SOIL MICROBIAL BIOMASS, CARBON POOL, AND GREEN HOUSE GAS FLUXES IN A LONG TERM TILLAGE EXPERIMENT ON THE NORTH ATLANTIC COASTAL PLAIN

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ABSTRACT

To assess the impact of tillage management on long term carbon sequestration as well as the short term balance of GHG emissions from agricultural land, measurements of total soil carbon stocks, microbial biomass related attributes and GHG emissions were performed on a tillage experiment. The measured microbial attributes included microbial biomass C (MBC) and N (MBN), respiration and metabolic quotient (qCO_2). In general, no tillage had higher values than plow tillage treatment with the main difference occurring in the top layer and lessening at increasing depths. For net GHG emissions, there was a tendency of net CH_4-C production for plow tillage and net consumption for no tillage. In general N_2O emissions were higher for no tillage than plow tillage treatment. For CO_2-C emissions, differences between the two treatments were not significant. Calculation of global warming potential under plow tillage gave a higher carbon equivalent (C_{eq}) value than no tillage with an overall difference of 1.05 mg C_{eq} m^{-2} h^{-1}.

INTRODUCTION

Soils play an important role on the fluxes of CH_4, CO_2 and N_2O. It is known that no till management practice enhances carbon sequestration, however its impact on CH_4 and N_2O is not clear. Although agricultural soils are possible sinks for atmospheric CH_4 through consumption by methanotrophic bacteria, several agricultural practices and soil management have adverse impacts on the activity of the CH_4 oxidizing bacteria. Nitrogen application in soil is a key factor for N_2O emission and also interferes with CH_4 oxidation. Multi-gas (CH_4, N_2O, and CO_2) flux measurements have been of increasing interest due to their global warming potential and the necessity of accounting for carbon-equivalents (IPCC, 2001) for the three gases. The contribution of soil to the budgets of greenhouse gases have been examined in many studies but there are many uncertainties due to emission variability in time and space. This information is relevant when accessing overall global warming impacts of different soil management practices.

The objective of this study was to measure microbial biomass-related parameters and emissions of CH_4, N_2O, and CO_2 in a 10-year tillage experiment and compare the efficiency of no till and plow till systems regarding conservation of carbon and the dynamic of these GHG.

MATERIAL AND METHODS

A ten-year tillage experiment under continuous culture of corn (Zea mays L.) was used for this study. Adjacent plots were selected for soil characterization in 2002 and for GHG measurement in 2003.

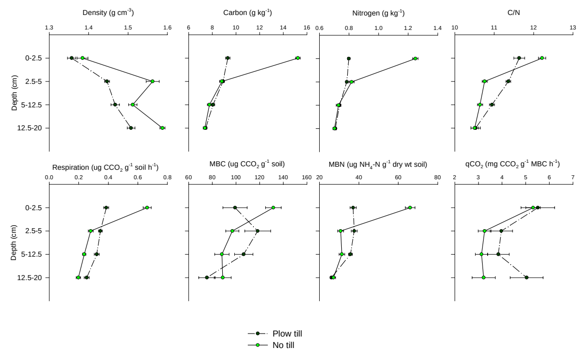
The soils were characterized within depth ranges (0-2.5, 2.5-5, 5-12.5 and 12.5-20 cm). Microbial biomass (MB) was determined by fumigation-incubation (FI) method. The final value for MBC and MBN were calculated by subtracting the unfumigated control from the fumigated treatment values. The unfumigated control was also used to calculate basal respiration and specific respiration (metabolic quotient, qCO_2) relative to MBC.

For GHG fluxes, static chamber method was used. Three chambers were placed in each plot making six chambers per treatment. On sampling day, a sample was taken immediately after placing the cover (time zero) with a deployment time of 30 and 60 minutes after time-zero. Global warming potential (GWP-100yrs) was calculated for each gas with a GWP CO_2:CH_4:N_2O ratio of 1:23:296, respectively (IPCC, 2001). On every sampling date, soil moisture and temperature, and ambient temperature were taken on site.

At the farm management level, chisel plowed and disked tillage was conducted for plow tillage on July 17. Corn was planted on the 18th, herbicide was applied on July 21 and August 21, and N fertilizer was applied on August 20 (UAN-urea ammonium nitrate). For a uniform fertilizer application within the collar area, each collar was covered during field application and afterwards, each received a direct manual surface application of 1.48 g UAN to its centerline parallel to corn lines. This corresponded to an application of 193 kg N ha^{-1}.

IMPACTS ON SOIL PROPERTIES

Figure 1. Soil characterization and MB related attributes



• Soil bulk density increased with depth and no-till soil had higher density at all depths than plowed soil. The greatest difference in density occurred within the 2.5 to 5 cm depth range.

• In general, MBC, C, MBN, N, C/N, respiration and qCO_2 decreased with depth for both treatments with a steep decrease for no till soil from first to second depth range and a much gentler decrease for plow tillage.

• The no till soil had higher total carbon stocks (0-20 cm) than plow tillage with the main difference occurring in the top layer of soil (0-2.5 cm).

