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Interactive Effects of Wheel-Traffic and Tillage System on Soil Carbon and Nitrogen

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ABSTRACT

Wheel-traffic induced soil compaction has been shown to limit crop productivity, and its interaction with tillage method could affect soil nutrient transformations. A study was conducted during 1993-1994 to determine interactive effects of tillage method (conventional tillage and no-tillage) and wheel-traffic (traffic and no traffic) on soil carbon (C) and nitrogen (N) at a long-term (initiated 1987) research site at Shorter, Alabama. The cropping system at this study site is a corn (*Zea mays* L.) - soybean [*Glycine max* (L.) Merr] rotation with crimson clover (*Trifolium incarnatum* L.) as a winter cover crop. Soil organic C, total N, and microbial biomass carbon (MBC) were not significantly affected by six years of traffic and tillage treatments. However, conventional tillage compared to no-tillage almost doubled the amount of CO_2-C respired over the entire observation period and during April 1994 field operations. Soil respiration was stimulated immediately after application of wheel-traffic, but notrafficked soils produced greater amounts of CO_2-C compared to trafficked soils during other periods of observation. Nitrogen mineralization was significantly lower from no-tillage-trafficked soils compared to conventional tillage-trafficked and no-tillage-nontrafficked soils for the 1993 growing season. A laboratory incubation indicated the presence of relatively easily mineralizable N substrates from conventional tillage-trafficked soil compared to conventional tillage-nontrafficked and no-till-trafficked soils. For the coarse textured soil used in this study it appears that conventional tillage in combination with wheel-traffic may promote the highest levels of soil microbial activity.

INTRODUCTION

Declining soil productivity due to intensive tillage and soil erosion has brought about a renewed interest in reduced no-tillage farming as a method of sustaining agricultural production. The C and N conserving nature of reduced or no-till soils as compared to conventionally tilled soils is well documented (Blevins et al., 1983; Havlin et al., 1990; Wood and Edwards, 1992). With no-tillage, plant residues remaining on the soil surface decompose more slowly resulting in more C and N being retained in the soil than when residues are incorporated into the soil profile (Holland and Coleman, 1987).

Powlson and Jenkinson (1981) reported that a change in microbial biomass C should provide early warning of changes in soil organic matter, long before changes in total C and N become measurable. Although it is well established that microbial biomass is higher in surface layers of no-tillage soils than conventional tillage soils, the effect of cultivation on microbial biomass of the plow layer is unclear. Follett and Schimel (1989) found decreased microbial biomass as tillage intensity increased, but several studies have concluded that there is no significant difference in microbial biomass between conventional and no-tillage agroecosystems (Powlson and Jenkinson, 1981; Lynch and Panting, 1982; Grace et al., 1993).

Soil respiration (CO_2-C efflux) is a measure of the rate of organic matter decomposition. An explanation of crop residue placement effects on soil respiration has been suggested by Blevins et al. (1984). Immediately following tillage events there is a flush of microbial activity due to incorporated organic substrates. However, after the flush of activity and breakdown ofreadily available substrates, respiration in no-tillage is higher because of more favorable conditions in the soil ecosystem. Presumably, because of the large release of CO, during the tillage event, the annual CO_2 efflux from tilled soils exceeds that from no-tilled soils (Hendrix et al., 1988).

Tillage method has been reported to regulate N cycling in soil agroecosystems (House et al., 1984). Reports from Dowdell and Cannel1 (1975) and Dowdell et al. (1983) indicate that cultivated soils result in a greater rate of N mineralization compared to no-tillage soils. Contrary to sources cited above, Follett and Schimel (1989) found that mineralization of N was higher from no-tillage and stubble-mulch than from the plowing.

Negative effects of soil compaction on plant growth have been attributed primarily to a restriction of root growth. It has been suggested that soil compaction could affect the size and activity of the microbial biomass and, therefore, result in changes in cycling patterns of nutrients needed for plant growth (Griffin, 1978; Dick et al., 1988). Soil compaction may affect microbial and biochemical parameters because of alterations in soil porosity, water infiltration, and diffusion rates of gases and liquids. In one of the few field studies addressing the impacts of compaction on soil C and N transformations, Dick et al. (1988) found that compacted skid trails contained lower levels of organic C in 10-20 cm depths and lower levels of total N in 0-20 cm depths than a control treatment. They also found that biomass C decreased by 38% in the 10-20 cm depth of compacted skid trails as compared to the control treatment. Biomass C had significant negative correlations with bulk density in that study. Likewise, studies have also shown a decreasing N mineralization with increasing bulk density (van der Linden et al., 1989; Whisler et al., 1965).

