Effect of Farming Systems Trial Manag

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Introduction

Climate change and its costly consequences motivate policy makers at all levels to implement ambitious and verifiable carbon sequestration programs. Scientists and policy makers have identified soil carbon sequestration for its potential to provide important and valuable greenhouse gas offsets. The current standard automated dry combustion method of quantifying soil C changes is laborious, cumbersome, costly, and cannot verify year-to-year changes (Chatterjee et al. 2009). Therefore, to encourage innovation in carbon sequestering farming practices and ensure that offset payments actually support soil carbon sequestration, there is a pressing need for improved soil carbon measurement.

Since 1981, Rodale Institute's Farming Systems Trial (FST) has maintained and compared organic and conventional systems in Kutztown, Pennsylvania. Mapping Soil Organic Carbon (SOC) quantity, temporal change, and spatial distribution in various farming practices over time is critical in understanding the effect of these practices, and in developing practice recommendations to enhance carbon sequestration. The objective of this research was to compare SOC content and change by system and tillage, using laboratory data dating back to 1981, informed by newly derived spatial composition data collected in 2009-2010.

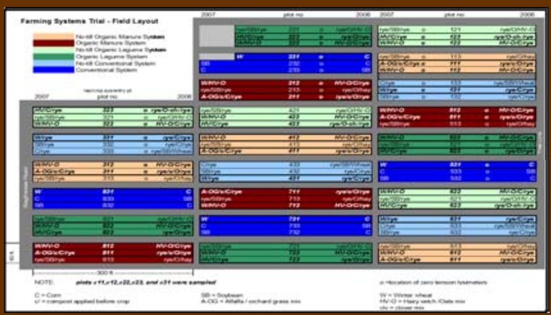
Trial Description

Site Description

The Trial is situated at the Rodale Institute in Kutztown, PA over 12 acres of a complex soil landscape in southeastern PA. The soil ranges from fine-loamy mixed superactive mesic Oxyaquic Fragiudalfs (Alfisol) to loamy-skeletal mixed active mesic Typic Dystrudepts (Inceptisol).

Experimental Design Description

The trial was established as 8 replications of 3 cropping systems. Each replication is subdivided into 3 entry points. The entry points allow comparison between multiple points in the cropping rotation within a single year. In 2008, half of the replicates in each system were transitioned into no-till tillage management. For this experimental work, soil was sampled in 5 subsections of each subplot.



Corn in rolled hairy vetch growing in the **Organic Legume No-Till System**

Corn no-tilled into corn stubble in the **Conventional No-till System**

The Systems Description

The Farming Systems Trial (FST) is a long-term grain cropping systems trial currently in its thirtieth year. Throughout this long history, the FST has contained 3 core farming systems, each of which features extremely divergent management practices including: a legume-based organic system (LEG), a legume- and manure-based organic system (MNR), and a synthetic-based conventional system (CNV). Table 1 summarizes the essential guiding principles that characterize each core system. Although those essential guiding principles have remained constant throughout FST's extensive history, important management characteristics such as tillage regime and rotation have changed within each of these 3-core farming systems several times.

Table 1. FST Systems' Guiding Principles

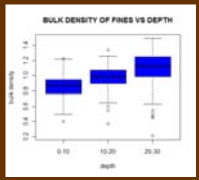
Manure Organic	Legume Organic	Synthetic Conventional
This system represents an organic dairy or beef operation. A long rotation, including both annual feed-grade grain crops and perennial forage crops, forms the basis of system fertility through leguminous crops and confers the primary line of defense against pests. Nutrients are also recycled through periodic manure-based applications.	This system represents an organic cash grain system. It features a mid-length rotation, consisting of annual grain crops and cover crops. The rotation is the sole source system fertility through leguminous crops and confers the primary line of defense against pests. All nitrogen is supplied by legumes.	This system represents the majority of grain farms in the US. It relies on synthetic nitrogen (ammonium nitrate and UAN) for N fertility. Weeds are controlled by synthetic herbicides, selected by, and at rates recommended by Penn State Extension.

Sampling and Processing Methods

Ten, 2-cm diameter cores were pulled from within five, 10'x20' subsections per each 20'x300' FST subplot. Sample subsections are 60 feet apart.

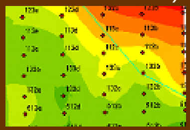
Cores were split into depth increments of 0-10, 10-20 and 20-30 cm, and then homogenized by depth within each of the 5 sampling subsections per plot.

