SOIL QUALITY- AGRONOMY

Technical Note No.3

Effects of Residue Management and No-Till on Soil Quality

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Soil Quality Institute
411 S. Donahue Dr.
Auburn, AL 36832
334-844-4741
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This is the third note in a series of Soil Quality-Agronomy technical notes on the effects of land management on soil quality. This information is general and covers broad application.

Compared to water or air quality, soil quality is a relatively new concept and relies on indicators, like organic matter, bulk density, nutrient status, and microbial biomass for measuring. Of this, organic matter is probably the most vital in maintaining a quality soil resource. It improves aggregate stability and soil structure, reduces erosion potential, provides energy for microorganisms, is important to nutrient cycling, and improves infiltration, water holding capacity, cation exchange capacity, and the breakdown of pesticides. The best ways to manage organic matter in a cropping sequence are to reduce tillage, plant cover crops, and practice crop rotations to increase organic inputs as root biomass. This technical note focuses on tillage and residue management, as the practices that most influence organic matter levels. Residue management includes no-till that is the method of preparing a narrow slit or strip for a seedbed and leaving surrounding residue cover on the surface undisturbed. Other forms of residue management are mulch till, ridge till and seasonal residue management. Conventional tillage usually includes a moldboard, disk or chisel plowing, and secondary tillage that disturbs the soil surface for seed preparation. This note focuses on the least disruptive form of conservation tillage, no-till. Local soil and climate conditions may dictate other forms of conservation tillage to be used to maintain economic sustainability.

Factors Influencing Organic Matter Levels

The amount of organic matter in soil is the result of the combined influences of climate, inherent soil characteristics, land cover and use, and management practices. When rainfall or irrigation is sufficient, the amount of vegetation (biomass) increases with warmer temperatures, but rates of decomposition of the biomass also increases dramatically. Generally, organic matter increases with higher rainfall and cooler temperatures. Conversely, soil formed under warm, arid climates is usually low in organic matter mostly due to low amounts of biomass production. Soil texture is another influence on organic matter. Clayey soils generally have higher levels of organic matter than sandier soils. Soils with drainage limitations due to landscape position or a slowly permeable layer will generally accumulate more organic matter as a result of slower decomposition from the anaerobic conditions that limit microbial activity, than more freely drained, aerobic soils. Humans influence organic matter through the selection of management practices. Agronomic inputs like adding manure or fertilizers increase vegetative growth (above and below ground), thus increases soil organic matter. Crop diversity, cover and green manure crops, reduced tillage, and rotations with pasture or hay will promote accumulation of surface residue and will generally increase soil organic matter in the surface layer. Conversely, management systems that require intensive tillage and low residue crops result in greater losses of soil organic matter. In the 1850s, the moldboard plow became the standard for primary tillage. The plow turned the soil over and buried most of the residue of the native vegetation or the previous crop residue. The stirring and turning of soil stimulated microbial activity and increased the rates of residual organic matter break down. For example, the Morrow research plots in Urbana, Illinois, established in 1876, had a 23% decline in organic carbon due to tillage (Odell et al., 1982). Soil aggregates

and large pores are disrupted when left unprotected from the impact of raindrops. This reduces water infiltration and increases runoff and erosion. In more arid climates, the unprotected soil surface becomes smooth, making it vulnerable to wind erosion until crusting occurs. Unfortunately, all forms of tillage decrease organic matter to some extent. Therefore, it is difficult to maintain soil organic matter levels when tillage is practiced. Adding organic materials, such as manure, may help maintain or increase the level of organic matter. However, research at Pendleton, Oregon showed that even after 40 years of adding manure at rates over 10 tons per acre per year, residual organic matter levels had not increased mainly due to tillage and summer fallow practices (Rasmussen et al., 1989). Reicosky and Lindstrom (1993) measured carbon dioxide released from soil 19 days after wheat stubble had been plowed. The moldboard plow caused as much carbon to be oxidized as had been photosynthesized in the roots and residue during the whole growing season. This rate was 5 times greater than the untilled plots. In summary, research has shown that it is practically impossible to increase organic matter when the entire land surface is tilled.

Tillage Effects on Organic Matter

Adoption of no-till has increased in acreage from approximately 14 million acres to nearly 41 million acres from 1989 through 1995 (Conservation Technology Information Center, 1996). Some of the benefits of no-till are erosion control, fuel, labor and time savings. Researchers have shown that no-till increases soil organic matter in the surface three inches (Ishmal et al., 1994; Mahboubei et al., 1993). However, the residue cover from no-till protects the soil surface from erosion and preserves the continuity of water conducting pores. The best way to increase organic matter throughout the surface is through the use of cover crops or sod rotations in conjunction with no-till (See Technical notes No. 1 and No. 2). Reicosky et al., (1995), summarized 9 long term no-till studies, all of which showed that organic matter increased an average of 986 pounds per acre per year, or about 0.1 percent per year. Locations of these studies were in the states of Minnesota, Nebraska, Illinois, Ohio, Kentucky, Georgia, and Alabama. Research ranged from 5 to 11 years, and rates of increase ranged from 80 pounds to 2,000 pounds of average annual residual soil organic matter. These increases were the result of no-till, crop rotations with grain crops and cover crops. Increases would not be expected in low residue crops without rotations of grain crops and the addition of cover crops. Increases in organic matter affect properties such as cation exchange capacity, aggregate stability, and available water holding capacity.