The role of tillage and residue management in nutrient transformations has been, and continues to be, the subject of much research. The role of soil compaction in these transformations has not been greatly studied and there remains a lack of research investigating the biological effects of soil compaction and its interaction with tillage/residue management systems. The purpose of this study was to determine seasonal changes occurring in C and N cycling due to tillage/residue management and traffic-induced soil compaction in a corn-soybean winter-legume cropping system. An incubation study was conducted in conjunction with the field study to further explain changes in C and N pools.

MATERIALS AND METHODS

Field Study

This study was part of a continuing long-term (initiated in 1987) project designed to determine the interactive effects of tillage method and wheel-traffic (compaction) on crop yields, crop quality, and soil properties (Reeves et al., 1992). The study site soil was a Norfolk loamy sand (tine, loamy, siliceous, thermic Typic Kandiudult) located at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station near Shorter, Alabama (32°24.5'N, 85°57'W) Tillage and compaction treatments selected for study included conventional tillage (disk/field cultivate) and no-tillage, and wheel-traffic or no traffic, respectively. The treatments investigated received a one-time-only subsoiling (45 cm deep, 25 cm spacing) in 1987 when the study was initiated. The subset of treatments from the larger long-term study was analyzed as a randomized complete block with four replications arranged as a split plot arrangement. Wheel-traffic treatments were main plots and tillage treatments were subplots. The cropping system at the study site, on which tillage and compaction treatments were imposed, was a corn (*Zea* *mays* L.) ‘Dekalb 689’ - soybean [*Glycine max* (L.) Merr.] ‘Delta and Pineland 105’ rotation with crimson clover (*Trifolium incarnatum* L.) ‘Tibbee’ as a winter cover crop. The study reported here was conducted during June 1993 to August 1994 to determine seasonal dynamics of soil organic C, total N, respiration, MBC, and *in situ* N mineralization as impacted by tillage system and traffic-induced compaction. Soybean was the summer crop of 1993, followed by a winter crimson clover crop. Corn was the summer crop of 1994.

Field activities were carried out using an experimental wide-frame tractive vehicle (WFTV) (Monroe and Burt, 1989). The WFTV spanned the 6.1-m-wide research plots and performed field operations without applying traffic to the plots. To simulate normal wheel-traffic on trafficked plots a 4.6-Mg tractor was utilized. Since 1987, fall traffic applied was random, simulating operations for harvesting and planting winter cover crop. The tractor was driven in trafficked plots during spring field preparation and planting, simulating operations used by a grower employing four-row equipment, i.e., every other row received wheel-traffic.

In the fall of 1987 and 1988, a cover crop of ‘Cahaba White’ vetch (*Vicia sativa* L.) was planted. Since that time the cover crop has been the aforementioned crimson clover. Prior to 1990, all plots received a fall disking to aid in cover crop establishment. Since 1990, the cover crop has been planted with standard no-till practices.

The crimson clover cover crop was generally killed with a herbicide three to four weeks prior to planting of the summer crop. The 1993 soybean crop was planted on 15 June in 75-cm rows at a seeding rate of 468,000 seed ha^{-1}. Tillage in the conventional tillage treatment occurred 18 days prior to planting and consisted of two trips with a disk (15 cm depth) and one with a field cultivator. Wheel-traffic was applied 17 days after planting (DAP) the 1993 soybean crop. Soybean harvest occurred 28 October 1993 (135 DAP). The cover crop was drilled on 2 November 1993.

The cover crop was killed on 24 March 1994 in preparation for the 1994 corn planting. Tillage in the conventional tillage treatment occurred on 5 May 1994, six days before planting and wheel-traffic were applied. The tillage operation involved two trips with a disk followed by one trip with a field cultivator. Corn was planted 11 April 1994 in 75 cm rows at a seeding rate of 59,000 seeds ha^{-1}, and the stand later thinned to 49,400 plants ha^{-1}. Wheel-traffic was applied to compaction plots the same day to simulate events occurring in a grower’s operation. Soil samples (0-20 cm depth) were collected bi-weekly during the growing season and monthly during the winter. Microbial biomass carbon was extracted following the procedures of Vance et al. (1987), and dichromate digested as suggested by Snyder and Trofymow (1984). Organic C and total N were determined with a LECO CHN-600®(LEC0 Corp., St. Joseph, MI)[1] analyzer on soil samples (0-20

[1]Trade names and products are mentioned solely for information. No endorsement by the Alabama Agricultural Experiment Station or U.S. Department of Agriculture is implied.

cm depth) collected in July and October of 1993 and in January and May of 1994. All measurements or samples were taken in row-middles and measurements made in trafficked plots were taken in row-middles that had received wheel-traffic. density measurements (3-8 cm) were made during the spring of 1993 using the core method (Blake and Hartage, 1986).

