SOIL RESPIRATION RATES AFTER 25 YEARS OF NO-TILLAGE

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ABSTRACT

Long-term conservation tillage management results in changes in the chemical and physical properties of soil, which likely affect CO_2 flux rates to the atmosphere. Our objective was to compare respiration rates of soil that had been in no-tillage management for 25 yrs to soil that was managed with conventional tillage. Soil respiration was measured in disked and no-tillage plots in 2003 on a Norfolk loamy sand soil (fine-loamy, siliceous, thermic *Typic Kandiudult*). This tillage experiment was established in 1978 and the surface 2-in of the no-tillage and disked tillage plots differed in soil C content. Measurements were collected for approximately 50 days during the summer and during the fall. Soil respiration rates during the summer ranged from 0.6 to 22.7 gm CO_2 m^{-2} hr^{-1} for disk tillage and from 0.6 gm to 1.4 gm CO_2 m^{-2} hr^{-1} for no-tillage. Soil respiration rates in the fall ranged from 0.3 to 3.7 gm CO_2 m^{-2} hr^{-1} for disk tillage and from 0.2 gm to 0.6 gm CO_2 m^{-2} hr^{-1} for no-tillage. Respiration rates within a season were highly dependant on soil water content, especially following disk tillage. Although respiration rates were usually much lower for no-tillage, the two tillage systems had generally had similar coefficients of variability for soil respiration. Low respiration rates with conservation tillage even after 25 yrs suggests that intensive cropping with high residue crops should cause the surface soil organic matter content to continue to increase.

INTRODUCTION

Many southeastern USA soils have low water and nutrient holding capacity because of their sandy texture and low organic matter concentrations. Conservation tillage production systems have the potential to increase the productivity of these soils by increasing soil C content. Understanding the dynamics of CO_2 losses to the atmosphere in different tillage systems aids in the development of systems to enhance C sequestration in these soils.

Buyanovsky and Wagner (1983) found that soil air CO_2 concentrations under crops could reach levels approaching 8% depending on time of year and the position in the profile. Tillage causes a high short-term flux of CO_2 from the soil (Reicosky and Lindstrom, 1993; Prior et al., 2000) due to a rapid physical release of CO_2 from the soil. In the weeks following tillage, the burying of crop residues with tillage results in CO_2 flux rates that are higher than when residues are left on the surface (Reicosky and Lindstrom, 1993). Dao (1998) compared moldboard plowing to no-tillage for soil CO_2 flux following wheat in the 11th year of a field tillage study and found the cumulative CO_2 evolved from the soil in a two-month period was much higher for moldboard plowing than for no-tillage.

Increasing soil productivity potential, together with environmental concerns about the rising global atmospheric CO_2 concentration, has created the need for greater knowledge on carbon sequestration in soils and the dynamics of soil C losses. We used plots that were established in 1978 to compare tillage management systems for soil CO_2 flux. The objectives were to compare disk tillage to no-tillage for soil CO_2 flux for several weeks following the disk tillage operation and to determine whether long-term no-tillage reduces the amount of variability for this measurement.

MATERIALS AND METHODS

Data were collected in 2003 during the 26th year of a tillage experiment on a Norfolk loamy sand soil at Clemson University's Pee Dee Research and Education Center near Florence, South Carolina. Two tillage systems, disk tillage and no-tillage, have been maintained since the beginning of the study. Disk tillage consisted of disrupting the soil surface to a depth of 4 to 6 inches with a disk harrow followed by smoothing with a S-tined harrow equipped with rolling baskets. Crops grown during the previous 25 years included corn (*Zea mays* L.), winter wheat (*Triticum aestivum* L.), soybean [*Glycine max* (L.) Merr.], and cotton (*Gossypium hirustum* L.) (Karlen et al., 1996; Hunt et al., 1997). Two identical sets of plots were established in 1978, and there were five replicates of both tillage systems within each set. Each plot was 75 ft wide and 200 feet long.

Since 1996, a two-year corn - winter wheat - soybean rotation was grown on the plots. Each year corn was grown on one set of the plots and doublecropped wheat and soybean were grown on the other set. The wheat and soybeans were grown in 7.5-in wide rows and planted with a John Deere model 750 drill. From 1996 through 2000, corn was grown in 30-in wide rows and planted with a six-row Case-IH model 800 planter. Beginning in 2001, corn was grown in 15-in wide rows planted with a Monosem planter equipped with Yetter wavy coulters. Soil fertility and weed control programs used were typical for these crops in this area.

