Soil Organic Matter Characterization by Physical and Chemical Methods and CO_2 Efflux Measurement from Long-term Experimental Plots

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Abstract

There has been great interest on the role of carbon dioxide (CO_2) in global climate change in recent years. The concentration of atmospheric CO_2 has been steadily increasing significantly since the Industrial Revolution. It has been established that fossil fuel combustion, deforestation and changes in land management are some of the main factors that contribute to atmospheric CO_2 enrichment. More carbon is contained in soil pool than vegetation and the atmosphere combined. Carbon sequestration in the soil has been suggested as a possible mitigation for the CO_2 enriched atmosphere. There are few studies that established relationships among soil organic carbon fractions, soil organic matter functional groups, total soil N and soil CO_2 efflux. The objectives of this study were to establish the impacts of different soil organic matter fractions, functional groups, fertilizer treatments and crop rotations on CO_2 efflux in historical long-term experimental plots, the Old Rotation and the Cullars Rotation established in 1896 and 1911, respectively at the Auburn University campus. These two long-term plots have fertilizer, crop rotation and other farming cultural practices that have been continuously maintained with periodic soil analysis and yield data records. We sampled soils at 0-5 and 5-10 cm depths from all plots of the Old Rotation and from selected plots in the Cullars Rotation. We determined Light, Heavy and Total organic matter fractions, C and N in each fraction, and chemically characterized soil organic matter functional groups on selected samples using Fourier Transform Infrared (FTIR) spectroscopy. We measured soil CO_2 efflux during different seasons. Our study indicated that the Heavy organic matter fraction was significantly greater than the Light fraction at each depth. Soil organic carbon and N were significantly higher in the 0-5 cm depth. The average C:N ratio of the soils in Old Rotation and Cullars Rotation were 10.3:1, and 9.8: 1, respectively. The FTIR spectral bands we measured indicated the presence of C-H, C=O, R-CH_3 and other organic functional groups. The average soil CO_2 efflux measured during summer 2008, 2010 and fall 2008 were 3.53, 3.75 and 1.88 $\mu molm^{-2}s^{-1}$ respectively. The summer CO_2 effluxes were significantly higher than fall 2008 measurements. In general, CO_2 efflux was significantly affected by fertilizer treatments, crop rotations and seasons. Soil organic matter fractions and soil CO_2 efflux are affected by factors that are interrelated and interdependent.

Introduction

SOM constitutes microbial biomass, detritus and humic substances. As a result of these components, it is heterogeneous varying in molecular structure, decomposition rate and stability. The role of SOM is far greater than its very small percentage in the soil affecting soil aggregate stability, water holding capacity, infiltration and as a source of food for microbes. Soil physical, chemical and biological activities are impacted by SOM. Soil contains more carbon than the atmosphere and plants combined. However, due to conventional tillage, more carbon is leaking to the atmosphere than that is entering as organic matter (IPCC, 2007). Changes in cultural practices are shown to increase SOM making soil a major reservoir for carbon sequestration. Even though a lot of interest is generated to mitigate the CO_2 in the atmosphere, very little information is available on the amount of CO_2 efflux from the soil during different seasons of the year and, the nature of SOM functional groups that are dominant in the soil. Since global population explosion, deforestation and burning of fossil fuels will continue to enrich the atmosphere with CO_2, establishing quantitative relationships among the many variables involved in SOM accumulation, transformation and decomposition is crucial to account for the role soil plays as a natural storage of carbon.

The objectives of this study were to establish the impacts of different soil organic matter fractions, functional groups, fertilizer treatments and crop rotations on CO_2 efflux in historical long-term experimental plots, the Old Rotation and the Cullars Rotation established in 1896 and 1911, respectively.

Materials and Methods

Study sites: The Old and the Cullars Rotations

- CO_2 efflux measured using LI-COR 6200
- Seasonally from spring, summer and fall of 2008 and 2009, respectively.
  Fertilization: Varied per plot and location of study
  Rotation: 1, 2 and 3-year for the Old Rotation and 3-year rotation for the Cullars rotation
- Soil samples: Sampling depth: 0-5 and 5-10 cm.

Laboratory Analyses

- Light density organic matter (LDOM) by physical separation (Cambardella and Elliott, 1993)
- C, N and S by combustion using Vario Macro CNS analyzer
- Chemical characterization of functional groups by extraction with water (W) and sodium pyrophosphate (PY) (Kaiser and Ellerbrock, 2005).