Soil respiration was measured bi-weekly during the growing season and monthly during the winter. Four measurements were taken per plot. Respiration was measured using an Environmental Gas Monitor (EGM) (PP Industries Stotford, Hitchin, Gertts SG5 4LA, UK). Carbon dioxide evolution was measured in g CO, $m^{-3}h^{-1}$ and is reported as CO_2-C m^{-2} h^{-1}.

In situ N mineralization was quantified by ion exchange resins (IER) (Crabtree and Kirby, 1985; Binkley et al., 1986). Soil samples were taken to determine initial inorganic N (NO_3-N and NH_4-N) levels in the soil. Initial inorganic N was quantified 7 days prior to inserting IER for the 1993 growing season and 12 days after inserting IER for the 1994 sowing season. Resin bags were constructed by placing a PVC ring within a nylon foot sock and filling each sock with a mixed bed resin [10 g of both anion exchange resin (A-400) and cation exchange resin (C-100); Purolite Co., Bala Cynwyd, PA]. An aluminum cylinder (7.3 cm diameter x 20 cm long) was used to extract an undisturbed soil core, displace approximately 2 cm of soil from the each resin bag bottom of the soil core, and insert a resin bag h the bottom of each core. The aluminum cylinders allowed for quantification of N mineralized without plant uptake of inorganic N. Four aluminum cylinders per plot were installed. At the end of each growing season inorganic N was measured on soil inside the core and that trapped on the IER. All soil and resin NO_3-N and NH_4-N were extracted with 2M KCL and analyzed calorimetrically with a LACHAT autoanalyzer (LACHAT QuikChem Systems, Milwaukee, WI). Nitrogen mineralization was calculated by subtracting initial soil inorganic N from the amount an the IER plus the ending inorganic N measured from soil inside the aluminum cylinder.

Laboratory Study

Soil for the laboratory incubation study was collected (0-10 and 10-20 cm depths) in February 1994. Soil organic C, total N, and soil potential C and N mineralization were measured following the techniques of Wood et al. (1990).

Prior to initiating the incubation, soil organic C, total N, and inorganic N (NO,-N and NH_4-N) were measured. At the end of the 30-day incubation, soil inorganic N and respired CO_2-C were measured. Organic C, total N, and inorganic N were determined as previously described. Carbon dioxide released was determined by titrating excess NaOH with 1M HCL in the presence of $BaCl_2$ (Anderson, 1982).

Analyses of variance were performed using the SAS package (SAS Institute, 1988). Where time or depth was a factor, data was analyzed as a split-split plot with wheel-traffic as main plots, tillage as subplots, and time or depth as sub-subplots. All statistical tests were performed at the α=0.05 level.

RESULTS AND DISCUSSION

Field Study

After six years of tillage and traffic treatments, over all sampling dates, there were no significant differences in organic C and total N concentrations in 0-20 cm depth owing to tillage method or wheel-traffic. Organic C concentrations in the 0-20 cm depth for no-tillage-no traffic, no-tillage-traffic, conventional tillage-no traffic, and conventional tillage-traffic soils were 4.22, 4.68, 4.59, and 4.59 g kg^{-1}, respectively. Likewise, soil total N concentrations were 0.39, 0.44, 0.44, and 0.44 g kg^{-1} for no-tillage-no traffic, no-tillage-traffic, conventional tillage-no traffic, and conventional tillage-traffic soils. These data are contrasted by findings of a study conducted by Wood and Edwards (1992) in northern Alabama, which showed higher levels of soil organic C and N with reduced tillage (0-10 cm) after 10 years of treatments. Our findings also differ from those of Dick et al. (1988). who showed significantly lower levels of organic C (10-20 cm) and total N (0-20 cm) as a result of compaction in skid bail soils.

As expected, soil bulk density (3-8 cm) was impacted by wheel-t&tic treatments (P 0.0003). Soils receiving wheel-traffic had a higher bulk density (1.6 1 Mg m^{-3}) as compared to nontrafficked soils which had a bulk density of 1.32 Mg m^{-3}.

Microbial biomass carbon levels were significantly affected by the interaction of traffic, tillage, and sampling date (P 0.05; Figure 1). There was a trend for conventional tillage soils to have higher levels of MBC than no-till soils (P 0.12). However, there was no consistent effect observed from treatment interactions on MBC, except on sampling dates immediately following tillage (Figure 1).