Soil CO_2 flux was measured during the summer and during the fall of 2003 with a Li-Cor 6000-09 soil respiration chamber connected to a Li-Cor 6250 CO_2 analyzer. Moisture content of the surface 2.5" was determined with a Delta T Soil Moisture Meter at the same time and in the same area (within 12") of each soil respiration measurement. Temperature of the chamber air was also measured.

The summer measurements were collected on 17 dates in one set of plots after wheat harvest. On 9 June, assigned plots were disked twice and then smoothed. On 10, 11, 12, and 13 June, data were collected at 20 places within each plot. Subsequent measurements in the summer were at five places within each plot. Soil respiration measurements were collected on 13 dates following corn during the fall. On 20 October, the assigned plots were disked twice and then smoothed. Soil respiration was measured at 10 places within each plot from 21 October through 3 November and thereafter at five places within each plot. Data were collected from three replicates during each season. Soil CO_2 flux measurements were made in plots that were last subsoiled in 1995.

Means and standard deviations for disk tillage and no-tillage were calculated for each measurement time. Coefficients of variability were calculated for each tillage system at each measurement time.

RESULTS AND DISCUSSION

Tillage had a substantial influence on soil respiration rates. In the summer, average soil CO_2 flux rates did not vary much in the no-tillage plots, ranging from 0.6 to 1.4 gm CO_2 m^{-2} hr^{-1} (Figure 1a). Summer soil CO_2 flux rates were more dynamic in the disk tillage plots, ranging from 0.6 to 22.7 gm CO_2 m^{-2} hr^{-1} (Figure 1a). Similarly, in the fall average soil CO_2 flux rates ranged only from 0.2 to 0.6 gm CO_2 m^{-2} hr^{-1} in the no-tillage plots but from 0.3 to 3.7 gm CO_2 m^{-2} hr^{-1} following disk tillage (Figure 2a). Previous research has shown that tillage increases soil respiration (Reicosky and Lindstrom, 1993; Dao, 1998).

Soil water content was consistently higher in no-tillage than in disk tillage both in the summer and in the fall (Figures 1b and 2b). With only small differences in soil respiration rates within a season for no-tillage, there was little impact of soil water content on respiration rates with that production system. Changes in soil respiration rates were more closely tied to changes in soil water content in the disk tillage system. For example, at the first two measurement dates (10 and 11 June) rates for the disk tillage plots were about 1.1 gm CO_2 m^{-2} hr^{-1}, even though a consider amount of wheat residues were incorporated through disking on 9 June. A 0.86-in rain occurred during the evening of 11 June. Soil CO_2 flux increased dramatically to 13.6 gm CO_2 m^{-2} hr^{-1} on 12 June (11 June was the second and 12 June was the third measurement time in Figure 1a) as a result of this rain wetting the soil surface (Figure 1b). Rates remained very high through the next two measurement times. At the sixth measurement time (23 June, day 174) the soil had dried and soil respiration rates declined. Wetting and drying of the soil had a similar (though less dramatic) affect on soil respiration rates throughout the rest of the summer and throughout the fall.

For both tillage systems, soil respiration rates (averaged over all measurement times) were greater in the summer than in the fall. For no-tillage, the respiration rate during the summer averaged 0.8 gm CO_2 m^{-2} hr^{-1} while the average rate in the fall was 0.4 gm CO_2 m^{-2} hr^{-1}. For disk tillage, the average rates were 6.0 gm CO_2 m^{-2} hr^{-1} in the summer and 1.6 gm CO_2 m^{-2} hr^{-1} in the fall. Part of the reason for the higher rates in the summer could have been due to differences in seasonal temperature as has been reported previously (Buyanovsky et al., 1986). Air temperatures during the summer measurements were between 26.9 C and 36.5 C, while temperatures in the fall ranged from 15.2 C to 28.4 C (Figure 3).

Another reason for the higher respiration rates in the summer could have been the difference in the productivity of the crop grown before these data were collected. The wheat grown prior to collecting the summer measurements was stressed from lack of water in the spring and yielded only 32 bu ac^{-1}. The corn-growing season, on the other hand, was excellent and corn yields averaged 150 bu ac^{-1}. Since 100 lb N ac^{-1} was applied to the wheat and 120 lb N ac^{-1} was applied to the corn, much more N was probably removed prior to the fall soil respiration measurements. This suggests that the C:N ratio in the soil was much more favorable for microbial degradation of residues and soil organic matter in the summer than in the fall. Sarrantonio (2003) measured higher respiration rates on soil with a legume mulch than on soil with a cereal mulch, and soil nitrate-N was greater in soil with the legume mulch. Further, the highest respiration rates in our study with disk tillage were considerably greater than rates found in previous studies (Reicosky and Lindstrom, 1993; Dao, 1998) while rates in the fall were similar to those previously reported. Although further research is needed, these findings may indicate that yield-reducing drought, through both reduced crop residue biomass production and reduced removal of N (which then serves to increase microbial degradation of residues when soil water status is favorable), may have a significant impact on C sequestration.

