# Tillage and Rotation Effects on Soil Organic Matter

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## INTRODUCTION

Maintenance of soil organic matter with its associated physical, chemical and biological benefits has been a problem in arable, humid region soils such as those of the southeastern states. Tillage practices used to produce crops on many southeastern soils over the past two centuries have resulted in widespread erosion and enhanced soil organic matter decomposition rates (Langdale et al., 1985).

Over the past 30 years, however, minimum or no-till practices have been developed that may maintain or even increase surface soil organic matter contents of degraded southeastern soils (Langdale et al., 1985). Minimum or no-tillage is utilized on approximately 48% of arable land in the southeastern states (Follett et al., 1987). These systems employ less tillage, allow greater surface residue cover and have been shown to inhibit soil organic matter losses when compared to conventional tillage systems (Lamb et al., 1985; Havlin et al., 1990; Hargrove, 1990). In addition, reduced tillage systems have been shown to enhance microbial activity and the nutrient supplying capability of surface soils when compared to conventional till systems (Doran, 1980; Hargrove, 1990; Wood et al., 1990).

Crop rotation (or lack of it) and crop type have also been factors controlling surface soil organic matter contents. Row crop culture, and in particular continuous cotton, diminished soil organic matter contents across several land classes in Georgia, while losses of soil organic matter were prevented and in many cases substantial soil organic matter gains were obtained with rotations including cereals or legumes (Gosdin et al., 1949). Similar findings were reported by Hargrove (1990) who concluded that levels of surface soil organic matter contents under no-till were a function of the amount of plant residues added to the soil. Cropping systems with more crops per unit time have been shown to conserve soil organic C and N Wood et al., 1991), and, in particular, double cropping systems in the southeast have prevented losses of soil organic matter (Langdale et al., 1985).

Most previous studies concerning the effect of cultural practices on surface soil organic matter content have concerned tillage. Little information exists, especially on southeastern U.S. soils, on the interactive effects of tillage and crop rotation on soil organic matter content. The objective of this study was to determine the impact of long-term tillage and crop rotation practices on soil organic C and N contents.

## MATERIALS AND METHODS

Soil organic C and organic N were measured on soil samples from a long-term tillage/rotation study at Crossville, Alabama (34° 18' N, 86° 01' W), that was established in 1980. Prior to 1980, the study site had been used for row crop production for more than 50 years. The soil was a Hartsell fine sandy loam (fine-loamy, siliceous, thermic Typic Hapludults). The experimental design was a two (tillage) by three (rotation) factorial with four replications arranged as a split plot with tillage treatments as main plots. Rotations included continuous soybean (*Glycine max* L.) - wheat (*Triticum aestiuum* L.) cover (SW); continuous corn (*Zea mays* L.) - wheat cover (CW); and corn -wheat cover - soybean -wheat cover (CWSW). Tillage treatments included conventional tillage (CT) (moldboard plowing the wheat cover in the spring followed by incorporation of herbicide with a disk) and no-till (NT) (planting in killed wheat residue with a double disk opener planter). Weed control, fertilization and other cultural practices utilized in the study were detailed by Edwards et al. (1988).

Soils from each tillage and rotation combination were sampled on 31 October 1990. Soils were sampled in 0- to 5-, 5- to 10- and 10- to 20-cm depth increments. Thirty soil cores (2.6-cm diameter) were collected per tillage/rotation combination and composited by depth increment. Surface plant residues were excluded from soil cores before sampling. Soil samples collected in the field were sieved to pass 2 mm. Soil organic C was determined with a LECO CHN analyzer. Total N was determined by a Kjeldahl procedure (Bremner and Mulvaney, 1982). Nitrate-N ($NO_3$-N) plus nitrite-N ($NO_2$-N) and ammonium-N ($NH_4$-N) were extracted with 2*M* KCl

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and measured with a Wescan Ammonia Analyzer. Organic N was calculated as the difference between soil total N $NO_3$-N plus $NO_2$-N plus $NH_4$-N.

Amounts of crop residues returned to the various cropping systems were summed for the years 1980 to 1990. Corn and soybean residues returned to the OIl were estimated from grain yields by multiplying grain production for each plot by a residue weight to grain weight ratio of 1.0 and 1.5 for corn and soybean, respectively (Larson et al., 1978). Wheat vegetation returned to the soil was determined from direct areal measurements.

Analyses of variance were performed using the SAS Package SAS Institute, Inc., 1988). Unless noted otherwise, all statistical tests were made at the $a = 0.05$ level.

