Biochar's Impact on Chemical and Microbial Processes in Nitrogen Cycling within Agricultural Soils

Matt Ramlow, M. Francesca Cotrufo

Colorado State University, Soil and Crop Sciences Dept, Natural Resource Ecology Lab, Fort Collins, CO

Overview

- N cycling in agriculture has many important impacts on water and air quality
- Biochar soil amendments have been shown to affect nitrogen (N) cycling by;
  - Reducing nitrous oxide (N_2O) emissions,
  - Impacting microbial activity
  - Sorbing ammonium (NH_4^+) and nitrate (NO_3^-)
- This study explores the affects of biochar on soil N cycling across a gradient of soil types and saturation levels to understand the chemical and biological mechanisms
- Here we present the scope of the study and preliminary results

Background

Biochar contains many unique properties:

- High % C, and aromatic condensation
- High pH
- Increased surface area with greater charge density
- Increased pore space impacting aeration and water holding capacity

There are many different hypotheses for how biochar properties may influence soil N cycling, some of which may be competing. This study explores some such hypotheses:

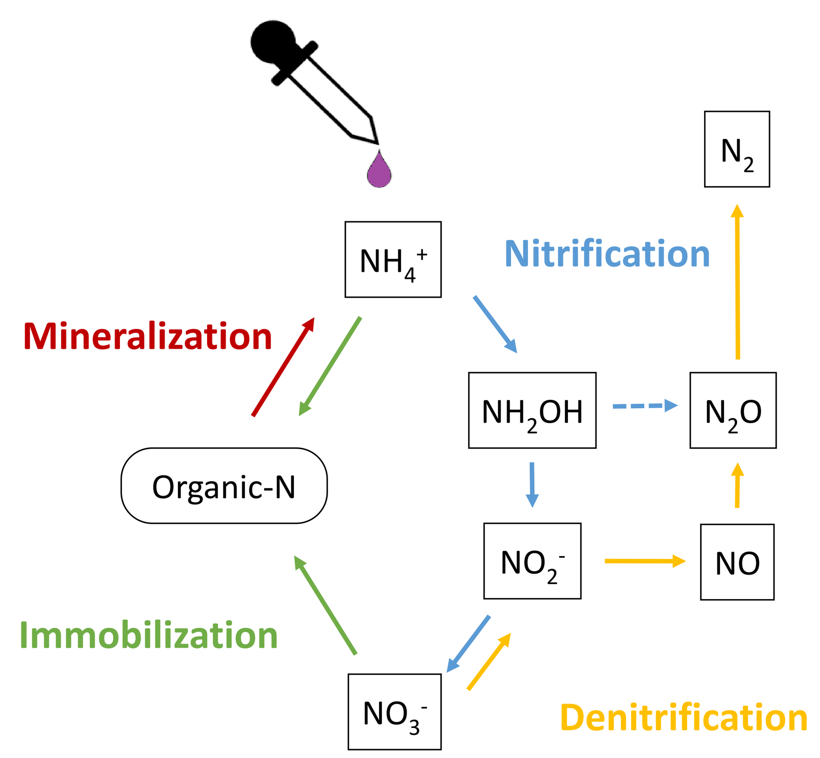


Fig 1: Nitrogen Cycle

H1) Biochar increases ion exchange capacity of soil

H2) Biochar provides chemical protection of N substrates affecting nitrification rates

H3) Biochar increases aeration through additional pore space affecting N_2O production from nitrification

H4) Biochar's additional pore space increases water holding capacity leading to more highly reducing sites enhancing complete denitrification

H5) Biochar contains labile C that could stimulate microbial N demand/mineralization

Results and Discussion

Biochar Retention

- Biochar consistently had greater capacity to hold NO_3^- but a lower capacity to hold NH_4^+ (H1)
- Biochar had no ability to preferentially retain NH_4^+ after 30 days (reject H2)
- Both NH_4^+ and NO_3^- showed a linear trend with increased N concentrations in bulk soil