Fig. 1. LDOM extraction method

Fig. 2. CO_2 measurement using LI-COR 6200

Table 1. Description of Study sites

Plots / Cropping System for both Study Sites	
Old Rotation	Cullars Rotation
1: Nothing	A: No N / + Winter Legume
2: Winter Legume (No N)	B: No N / No Legume
3: Winter Legume (No N)	C: No soil amendments
4: Winter Legume (No N) 2	2: No P
5: Winter Legume (N) 2	3: No micronutrients
6: No Winter Legume	6: No K
7: Winter Legume (No N) 2	10: Complete Fertilization + Micronutrients
8: Winter Legume	
9: Winter Legume (N) 2	
10: Winter Legume, SB, Sm. grain (No N) 3	
11: Same as plot 10	
12: Same as plot 10	
13: No Winter Legume (N)	

Fig. 3. The Study Sites

Table 2. Analysis of Variance Table

Effect	Light Fraction	Heavy Fraction	Total Fraction
Rotation	*	NS	NS
Treatments	*	NS	NS
Sampling Year	**	NS	NS
Depth of Sampling	**	**	**
Plot	NS	NS	**
Sampling Year * Depth	**	NS	NS

NS denotes not significant; * - significant at 0.05; ** - significant at 0.01

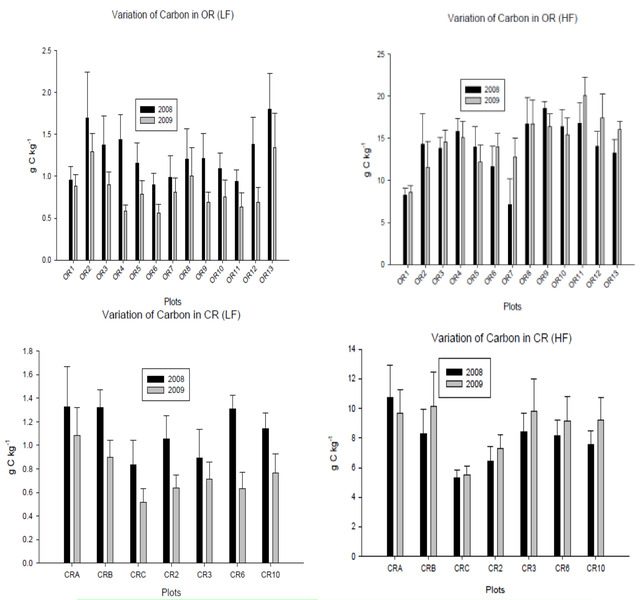

Fig. 4. Soil organic Carbon in Different Soil Organic matter Fractions

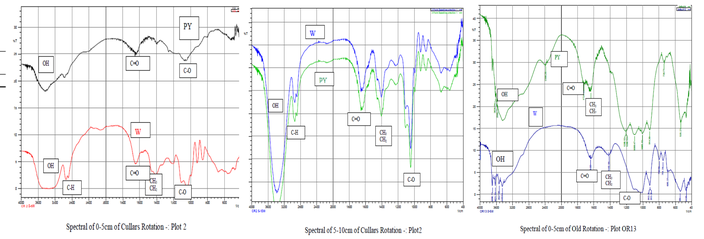

Fig. 5. FTIR Spectral bands from two plots in two locations

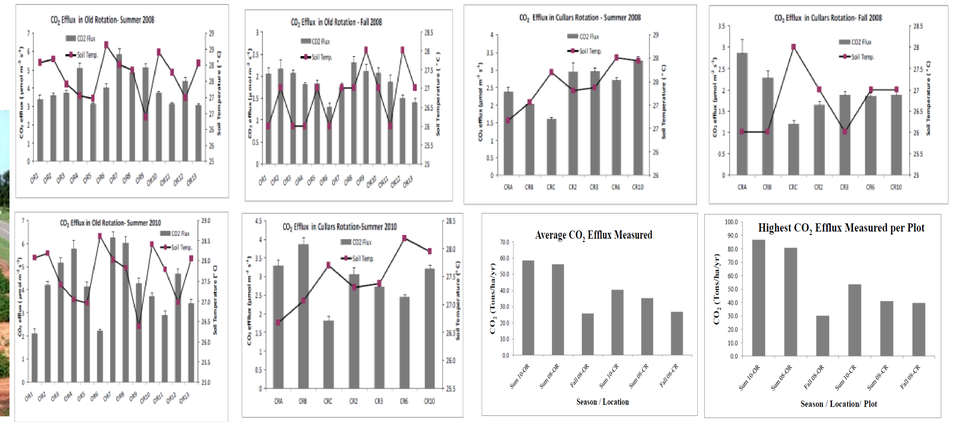

Fig. 6. Carbon dioxide efflux measured at different locations and seasons

Results

1. **Physical fractionation**: Crop rotation and fertilizer application increased SOM, and 2- 3 year crop rotation plots accumulated more SOM than the yearly and mono cropping plot. Heavy Fraction of carbon is higher than the Light fraction by at least 10 folds.
2. **Chemical characterization**: There were less transmittance intensity for PY extractable OM functional groups in 5-10 cm depth and less for water extractable functional group in the 0-5 cm depth. In general, treatments and crop rotations attributed to the presence of different organic functional groups.
3. **CO_2 effluxes**: summer 2008 CO_2 effluxes were higher than fall 2008 for both locations. Summer 2010 CO_2 effluxes were higher compared to summer 2008. Soil CO_2 effluxes were affected by fertilizer application, crop rotations, season of sampling and soil characteristics.

Summary

Fertilization and crop rotations increased SOM. In general, SOM fractions, organic matter functional groups and CO_2 efflux were affected by factors that are interrelated and interdependent. Since soil is a leaking carbon reservoir, more studies are needed to establish both qualitative and quantitative relationships among the major factors. Soil will play a pivotal role in CO_2 sequestration.

Reference

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