## RESULTS AND DISCUSSION

After 10 years of cropping, when averaged across soil depth and crop rotation effects, NT had 48% and 47% more soil organic C and N, respectively, than CT management (Table 1). No-till also exhibited a different depth distribution of soil organic C and N than CT; greater amounts of soil organic C and N were found in 0- to 5- and 5- to 10-cm soil layers of NT than in CT. Below 10 cm, amounts of soil organic C and N did not differ between tillage treatments, as evidenced by the significant tillage by soil depth interaction.

Previous studies have shown that amounts of organic C and N stored in surface soils is a function of amount of plant residues added to the soil and soil organic matter decomposition rates (Wood et al., 1990, 1991). In this study it appears that differ-

**Table 1. Soil organic C, organic N and C N as affected by 10 years of Ullage and crop rotation management at Crossville, Alabama.**

| | | Organic C | | | Organic N | | | C:N | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rotation[1] | Depth | CT[2] | NT | Mean | CT | NT | Mean | CT | NT | Mean |
| | cm | g/kg | | | | | | | | |
| SW | 0-5 | 5.7 | 9.3 | 7.5 | 0.51 | 0.77 | 0.64 | 11.3 | 12.2 | 11.7 |
| | 5-10 | 5.6 | 8.8 | 7.2 | 0.48 | 0.75 | 0.61 | 11.6 | 11.8 | 11.7 |
| | 10-20 | 5.8 | 5.8 | 5.8 | 0.48 | 0.44 | 0.46 | 11.9 | 13.2 | 12.6 |
| | Mean | 5.7 | 8.0 | 6.8 | 0.49 | 0.65 | 0.57 | 11.6 | 12.4 | 12.0 |
| CW | 0-5 | 6.2 | 12.0 | 9.1 | 0.44 | 0.99 | 0.71 | 46.5 | 11.9 | 14.2 |
| | 5-10 | 6.2 | 10.5 | 8.4 | 0.53 | 0.68 | 0.60 | 11.8 | 20.2 | 16.0 |
| | 10-20 | 5.8 | 6.3 | 6.1 | 0.47 | 0.68 | 0.58 | 12.1 | 10.5 | 11.3 |
| | Mean | 6.1 | 9.6 | 7.8 | 0.48 | 0.78 | 0.63 | 13.5 | 14.2 | 13.0 |
| CWSW | 0-5 | 5.9 | 10.7 | 8.3 | 0.53 | 0.95 | 0.74 | 11.2 | 11.2 | 11.2 |
| | 5-10 | 5.8 | 9.3 | 7.6 | 0.51 | 0.80 | 0.65 | 11.6 | 11.5 | 11.5 |
| | 10-20 | 5.2 | 5.1 | 5.1 | 0.46 | 0.44 | 0.45 | 11.2 | 11.5 | 11.4 |
| | Mean | 5.6 | 8.4 | 7.0 | 0.50 | 0.73 | 0.61 | 11.3 | 11.5 | 11.4 |
| Rotation Mean | 0=5 | 6.0 | 10.6 | 8.3 | 0.49 | 0.90 | 0.70 | 13.0 | 11.8 | 12.4 |
| | 5-10 | 5.9 | 9.5 | 7.7 | 0.50 | 0.74 | 0.62 | 11.7 | 14.5 | 13.1 |
| | 10-20 | 5.6 | 5.7 | 5.7 | 0.47 | 0.72 | 0.60 | 12.2 | 12.7 | 12.4 |
| Tillage Mean | | 5.8 | 8.6 | 7.2 | 0.49 | 0.72 | 0.60 | 12.2 | 12.7 | 12.4 |

| Analysis of Variance[3] | P>F | $LSD_{.05}$ | P>F | $LSD_{.05}$ | P>F | $LSD_{.05}$ |
|---|---|---|---|---|---|---|
| Tillage (T) | <0.001 | | <0.001 | | 0.628 | |
| Rotation (R) | <0.001 | 0.3 | 0.389 | | 0.205 | |
| Depth (D) | <0.001 | 0.3 | 0.001 | 0.09 | 0.631 | |
| TXR | <0.001 | 0.4 | 0.296 | | 0.967 | |
| TXD | <0.001 | 0.4 | 0.002 | 0.09 | 0.332 | |
| RXD | 0.002 | 0.5 | 0.464 | | 0.533 | |
| TXRXD | 0.124 | | 0.312 | | 0.246 | |

[1]SW = continuous soybean, CW = continuous corn, and CWSW = alternate corn-soybean; wheat (W) was used for a winter cover crop in all systems.