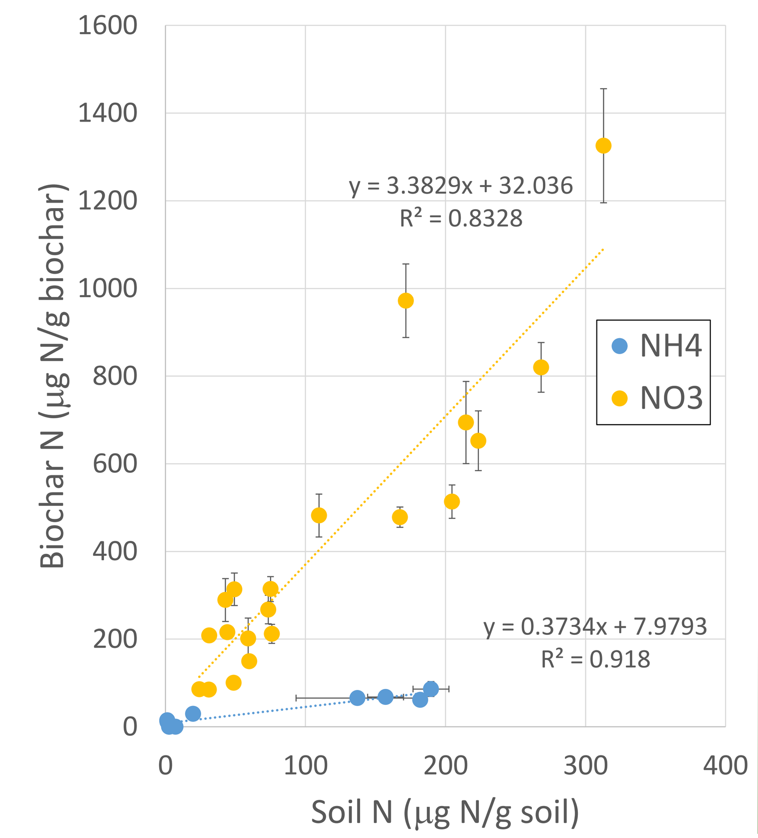


Fig 2: Relative retention of NH_4^+ and NO_3^- between biochar and bulk soil

N Transformation

- NH_4^+ loss in fertilized soils was equivalent to NH_4^+ addition (140 µg N / g soil)
- Biochar did not have a significant effect on the NH_4^+ loss or NO_3^- gain
- NH_4^+ loss can explain the NO_3^- gain via nitrification for ND and TX soils
- Unfertilized soils' NO_3^- levels indicate mineralization and subsequent nitrification of organic N with no biochar effect
- Biochar did not appear to simulate N mineralization (reject H5)