Although mean respiration rates often differed considerably between the two tillage systems both in the summer and in the fall, coefficients of variability of the two tillage systems were similar (Figure 4). Coefficients of variability ranged from about 20% to 80%. Rochette et al. (1991) found a large sample number is needed to determine statistically significant differences among tillage systems for soil CO_2 evolution because both spatial and temporal variation are usually high with soil respiration measurements. Our data suggest that even long-term no-tillage management will not lessen the need for high sampling intensity.

In summary, rainfall events had little influence on soil respiration in no-tillage, but rates in disked soil were closely related to soil water content both in the summer and in the fall. Our data agree with previous studies (Reicosky and Lindstrom, 1993; Dao, 1998) in that conservation tillage substantially reduces the maximum rates of soil respiration compared to tillage systems that disturb the soil. Low respiration rates with conservation tillage even after 25 yrs suggests that intensive cropping with high residue crops should cause the surface soil organic matter content to continue to increase.

DISCLAIMER

Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA, and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Figure 1. Soil CO_2 flux (a) and soil water content (b) during the summer of 2003 at Florence, SC in soils that were disked and in soils managed with no-tillage since 1978. Data presented are means plus or minus the standard deviation.

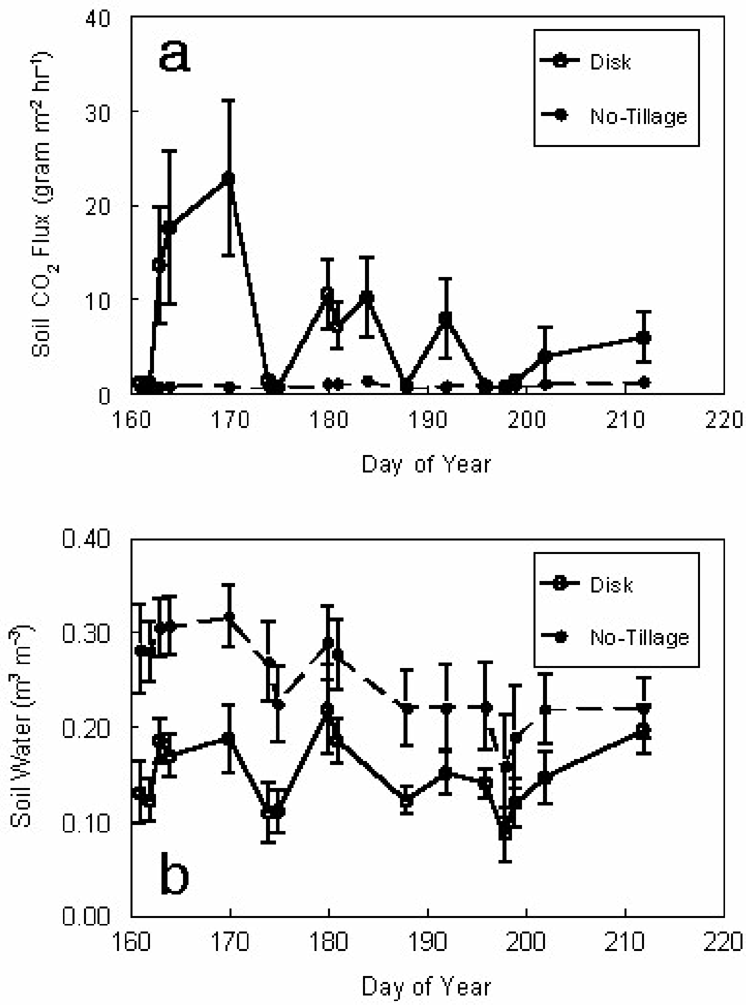

Figure 2. Soil CO_2 flux (a) and soil water content (b) during the summer of 2003 at Florence, SC in soils that were disked and in soils managed with no-tillage since 1978. Data presented are means plus or minus the standard deviation.