In 1994, five measurements were taken in the three weeks immediately following tillage and traffic events to investigate immediate effects of tillage and compaction on MBC. Tillage had a significant effect on MBC during 1994 field operations (P 0.01). Conventional tillage soils had significantly higher levels of MBC than no-till soils (Figure 2). Before wheel-traffic application, conventional tillage in combination with traffic had the highest MBC levels immediately following tillage (Figure 2). Five and nine days later, MBC from the conventional tillage-traffic treatment remained highest, though the difference was not significant (Figure 2). These results are similar to findings of Lynch and Panting (1980), who found higher microbial biomass (0-5 cm depth) under tillage compared to no-till immediately following tillage. However, their study showed higher microbial biomass from no-till compared to conventional tillage during all other sampling dates in the 0-5 cm depth.

Dick et al. (1988) reported that compaction decreased MBC (10-20 cm depth) on a forest soil. However, we found no detrimental effects on MBC owing to compaction in our study. van der Linden et al. (1989) reported soil compaction decreased available pore space, which slowed the rate at which organic substrates were incorporated into and released from microbial biomass, on a silt loam soil,

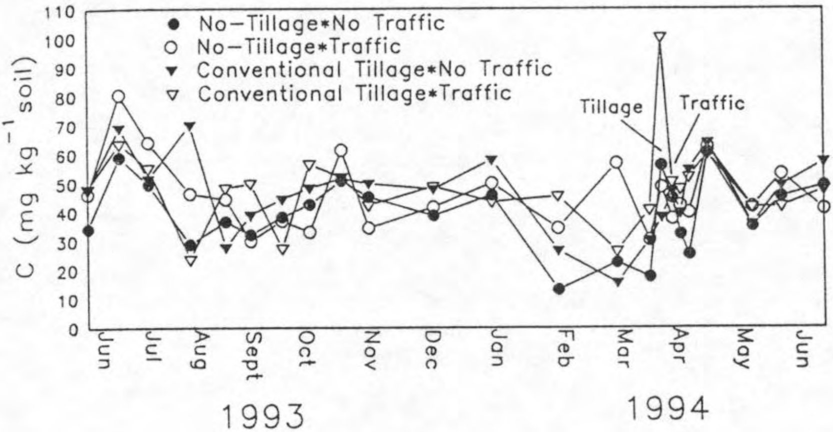

FIGURE 1. Microbial biomass C concentrations as affected by traffic, tillage, and sampling date for 1993-1994. $LSD_{0.05}$=26.0 for comparison of traffic means at same combination of tillage treatment and day. $LSD_{0.05}$=25.1 for comparison of tillage means at same combination of traffic treatment and day. $LSD_{0.05}$=24.1 for comparison of day means at same combination of traffic and tillage.

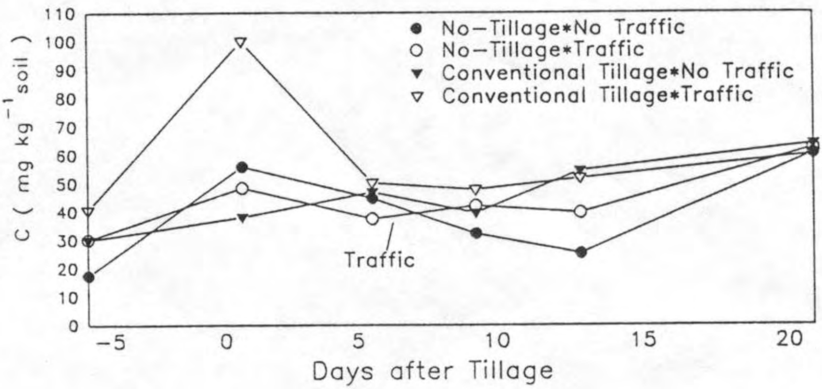

FIGURE 2. Microbial biomass C concentrations as affected by traffic, tillage, and sampling date during 1994 tillage and wheel-traffic operations. $LSD_{0.05}$=31.6 for comparison of traffic means at same combination of tillage treatment and day. $LSD_{0.05}$=24.6 for comparison of tillage means at same combination of traffic treatment and day. $LSD_{0.05}$=25.2 for comparison of day means at same combination of traffic and tillage treatments.

but not on a loamy sand. Even though bulk densities from trafficked soils were significantly higher than nontraffIcked soils in our study, it appears that soil texture (loamy sand) played a significant role in lack of effects from compaction on MBC. Because of the coarse texture of this Coastal Plain soil, available pore space was apparently not decreased enough to affect MBC.

