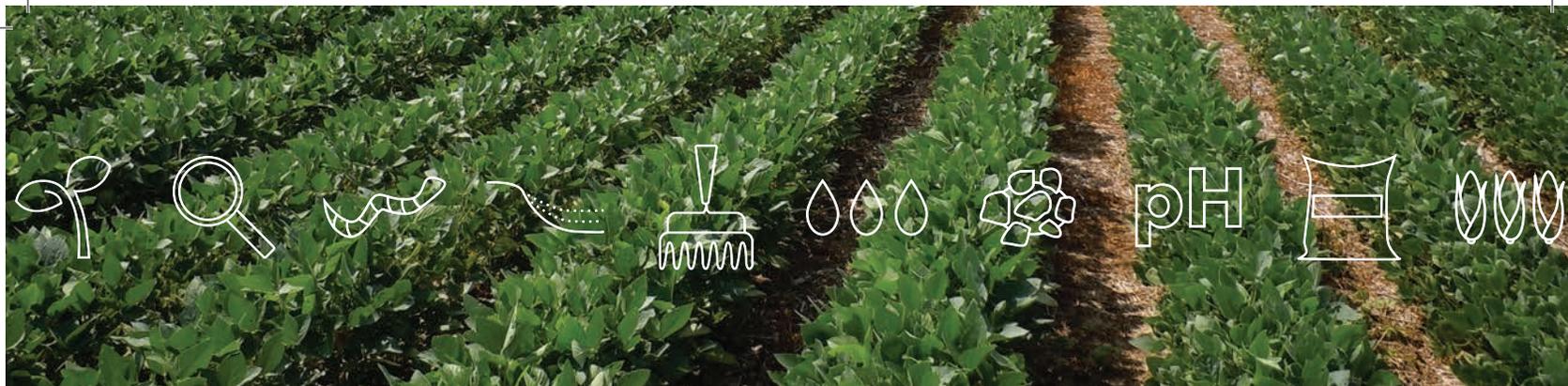
What practices are recommended based on this research?

Adopt crop production practices that build soil organic matter and improve soil quality. Efforts to improve soil quality should begin with the implementation of practices that build soil organic matter such as the addition of organic residues, the reduction of tillage intensity, the diversification of rotations, and avoiding the removal of crop residue for other uses.

Improved soil quality will lead to long-term productivity and protect the soil from the degrading forces associated with soil erosion. Some management practices will result in immediate returns and others will require considerable time. It is expected that improved soil quality will increase a soil's resilience to the impacts of climate change. A key management practice will be the adoption of no-till or similar systems that leave the soil undisturbed and do not incorporate residue. When a soil is intensively tilled it is difficult to maintain its organic matter content

and soil quality factors such as aggregate stability, internal drainage, and resistance to erosion are negatively affected.

Other practices that will provide resilience whenever practical and economical is the planting of perennials on highly erodible soils, using extended rotations that include small grains and forages, and considering the use of cover crops. Each of these options have been shown to build soil organic matter and improve soil quality.



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