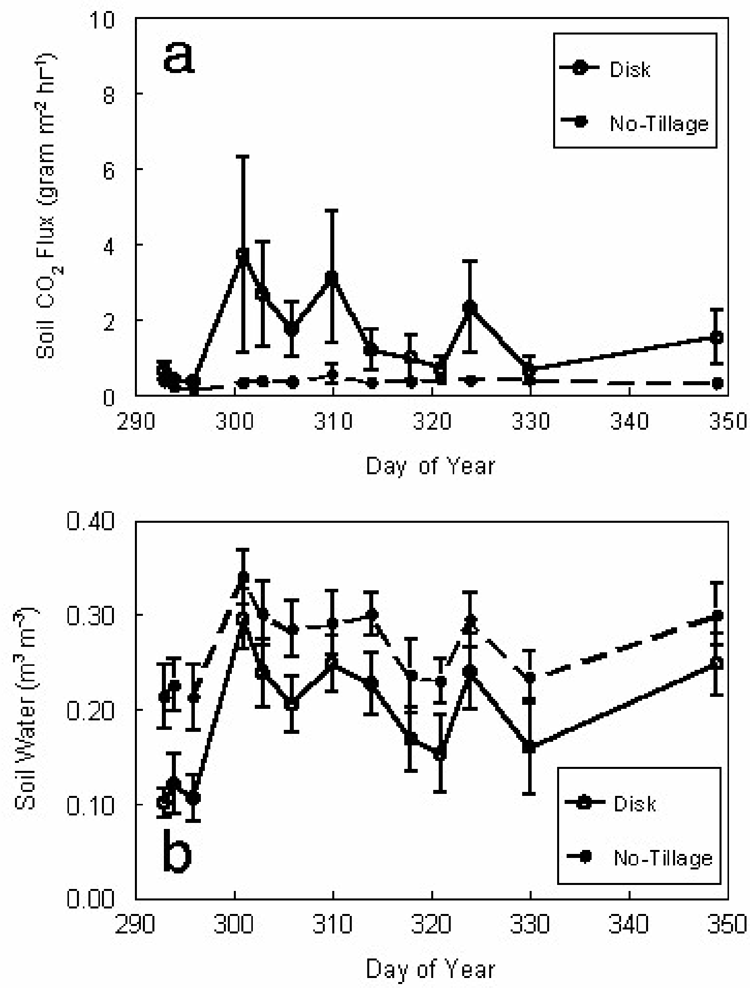

Figure 3. Average air temperature in the soil respiration chamber during the summer and fall measurements in 2003 at Florence, SC.

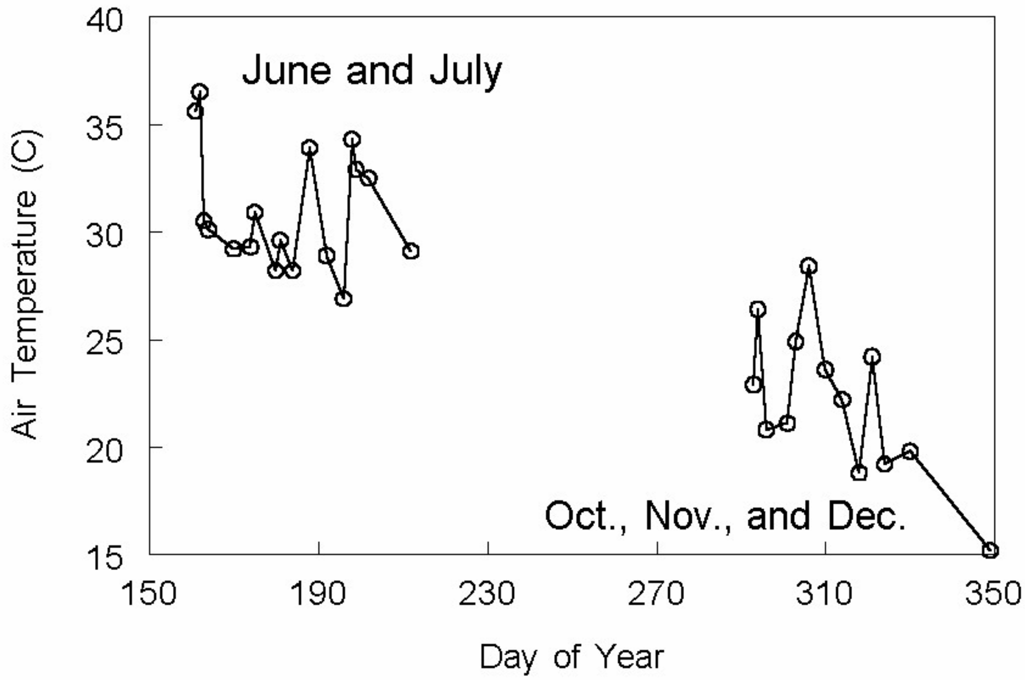

Figure 4. Coefficients of variability for the disk (open circles) and no-tillage (closed circles) soil respiration measurements at each measurement time during the summer and fall in 2003 at Florence, SC.