Averaged over sampling dates, soil respiration was significantly affected by tillage ($P \leq 0.0001$) and there was a trend for a wheel-traffic effect ($P \leq 0.09$). Conventional tillage had significantly higher rates of soil respiration than no-till soils on many measurement dates (Figure 3). There was a trend for traffic to decrease soil respiration ($P \leq$ O.O9), but the response was dependent on time of wheel-traffic application (Figure 3).

Several researchers reported soil respiration to be higher from no-tillage soils compared to conventionally tilled soils (Hendrix et al., 1988; Follett and Schimel, 1989). Blevins e t al. (1984) suggested that soil respiration is generally higher in no-till soils than conventionally tilled soils because of more favorable conditions for microbial activity. However, immediately following tillage events CO_2 efflux is stimulated due to placement of organic substrates where they are more readily available, resulting in higher rates of soil respiration from conventionally tilled soils than no-till soils.

In this study, soil respiration was stimulated by tillage, but conventionally tilled soils maintained a higher level of soil respiration than no-till soils over most of the observation period (Figure 3). Higher rates of soil respiration (C Mineralization) from conventionally tilled soils compared to no-till soils should result in higher levels of organic C being retained in the no-till soils. However, as previously discussed, there were no significant differences in organic C between conventionally tilled and no-till soils.

In 1994, eight soil respiration measurements were taken immediately encompassing tillage and traffic events to monitor direct effects of tillage and traffic on soil respiration (Figure 4). Equipment failure delayed the first measurement to six days after tillage had occurred. Soil respiration was influenced by a significant traffic x tillage x measurement date interaction ($P \leq 0.0001$). A large flush of CO_2 was observed eight days following the tillage operation and two days following wheel-traffic application for the conventionally tilled soils (Figure 4). This flush fluctuated, but remained significantly higher than that observed in NT soils for approximately 10 days. These results agree with the hypothesis of Blevins et al. (1984) concerning the immediate effect of tillage, but soil respiration was equal or higher from conventionally tilled soils compared to no-till soils over the remainder of the observation period (Figure 3).

Compaction was expected to slow soil respiration, but on this soil the effect of compaction appeared to be dependent on time of wheel-traffic application. A laboratory study conducted by Torbert and Wood (1992). on a loamy sand, showed that microbial activity was reduced by 65% at a bulk density of 1.8 Mg m^{-3}

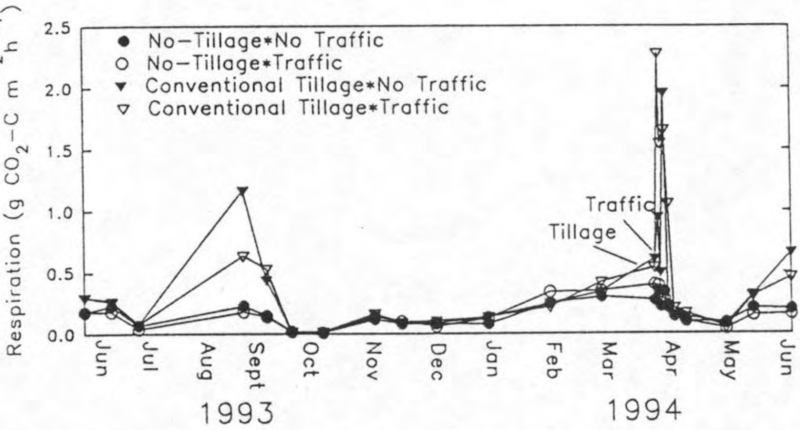

FIGURE 3. Soil respiration rates as affected by traffic, tillage, and sampling date for 1993-1994. $LSD_{0.05}$=0.18 for comparison of traffic means at same combination of tillage treatment and day. $LSD_{0.05}$=0.17 for comparison of tillage means at same combination of traffic treatment and day. $LSD_{0.05}$=0.17 for comparison of day means at same combination of traffic and tillage.

