EFFECTS OF COTTON TILLAGE SYSTEMS ON SOIL QUALITY USING ON-FARM TESTS

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Abstract

Soil functions refer to what the soil does in an ecosystem. Changes in these functions as a result of management are equated with changes in soil quality. The USDA soil quality test kit is a tool that farmers or land managers can use to measure change in soil quality. Long-term studies have shown that converting from conventional tillage to no-till cropping systems improves soil quality (soil functions). The objectives of this study were (1) to demonstrate the use of the kit for measuring relative change in soil quality, and (2) to evaluate the relative differences in soil quality between no-till and conventional tillage systems in continuous cotton (*Gossypium hirsutum* L.). A 10-year no-till field was compared to a conventionally tilled field for differences in soil quality. The soil type on both fields is the Memphis silt loam. Nine soil quality kit tests (aggregate stability, soil slaking, soil respiration, infiltration, soil pH, electrical conductivity (EC), nitrates, bulk density, and water content) were measured. Aggregate stability, slake rating, bulk density, and soil pH measurements indicated better soil quality on the no-till field than on the conventionally tilled field. The no-till field had 70 % less predicted erosion and 60 % more carbon. This suggests that long-term no-till under continuous cotton maintains and improves soil quality over conventional tillage at this site. Adding cover crops to the no-till system would add additional biomass and enhance the soil quality benefits of no-tillage system. The soil quality test kit is a good on-farm tool that can be used to show trends in soil as a result of management.

Introduction

Soil quality is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al., 1997). Soil functions refer to what the soil does in an ecosystem, such as sustaining productivity and biological diversity, regulating and partitioning water and solutes, buffering and degrading pollutants, and storing and cycling nutrients. Changes in these functions as a result of management and use of the soil are equated with changes in soil quality. Soil quality cannot be measured directly but must be inferred from its attributes or indicators (Seybold et al., 1998).

A soil quality field testing kit (Sarrantonio et al., 1996) has been adapted for general use by NRCS field staff to evaluate and raise the level of awareness about soil quality with farmers. (Soil Quality Institute, 1999). The kit contains 11 tests (soil respiration, infiltration, bulk density, water content, electrical conductivity (EC), pH, soil nitrates, aggregate stability, slake test, earthworm numbers, and physical observations) that are used to indicate change in soil quality as a result of management.

No-till systems tailored to local soil and climatic conditions may be one of the best management practices for improving soil quality. When the amount of tillage is reduced or eliminated, biological activity and the soil organic matter content tend to increase resulting in soil quality improvements (Karlen et al., 1992). No tillage preserves residues on the surface and allows soil organic matter levels and soil quality to increase compared to conventional systems (Blevins et al., 1983). Frye and Blevins (1989) also reported increased soil organic matter levels in no-till compared to conventional tillage. They also have shown in continuous no-till corn, greater soil organic matter levels with legume cover crops compared to no cover. Edwards et al. (1992) showed significant differences in soil organic matter levels due to different tillage systems and crop rotations. In over 100 years in conventional tillage, Hubbs et al. (1997) reported better soil quality with cover crops and crop rotation compared to continuous cotton systems. Reeves (1997) suggests that conventional tillage can mask the full benefits of crop rotations and cover crops. Without significant inputs of carbon from crop residues, manure and/or cover crops, no-till alone has been shown only to slow the loss of soil organic matter, not reverse it (Reeves, 1997).

The uniqueness of the long-term research on no-till at the University of Tennessee Milan experiment station provides the opportunity to evaluate the effects of tillage on soil quality. The objectives of this study are (1) to demonstrate the use of the kit for measuring soil quality, and (2) evaluate the relative differences in soil quality between no-till and conventional tillage systems in long-term continuous cotton at the Milan experiment station in Tennessee.

Materials and Methods

A 10-year no-till field was compared to a conventionally tilled (disk-disk-rolled-cultivate) field for differences in soil

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quality under continuous cotton without winter cover crops. The two study fields are located on the Milan experiment station in Tennessee. The fields are approximately a quarter mile apart. The soil type on both fields is the Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs). These soils formed in thick loess on uplands and are well drained. On July 21, 1999, the fields were tested with the soil quality field test kit. The tests conducted were soil respiration, infiltration rate, bulk density, soil water content, soil slaking, aggregate stability, soil pH, EC of 1:1 soil-water mixture, and soil nitrates. Tests were conducted at four sites within each field on the top 3 inches of soil. All test procedures are described in the Soil Quality Test Kit Guide (Soil Quality Institute, 1999). Aggregate stability was performed using the field kit described in Seybold and Herrick (2000) and the slake test as described in Herrick et al. (2000).

Discussion

The data from the kit's tests are presented in Table 1. The soil water contents at both field sites were below field capacity, therefore a direct comparison between their water holding capacities could not be made. The no-till field had significantly greater water content than the conventionally tilled field. The difference was 8% or more than two and half times greater for the no-till field. Greater amounts of soil organic matter can contribute to greater water holding capacities. This was shown to be the case in a comparison between long-term no-till and conventionally tilled fields at Milan on the same soil type (Seybold et al., 2000). In the present study, the no-till field has a higher organic carbon content (1.12% organic carbon) compared to the conventionally tilled field (0.70% organic carbon). The higher organic carbon content of the no-till field indicates a greater potential to hold water.