[2]CT = conventional till; NT = no-till.

[3]Tillage has only two means; no LSD value given.

ent amounts and distribution of soil organic C and N between tillage systems were due to differences in crop residue management that lowered soil organic matter decomposition rates under NT in comparison to CT management. Conventional tillage mixed crop residues into the surface soils and promoted a nearly even distribution of soil organic C and an even distribution of soil organic N (Table 1). Greater soil organic C and N under NT than under CT were not due to greater additions of crop residues under NT because amounts of crop residues added to the soil over the 10-year cropping period did not differ between tillage systems (Fig. 1).

Crop rotation interacted with tillage to impact soil organic C concentrations (Table 1). Soil organic C concentrations under no-till increased in the order of SW < CWSW < CW. Lower organic C concentrations were found with CT than with NT management with all cropping systems, and under CT management CW had greater soil organic C concentrations than CWSW or SW. Depth distribution of soil organic C differed among crop rotation treatments with clear stratification of organic C between 0- to 5-, 5- to 10- and 10- to 20-cm depth increments in CW and CWSW systems. Less stratification of organic C was evident in the SW system than in the CW or CWSW systems, as shown by the significant rotation by soil depth interaction. Although no significant rotation effects were observed, soil organic N followed trends similar to soil organic C.

Greater soil organic C and a trend towards greater soil organic N under the CW system followed by the SW and CWSW systems was likely

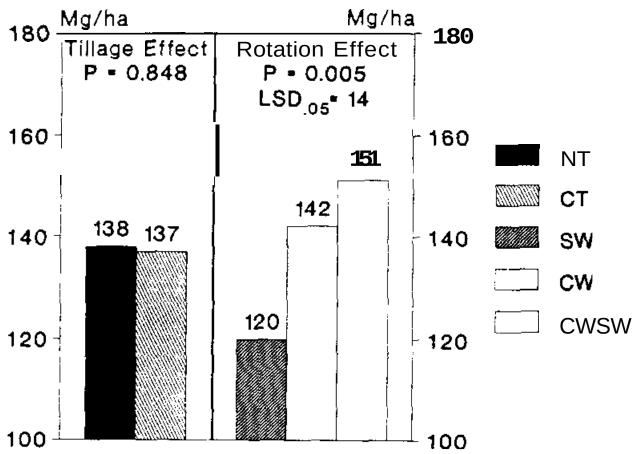


**Fig. 1. Amount of crop residues added to the soil between 1980 and 1990 at Crossville, Alabama as affected by tillage and crop rotation.**

due to greater inputs of crop residues into the CW system (Fig. 1). Several long-term studies have shown a strong relationship between soil organic C and N levels and plant residue inputs into the soil (Havlin et al., 1990; Hargrove, 1990; Parr and Papendick, 1978). Soils under crop rotations including soybeans have been shown to have less soil organic C and N than soils under rotations including grain sorghum (Havlin et al., 1990), and this agrees with the findings of this study when rotations including corn and soybeans are compared.

Greater soil organic C and N under the CW system than under the CWSW or SW systems may not have been due entirely to greater additions of crop residues under CW, because crop residues added over the 10-year cropping period did not differ between the CW and CWSW systems (Fig. 1). Higher C:N ratios of corn residues than of soybean residues and subsequent greater resistance to decomposition of corn residues in comparison to soybean residues (Parr and Papendick, 1978) may have been factors promoting greater soil organic C and N concentrations in the CW system than in CWSW or SW systems.

Soil C:N ratios generally widen with decreased tillage and increased addition of crop residues (Black, 1973). In this study, soil C:N ratios tended to be higher in CW systems and under no-till management, although no significant effects were observed (Table 1). Lack of difference in soil C:N ratios between tillage or rotation systems was probably due to similar magnitude of difference in soil organic C and N between the various tillage and rotation treatments.

## CONCLUSIONS

Soil organic C and N waa greater under NT than under CT management after 10 crop years. Differences in soil organic matter between tillage systems were a function of crop residue management instead of total crop residue inputs over the 10-year period. The results of this study indicate that rotations including corn conserve more organic C and N than those including soybean. Greater soil organic C and N under rotations including corn (CW and CWSW) than those with soybean only were a function of amount of crop residue added to the soil under CW and CWSW and were probably enhanced by slower decomposition rates of corn in comparison to soybean residues.

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