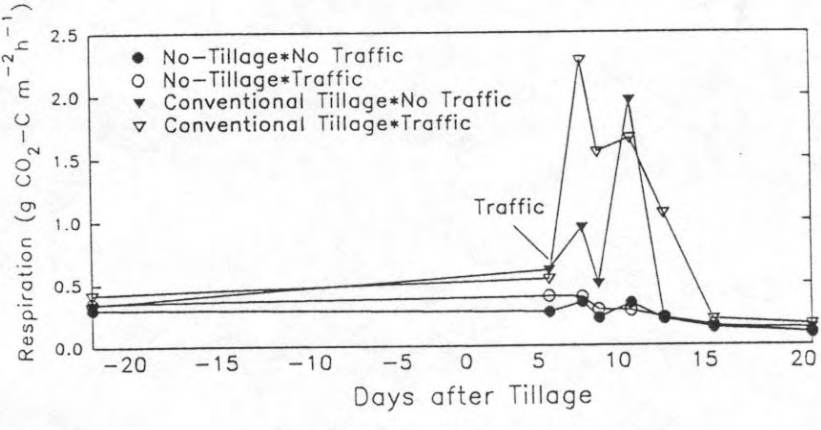

FIGURE 4. Soil respiration rates as affected by traffic, tillage, and sampling date during 1994 tillage and wheel-traffic operations. $LSD_{0.05}$=0.29 for comparison of traffic means at same combination of tillage treatment and day. $LSD_{0.05}$=0.25 for comparison of tillage means at same combination of traffic treatment and day. $LSD_{0.05}$=0.21 for comparison of day means at same combination of traffic and tillage treatments.

compared to 1.4 Mg m^{-3} while both soils were at 60% water filled pore space WFP). In our study, also on a loamy sand, mean bulk density was 1.61 Mg m^{-3} for conventional tillage-trafficked soils and 1.32 Mg m^{-3} for conventional tillage-nontrafficked soils: In September 1993, conventional tillage-nontrafficked souls had a higher rate of soil respiration than conventional tillage-trafficked soils (Figure 3). This also occurred five days after traffic was applied and again in June 1994 (Figures 3 and 4).

Immediately following the April 1994 wheel-traffic application, soil respiration was significantly higher from conventional tillage-trafficked roils compared to conventional tillage-nontrafficked soils (Figure 4). Soil respiration was significantly higher from conventional tillage-traffic soils than conventional tillage-nontrafficked soils two, three, and seven days after traffic application, but five days after traffic, there was a large flush of CO_2 from conventional tillage-nontrafficked soils (Figure 4). It appeared that immediate traffic effects on microbial activity had decreased or disappeared by 10 to 15 days after wheel. traffic was applied. Soil respiration could have been increased in conventional tillage-trafficked soils via increased soil-substrate contact and WFP. Linn and Doran (1984) reported microbial activity to reach a maximum at 60% WFP and decrease above 60% WFP. Water filled pore space was calculated using gravimetric water contents averaged over the entire study, bulk density data and an assumed particle density of 2.65 Mg m^{-3}. Using these calculations, soils receiving traffic had an average WFP of 24.9% while nontrafficked soils had an average WFP of 15.0% Within this range of WFP, the greater WFP in trafficked soils should be expected to maintain higher rates of soil respiration than the lower WFP of nontrafficked soils.

The flush of microbial activity that occurred 11 days after tillage from conventional tillage-nontrafficked soils (Figure 4) likely resulted from incorporation of organic substrates, but the flush was delayed compared to conventional tillage-trafficked soils because there was a lack of traffic-induced contact with soil microorganisms. Soils receiving tillage and wheel-traffic resulted in higher rates of soil respiration than other treatments during the April 1994 field operations, which was enhanced by the presence of fresh organic substrates from the crimson clover cover crop (Figure 3). It is likely conventional tillage-trafficked soils did not result in higher rates of soil respiration than conventional tillage-nontrafficked soils during other periods of observation because of the lack of fresh organic substrates for microbial decomposition. Higher rates of soil respiration from conventional tillage-nontrafficked soils compared to other treatments was in some periods of observation (September 1993 and June 1994) (Figure 3) not due to greater aeration because of the low levels of WFP, but could have resulted from lower bulk densities of conventional tillage-nontrafficked soils as suggested by Torbert and Wood (1992).

TABLE 1. Cumulative soil respiration as affected by tillage averaged across traffic during 1993-1994 and April 1994 field operations.

	Soil respiration	
Treatment	1993-1994[1]	April 1994[2]
	g CO_2-C m^{-2}	
No-tillage	1372 b	309 b
Conventional tillage	2586 a	593 a
	$LSD_{0.05}$=380	$LSD_{0.05}$=53.3

[1]1993-1994 sampling period was 369 days.
[2]April 1994 sampling period was 4 days.

Cumulative soil CO_2-C efflux was calculated for both the entire observation period (369 days) and the April 1994 field operations (44 days), assuming linear rates of soil respiration between sampling dates. From June 1993 to June 1994, conventional tillage soils almost doubled the amount of CO_2-C respired from no-tilled-soils ($P \leq 0.0002$, Table I). Also, conventional tillage soils almost doubled CO_2-C efflux from no-till roils during the April 1994 field operations ($P \leq 0.0001$, Table 1). However, after six years of treatments, there has been no corresponding reduction in organic C from conventional tillage soils.