Impacts on Aggregate Stability/Soil Structure

Residues, left on the surface, increase aggregate stability. Soil aggregates, in no-till systems, are more stable than in conventional tillage soils due to the added strength provided by products from the decomposition of soil organic matter and presence of bacteria and fungal hyphae. The hyphal material acts like strings that bind or tie smaller aggregates and soil particles together. A demonstration was recently conducted in the Central Valley of California compared cover crops in an orchard tilled annually, to permanent cover crops. To illustrate the benefits of a permanent cover, the researchers placed one clump of soil in a glass of water from the untilled site that had accumulated surface organic matter, and one from the tilled site that had not. The tilled sample began to disperse immediately and the water became very cloudy. The untilled sample with increased surface organic matter was stable and the water remained clear. Surface residues in no-till systems help protect aggregate stability and maintain the continuity of soil pores resulting in increased infiltration rates and reduced soil erosion.

Impacts on Biological Activity

It is generally acknowledged that residues have several positive effects on the microbial populations in agricultural systems. Residue accumulations in the surface 3 inches provide cooler and moister environments than conventional tillage systems. Surface residues provide more substrates or food for nitrifying and denitrifying microbes. The increased residues, with high carbon to nitrogen ratio, slow the rate of mineralization over a longer period of time (Coleman and Crossley, 1996). Soil invertebrate populations such as microarthropods and earthworms increase with less tillage as a result of increased populations of litter-decomposing fungi and help's increase nitrogen availability for plant growth. Research comparing 22 components of no-till and conventional tillage (House, et al. 1984), indicated no-till systems had greater resilience, greater invertebrate species richness, greater soil organic matter, and nitrogen turnover time. The following table highlights some of the components compared between no-till and conventional tillage.

Component	No-Till vs. Conventional
Crop Yields	NT=CT (except during drought)
Weed Biomass	NT>CT
Residue Decomposition Rates	CT>NT
Surface Crop & Weed Residues	NT>CT
Surface Litter (%N)	NT>CT
Nitrification Activity	NT>CT in upper soil layer
Total Soil N	NT>CT in upper soil layer
Organic Matter	NT>CT
Soil Moisture	NT>CT
Foliage Arthropods	CT=NT
Arthropods Species Diversity	NT>CT

High residual organic matter levels increase the general fertility and productive capacity of soil (Moldenhauer et al., 1995). Residual organic matter and slow decomposition rates provide crops with a limited but continuing source of nutrients. Residual organic matter also promotes deeper rooting by improving infiltration and water holding capacity.

Management Concerns

Soil compaction may become a problem with no-till. Limited deep tillage and strip tillage may be useful in breaking up compacted areas without disrupting the entire surface area. Also, no-till crop production in the beginning, may require more chemical weed control, but over time the residue cover increases to the point weed seeds cannot germinate because they are not brought to the surface by tillage. Vines and other perennial weeds can become more prevalent in no-till monoculture systems, because certain weeds may not be controlled by the herbicides. Crop rotations with no-till systems may alleviate some pest and compaction problems. In agricultural soils that have been degraded, it may take 3 to 5 years to see benefits from no-till. However, no-till used in combination with crop rotations and cover crops can be a valuable tool for improving the soil resource.

Summary

Organic matter is one of the most important indicators of soil quality. Some of the beneficial effects of soil organic matter include better aggregation and aggregate stability, longer cycling of nutrients, higher microbial activity, more water holding capacity, greater cation exchange capacity, and lower bulk density. Tillage operations have a significant effect on soil organic matter. Even high inputs of manures have limited success in maintaining levels of soil organic matter if the soil is continually tilled. Following are some beneficial practices for protecting soil organic matter.

1. No-till and other reduced tillage practices leave residues on the surface and protect the soil from wind and water erosion.

Along with crop residue the no-till system increases aggregate stability, organic matter, microbial activity and invertebrates, infiltration, and available water holding capacity.

2. Crop rotations provide biodiversity to reduce insects, weeds, and disease in no-till systems.

3. Cover crops provide protection of the soil surface, add residue, and organic matter to the soil.

4. Rotations that include grass and legumes are good for erosion control and increase organic matter.

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