Carbon Distribution within Intact Soil Macro-Aggregates

Michelle Quigley[1] Wakene Negassa[2] Alexandra Kravchenko[1] Andrey Guber[1] Mark Rivers[3]

[1]Plant, Soil and Microbial Sciences, Michigan State University [2]IASS-Global Soil Forum, Institute for Advanced Sustainability Studies, Potsdam, Germany [3]Department of Geophysical Sciences and Center for Advanced Radiation Sources, The University of Chicago

Introduction

Increasing soil carbon in agricultural soils is important for agricultural productivity, general soil health, as well as, climate change mitigation. Recently, physical protection of soil carbon within soil aggregates has been seen as a key driver in the fate of soil carbon. Much of this physical protection is thought to be accomplished through pore structure. Cover crops have been known to increase soil carbon, but whether this increase comes simply from increased biomass, an increase in root action that might help protect soil carbon, or a combination of the two processes is yet unknown.

Objectives

The objectives of this study were:

- Determine incorporation of fresh inputs into soil aggregates from cover crop addition using stable isotopes and the natural isotopic difference between C3 and C4 plants
- Determine if fresh input incorporation into soil aggregates is related to pore structure
- Use incubation experiments to see CO_2 emissions and $\delta^{13}C$ measurements to determine carbon utilization by soil microbes.

Sample Collection

Soil was collected from the Living Field Lab at Kellogg Biological Station, Hickory Corners, MI from a 20 year continuous corn plot.

A portion of the soil was sieved through a 5mm sieve and then crushed to look at aggregates only formed under rye.

Rye was planted in both sieved and un-sieved (raw) soil and let grow for 5 months. Soil aggregates 5-6 mm in size were collected from rye sieved and raw samples, as well as a non-rye planted control.

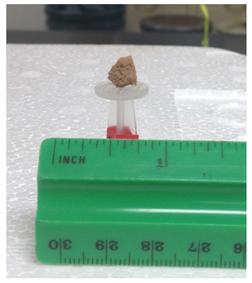
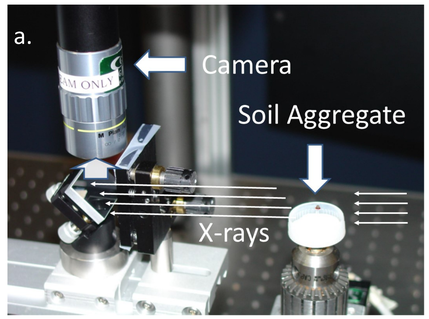


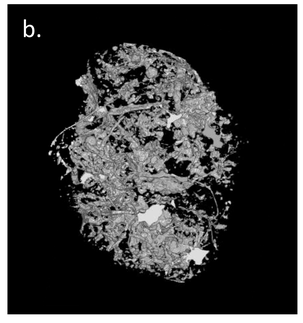
Figure 1: Collected soil with rye growth (left). A typical soil aggregate used in this experiment.

Imaging

Collected soil aggregates were mounted and scanned at 6.5 μm resolution at the Advanced Photon Source, Argonne National Lab, Argonne, IL.

Indicator kriging and burn number analysis in 3DMA were used to identify pores and pore size distributions.





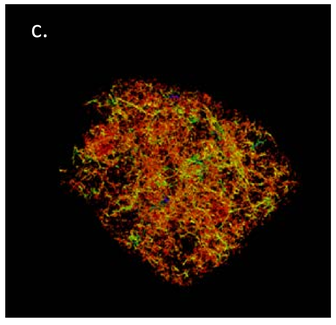
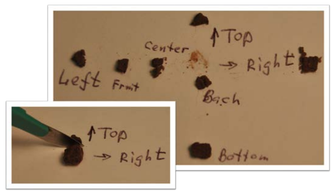


Figure 2: a. Schematic of how aggregates are scanned at Argonne. b. 3D rendering of an aggregate's pore network. c. 3D "map" of soil pores with colors indicating pore sizes. Warm colors (reds, yellows) denote smaller pores, while cool colors (greens, blues) denote larger pores.