Cumulative soil respiration during April 1994 field operations was significantly greater from trafficked soils (501 g CO_2-C m^{-2}) than nontrafficked soils (401 g CO_2-C m^{-2}). As mentioned earlier, it is believed that wheel-traffic catalyzed higher CO_2-C efflux during April 1994 because fresh organic substrates had greater contact with soil microorganisms than soils nor receiving wheel-trafffic. However, over an entire year, this effect was not evident. Total soil respiration was 9.5% higher from nontrafficked soils compared to trafficked soils (data not shown) from July 1993 to July 1994, though this difference war not significant ($P \leq 0.46$). Since differences in WFP were not high enough to suppress soil respiration, perhaps increased bulk density of trafficked soils was responsible for the differences.

Nitrogen mineralization was significantly affected by the interaction of tillage and wheel-traffic during the 1993 growing season (June through October, 107 days; $P \leq 0.04$) but not the 1994 growing season. Nitrogen mineralized during the 1994 growing season was double the amount of N mineralized during the 1993 growing season. The 1994 corn growing season was 18 days longer than the 1993 soybean growing season and 1994 was a year of high rainfall (Figure 5). The large differences in N mineralization between seasons could also be due to

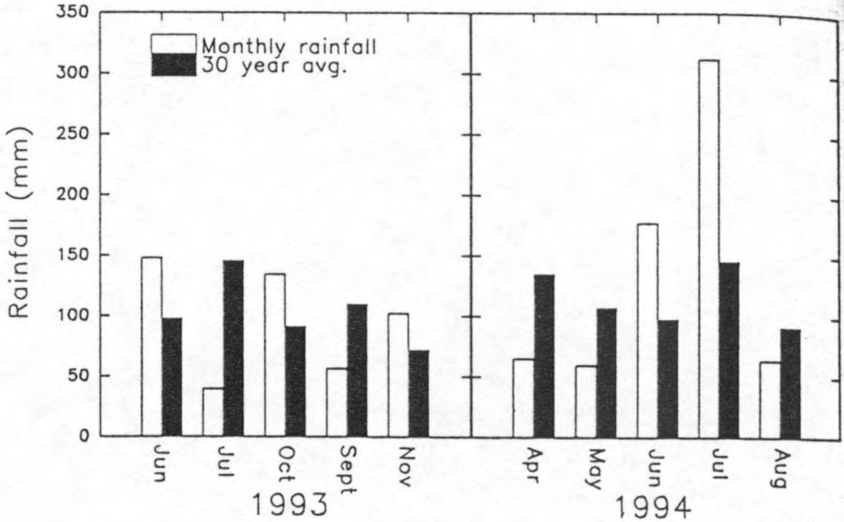

FIGURE 5. Monthly rainfall for the 1993 and 1994 growing seasons compared to monthly 30-year rainfall average. The 1993 soybean growing season was 15 June through 28 October. The 1994 corn growing season was 11 May through August 25.

residual effects of previous crops. Corn was the 1992 summer crop that preceded the 1993 growing season and soybean the summer crop that preceded the 1994 growing season.

During the 1993 growing season, N mineralization was significantly lower from no-till-trafficked soils compared to conventional tillage-trafficked and no-till-nontrafficked soils (Figure 6). Although not significant, no-till-trafficked soils mineralized 10 kg ha^{-1} more N than any other treatment during the 1994 growing season (data not shown). No other differences were observed in N mineralization among treatments.

Incubation Study

Surprisingly, no treatment differences were observed for organic C and N at either depth increment (0-10 and 10-20 cm). Other studies have found significantly higher amounts of both organic C and N in upper layers ofreduced or no-till soils compared to more intensively tilled soils (Tracy et al., 1990; Wood and Edwards, 1992). There was a significant tillage x depth interaction for C:N ratio ($P \leq 0.04$), with no-till soils having a higher C:N ratio (8.38) in the 0-10 cm depth than conventional tillage soils (7.05) in the 10-20 cm depth.