• Values for respiration, N, MBC, and MBN were much higher in the top layer for no till compared to plow tillage soil and the difference between the two treatments decreased with depth.

• Values for qCO_2 were similar at 0-2.5 cm depth for both treatments but higher for plow tillage with increasing depth.

IMPACTS ON GLOBAL WARMING POTENTIAL

Table 1. Carbon stock for plow till and no till treatments considering volume and mass equivalence

C Stock (t ha^{-1}, 0-20 cm depth)

Tillage	Vol. equivalent	Mass equivalent
Plow till	23.65	24.69
No till	26.24	26.24
P value, F test	0.0001	0.0151

• Carbon stock over the 10 year tillage experiment shows a higher value for no till than plow till management practice.

• No till is 6% higher by volume equivalent and 10% higher by mass equivalent than plow tillage.

Table2. Carbon equivalent for each GHG under the two tillage systems

Global Warming Potential – GWP (mg C m^{-2} h^{-1})

Tillage	Ceq-CH_4	Ceq-N_2O	Ceq-CO_2	Sum
Plow till	0.15	9.9	101.7	111.7
No till	-0.24	12.6	98.3	110.7
p value, F test	0.0004	0.9067	0.5590	

GWP 100yr, ratio CO_2:CH_4:N_2O as 1:23:296 (IPCC 2001)

• Over the one-year study, both tillage systems had Ceq-CO_2 values approximately 10-fold higher than those of Ceq-N_2O, and Ceq-N_2O values were approximately 100-fold higher than Ceq-CH_4 values.

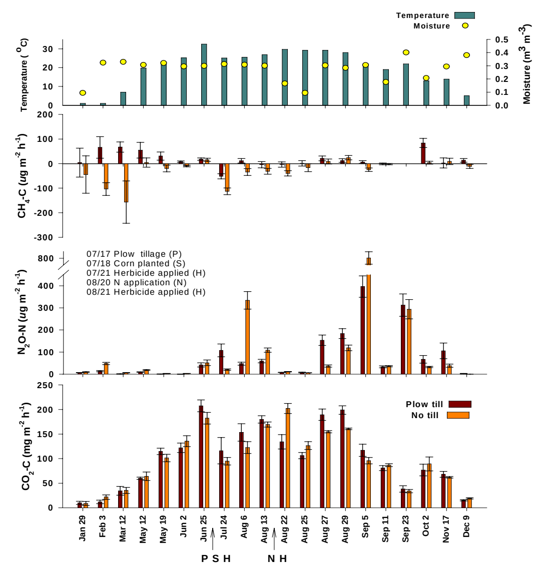
• Ceq-CO_2 and Ceq-CH_4 values for plow tillage were 3% and 150% higher, respectively, than values for the no-till system.

• The Ceq-N_2O value for no-till was approximately 25% higher than that of the plow-till system.

• The overall sum of the three gases was 1% higher for plow tillage than the no tillage system.

IMPACTS ON GHG EMISSIONS

Figure 2. GHG emissions and soil moisture and temperature on each date



• **Plow tillage soil had a tendency for net CH_4-C production and no tillage soil had a net consumption of atmospheric CH_4-C (oxidation) throughout the year.** This differential in CH_4 dynamics between treatments was greatest in winter and early spring. For the rest of the year, emission and oxidation levels were very low, not surpassing 15 µg m^{-2} h^{-1}. However, on the October 2nd sampling CH_4-C emissions were much higher under plow tillage treatment.

• **In general, N_2O-N emissions were higher for the no tillage treatment than for the plow tillage treatment.** Winter period emission levels were low although a freeze/thaw effect (February 3) caused high N_2O-N emissions. This effect maybe caused by the rapid dynamics in biomass populations associated with such perturbations. The highest N_2O-N emissions occurred during the summer. However, for sampling periods of low soil moisture, emissions were as low as those measured during the winter months.

• **CO_2-C emissions were generally high during the summer and low during the winter. However, the difference between treatments was not significant for most sampling dates.** Soil temperature and plant respiration are the most likely driving forces for CO_2-C emissions.

CONCLUSIONS

• Tillage methods affect C and N mineralization patterns and distribution of residues in soil. These parameters in turn influence soil respiration, soil biomass, metabolic quotient, and flux of CH_4, N_2O, and CO_2.

• Differences in soil hydrology between treatments have been previously observed in this field site. These differences also affect microbial behavior governing fluxes of CH_4, N_2O, and CO_2.

• Carbon accumulation within the top soil layer was significantly higher under no till than plow till management (Figure 1).

• Our study found net oxidation of CH4 under no tillage management and net production under plow tillage. The results for no tillage are consistent with the literature indicating high CH4 oxidation rates occur below the surface of no tillage and forest soils.

• Nitrogen application caused a spike in N_2O emissions. However, soil moisture was also important since N_2O emissions were very low for sampling dates of low soil moisture even after N application.

• Multi-gas flux measurements (as opposed to C sequestration measurements alone) give a more comprehensive assessment of cropland management efficiency for mitigating global warming.

• The no tillage management system was shown to play a positive role in global warming mitigation. However, there is a need to carefully manage N application due to the great potential of N_2O emission under no tillage management.