Cutting, Isotope Analysis, and Incubation

14 scanned aggregates were cut into pieces (Figure x) and sent to the Stable Isotope Facility at UC Davis for $\delta^{13}C$ and total C analysis. The images of these aggregates were also "cut" to match the physical cutting.

13 additional aggregates were incubated for 28 days at 23°C with CO_2 measurements being taken. CO_2 was also sent to the Stable Isotope Facility at UC Davis for $\delta^{13}C$ analysis.



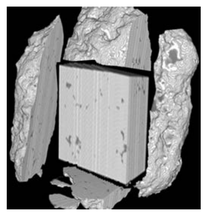


Figure 3: Soil aggregate cutting physically (left), which is sent for analysis and then matched to digital cutting (right) to correlate the image derived properties to the chemically derived properties.

Results

Table 1: $\delta^{13}C$ and %Carbon from studied soil aggregates

Sample	Crop	Disturbance	$\delta^{13}C$	%C
Bare	Corn	Undisturbed	-21.6a	0.74a
Raw	Corn-Rye	Undisturbed	-21.4a	0.86b
Sieved	Corn-Rye	Crushed	-22.0b	0.86b

Table 2: Image derived porosity and difference between small pores in the studied aggregates

Sample	Porosity	Small pores
Bare	10.7a	0.86a
Raw	15.2a	0.84a
Sieved	12.4a	0.51b

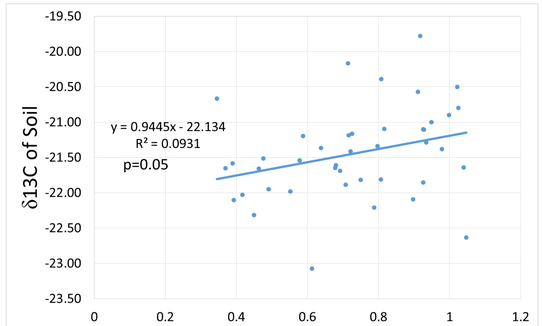


Figure 4: Correlation between small pores and $\delta^{13}C$ in sampled aggregates. This model was the only statistically significant model between pore size and δ13C .

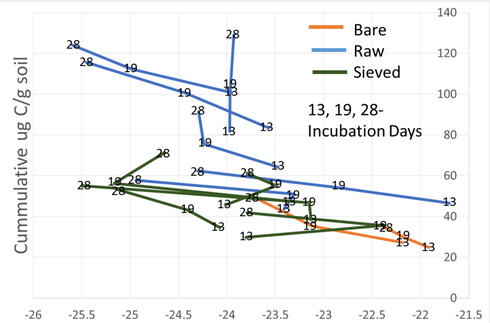


Figure 5: $\delta^{13}C$ of CO_2 produced during incubation of the soil aggregates vs. the cumulative CO_2 produced. Measurements were taken at 13, 19 and 28 days of incubation.

Conclusions

- After 5 months of growth, percent carbon in the soil was greater under rye growth than with bare soil. $\delta^{13}C$ was not significantly different between the intact soil and the soil with no rye growth, however, it was significantly different in the sieved soil where roots would be the main driver of soil aggregate formation.
- Size of pores were not significantly different between treatments, except for small pores. This was also the only pore size that correlated to $\delta^{13}C$ measurements.
- More depleted $\delta^{13}C$ values was correlated with large pores, implying that large pores are where the most incorporation of fresh carbon occurred.
- CO_2 emission was largest for the raw soil. This treatment was also the samples with the largest porosity. Porosity is known to be correlated to CO_2 emissions in bulk soil.
- Where rye growth was present, the CO_2 emitted during incubations showed a presence of rye derived carbon in the CO2 emissions. Further studies into the trends in CO_2 $\delta^{13}C$ from the beginning of an incubation will be preformed in the future.

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