Samples were weighed, dried, re-weighed and sieved in order to determine rock fragment percentage, moisture, and mass per area, by depth.



Preliminary data are checked and modeled across the landscape.

In all, 1080 samples will be processed (with 915 taken to date).



Excerpt from rock fragment concentration results.

ement Practices on Soil Organic Carbon

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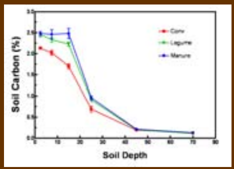
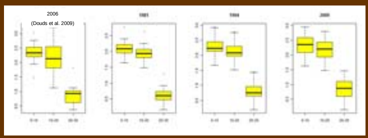
Data Analysis- Adjustments for Depth

Because most of our historical carbon analysis data were from samples homogenized at 0-20 cm, we needed an adjustment method to account for carbon variability at finer, and deeper, increments.



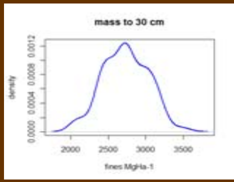
A 2006 partial sampling at GRACENET increments provided carbon gradient patterns for each farming system.

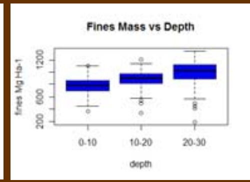
It also provided a pathway to approximating finer depth increment carbon levels from the 0-20 cm historical data. We accomplished this with a regression:carb=a+**b***[system+0-20+depth]. Modeled carbon by depth was reasonable compared to the reference measured set (on left).



Data Analysis – Accounting for Soil Mass

We randomly selected 10 plots from each farming system for the analysis of carbon effects. The distribution of their average mass of fines (soil < 2mm) is shown at left; the distribution by depth increment, at right. *n=10 x 3 x 5~150*

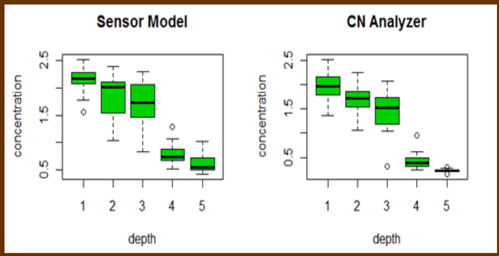




The effect of using the stratified composition, (depth-wise carbon x depth-wise mass) vs a (flat mass of 4000 x a flat carbon rate) at the shallower depths, is shown below.

AVERAGE ANNUAL CHANGE IN SOIL CARBON, Mg Ha-1	Manure	Legume	Conventional
1994 vs 1981	0.594	0.426	0.302
2003 vs 1981	0.444	0.240	0.168
2009 vs 1981	0.362	0.239	0.126
2009 vs 1994	0.161	0.077	-0.027
2003 vs 1981, evaluated at at flat 4000 Mg Ha-1 mass	1.218	0.857	0.217

Data Analysis – Supplementing the Assessment with Spectral Data



A model employing both visible and mid-infrared spectrometers is already showing promise in providing accurate depth-wise predictions of soil carbon. Its efficiency and low cost make it potentially central in any wide-scale, carbon stock assessment campaign as far as deriving better depth-wise carbon estimates to apply to the soil mass numbers.

Key Findings, Conclusions and Next Steps

- The manure system has exhibited the largest soil carbon increase since trial initiation, averaging annual increases of 0.59 Mg C ha^{-1} between 1981 and 1994, and 0.16 Mg C ha-^{1} between 1994 and winter 2009-2010.
- The legume system average annual soil carbon increases were 0.43 Mg C ha^{-1} and 0.08 Mg C ha^{-1}, 1981-1994 and 1994-2009 respectively, while the conventional system has not changed significantly since the beginning of the trial.
- These carbon change estimates are much lower than previously reported for the Farming Systems Trial (Pimentel et al. 2005) due to the adjustments for spatial composition and the decreasing carbon concentration by depth.
- The spectral models will provide plentiful data on soil carbon predictions at deeper increments, which will be essential in refining soil carbon stock assessments on an equivalent mass basis.
- Next steps include: 1) completing a comprehensive sampling of FST, 2) matching CN analysis with the exact samples that were processed for composition properties, and 3) updating this analysis with carbon and soil mass measurements. One limitation of this study is that bulk densities, and therefore soil mass to fixed depths, may be subject to change from between years, and even within years due to management schedules and rotation differences within and between systems (Wuest 2009).

Acknowledgements

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