A similar study at Milan (Seybold et al. 2000), showed more dramatic differences in soil organic carbon (2.31% and 1.12% organic carbon for no-till and conventional, respectively), which was due to the higher residues produced by a crop rotation of corn (*Zea mays* L.)-wheat (*Triticum aestivum* L.)-double crop soybeans [(*Glycine max* (L.) Merr.)]. Adding higher residue cover crops to a continuous cotton system can increase total biomass and thus, increase the potential to store more carbon in the soil (Reeves, 1994).

Soil respiration measures the amount of carbon dioxide (CO_2) given off by the soil. The source of CO_2 is from the respiration of soil organisms and plant roots. Soil respiration was significantly greater on the no-till field than on the conventionally tilled field. However, the soil water content was also significantly higher on the no-till field compared to the conventionally tilled field (Table 1). Soil moisture and temperature greatly affect soil respiration rates. Therefore, the difference in respiration rates between the tillage systems cannot be separated from that which is due to differences in water content.

Infiltration measures the rate of water intake through the soil surface. Infiltration rate is important for determining if water will runoff and cause erosion or infiltrate the soil and be available for plant use. There were no significant differences in infiltration between the tillage systems. The no-till field had higher initial water content, which could be the reason for a slower infiltration rate than for conventional tillage (Table 1). No tillage, with residues left on the surface, has been shown to reduce erosion (Moldenhauer and Wichmeier, 1960) and improve infiltration and water use efficiency (Unger and Phillips, 1973). Erosion prediction at the site, using Revised Universal Soil Loss Equation (RUSLE) was 3 tons/a and 11 tons/a for no-till and conventional systems, respectively. A similar study at Milan also showed an increase in the infiltration rate in no-till compared to conventional tillage (Seybold et al., 2000).

Bulk density is an indicator of compaction and relative restrictions to root growth. There were significant differences detected in bulk density in the top 3 inches of soil between the no-till and conventionally tilled fields. The bulk density in no-till was 1.25 g/cm^3 and 1.37 g/cm^3 for the conventional tillage, which indicates very good conditions for root growth and development in top 3 inches of soil for both tillage systems. Higher soil moisture and increased carbon contents could be contributing to the lower bulk density in the no-till.

Aggregate stability measures the amount of stable aggregates that resist the forces of flowing water. This is similar to the slake test, which measures the stability of soil fragments against the forces of rapid wetting. Both tests indicate the ability of soil to withstand soil disruption by water. Lack of soil aggregation or aggregate breakdown can result in erosion, poor water infiltration, and surface crusting. Aggregate stability of the top 3 inches of soil in the no-till field was about 1.7 times greater than in the conventionally tilled field (Table 1). Higher aggregate stability prevents decomposition of soil organic matter entrapped in the aggregates, decreases soil erodibility, improves water and air movement, and improves the physical environment for root growth and soil organism habitat. The slake test showed a similar trend in soil stability to that of the aggregate stability test (Table 1). The no-till field had a significantly higher slake rating, and thus better soil stability than the conventionally tilled field. The higher aggregate stability and soil slake rating in the no-till field is probably the result of greater organic matter contents and biological activity (Bruce et al., 1990).

The chemical tests in the soil quality test kit showed some significant differences between the two tillage treatments.

Soil pH was significantly higher in the no-till field (5.2) compared to the conventionally tilled field (4.6). Both fields indicated a need for liming. Electrical conductivities of the soil extracts were very low (0.08 and 0.12 dS/m for the no-till and conventional tillage, respectively), and indicate that no excess salts were present. The conventionally tilled field had higher nitrate levels but was not significant.

Conclusions

Aggregate stability, slake rating, bulk density, and soil pH indicate better soil quality (capacity to function) on the no-till field than on the conventionally tilled field. The no-till field had 70% less predicted erosion than the conventional tillage. As a result of residue management, the no-till field had 60% more soil carbon in the top 3 inches compared to the conventional tillage system. This suggests that under continuous cotton systems, long-term no-till can maintain and improve soil quality over conventionally tilled systems at this site. To further enhance soil quality in continuous cotton systems, biomass production needs to be increased, such as by adding winter cover crops. The soil quality test kit was able to show trends in soil quality or compare changes in soil quality as a result of management.

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Table 1. Soil properties measured using the soil quality field test kit. Continuous cotton in conventional tillage and no-till systems was compared for differences in soil quality (values represent the mean of four samples from a field).

	Tillage Systems		
Indicators	**No-till**	**Conventional**	**P values**
Water Content (g/g)	0.13	0.05	0.04
Soil Respiration (lb CO_2-C/a/d)	24.4	17.4	0.03
Soil Temp (C°)	33.3	35.2	0.12
Infiltration (in/hr)	0.5	0.8	0.08
Bulk density (g/cm^3)	1.25	1.37	0.05
Aggregate stability (%>0.25mm)	33.7	20.1	0.03
Slake test	4.8	3.3	0.04
Soil pH	5.2	4.8	0.02
EC (dS/m)	0.08	0.12	0.48
Nitrates (lb NO_3-N/a)	1.6	5.0	0.21

P values greater than or equal to 0.05 were considered significantly different.