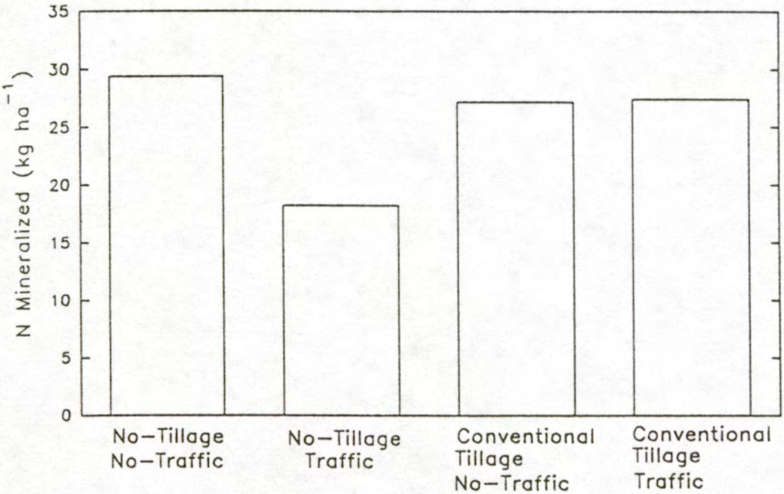

FIGURE 6. Nitrogen mineralized (kg ha^{-1}) as affected by tillage and traffic during the 1993 growing season (107 days). $LSD_{0.05}$=7.63 for comparison of tillage means at same level of traffic. $LSD_{0.05}$=11.06 for comparison of traffic means at same or different level of tillage.

All measured or calculated variables resulting from the laboratory incubation study were significantly affected by depth. Potential soil respiration (C mineralization) was significantly affected only by soil depth ($P \leq 0.0002$). Potential N mineralization (0-10 cm depth) was significantly affected by the traffic x tillage x depth interaction ($P \leq 0.0006$). In the 0-10 cm depth, potential N mineralization was higher from conventional tillage soils compared to no-till-trafficked and conventional tillage-nontrafficked roils (Table 2). Relative N mineralization behaved similarly to potential N mineralization (Table 2) due to the lack of difference in organic N. These data suggest that conventional tillage-trafficked soils contain higher quality N substrates than both no-till-trafficked and conventional tillage-nontrafficked soils. Field N mineralization data from 1993 (Figure 3) agree with conventional tillage-trafficked soil mineralizing more N than no-till-trafficked sods, but 1993 field data showed N mineralization from conventional tillage-traffic and conventional tillage-nontrafficked soils to be almost equal.

TABLE 2. Potential N mineralization and relative N mineralization measured for laboratory incubation.

Treatments[1]	Potential N mineralization ($mg\ kg^{-1}$)		Relative N mineralization (%)[1]	
	Soil depth (cm)			
	0-10	10-20	0-10	10-20
No-till-nontrafficked	9.32	2.96	1.63	0.73
No-till-trafficked	7.77	3.00	1.37	0.67
Conventional tillage-nontrafficked	8.01	3.88	1.41	0.83
Conventional tillage-trafficked	12.41	3.12	2.02	0.66
	$LSD_{0.05}$=1.59[2]		$LSD_{0.05}$=0.40[2]	
	$LSD_{0.05}$=2.29[3]		$LSD_{0.05}$=0.48[3]	
	$LSD_{0.05}$=2.07[4]		$LSD_{0.05}$=0.44[4]	

[1]Relative N mineralization = potential N mineralization/organic N.
[2]LSD for comparison of depth means at same combination of tillage and traffic.
[3]LSD for comparison of tillage means at same combination of traffic and depth.
[4]LSD for comparison of traffic means at same combination of tillage and depth.

CONCLUSIONS

Although respiration was significantly greater from conventional tillage soils than no-till soils, soil organic C, and total N were unaffected by tillage or traffic treatments. Microbial biomass C showed no consistent effect owing to traffic and tillage treatments, which agrees with organic C and total N data. Both tillage and wheel-traffic stimulated soil respiration during April 1994 field operations, but wheel-traffic did not cause increased soil respiration during other measurement periods as did tillage. Cumulative CO_2-C soil respiration from conventional tillage soils almost doubled that from no-tillage soils during the entire observation period and during April 1994 field operations. Total soil respiration was significantly greater from trafficked soils compared to nontrafficked soils during April 1994 field operations, but traffic was not significant for cumulative soil respiration over the entire observation period. During the 1993 growing season, N mineralization was significantly lower from no-till-trafficked soils than all other treatments.

The laboratory incubation study indicated the presence of higher quality N substrates from conventional tillage-trafficked soils compared to conventional tillage-nontrafficked and no-till-trafficked soils. No other differences were observed from the incubation. Nonintuitively, it appears that conventional tillage in combination with wheel-traffic may promote the highest levels of soil microbial activity in southeastern Coastal Plain soils.

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