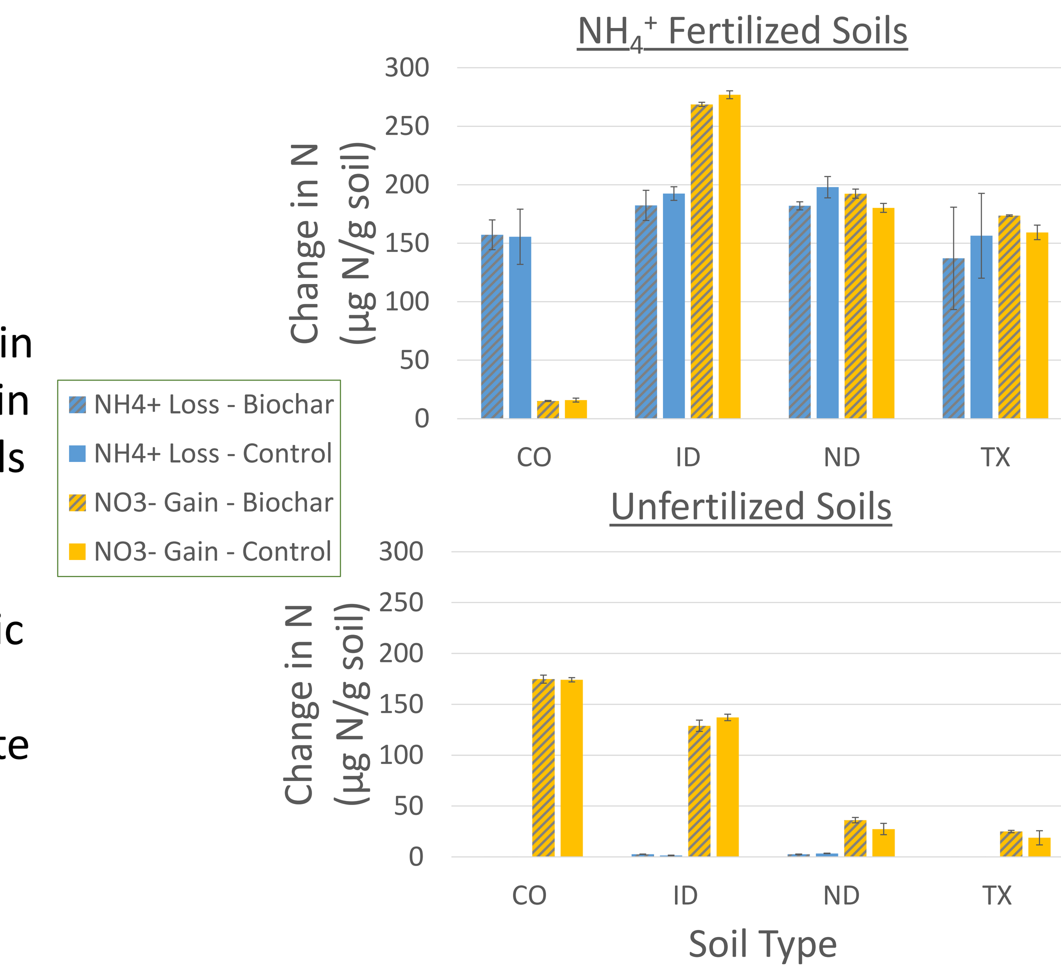


Fig 3: Transformation of NH_4^+ and NO_3^- in bulk soil from day 1 to 30

N_2O Emissions

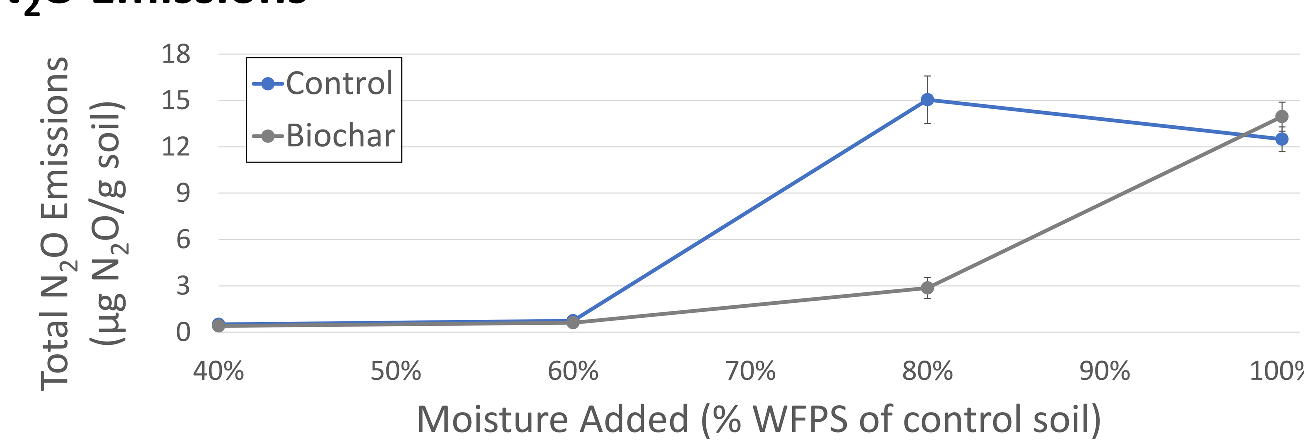


Fig 4: Total N_2O emissions over the 30 day lab incubation

- Denitrification appeared to dominate the N_2O signal in the CO soil
- Biochar led to a significant decrease at 80% WFPS
- The additional pore space in the biochar soils may have shift the soil towards nitrifying conditions (H3)
- Fully saturated biochar soils did not lead to a reduction in N_2O (reject H4)

Microbial Biomass

- No difference between control and biochar soils in the fertilized soils (reject H5)
- Minor biochar effects on microbial biomass in unfertilized soils, with either decreases (CO and ID) or increases (TX)
- Soils with high C resources had higher microbial biomass

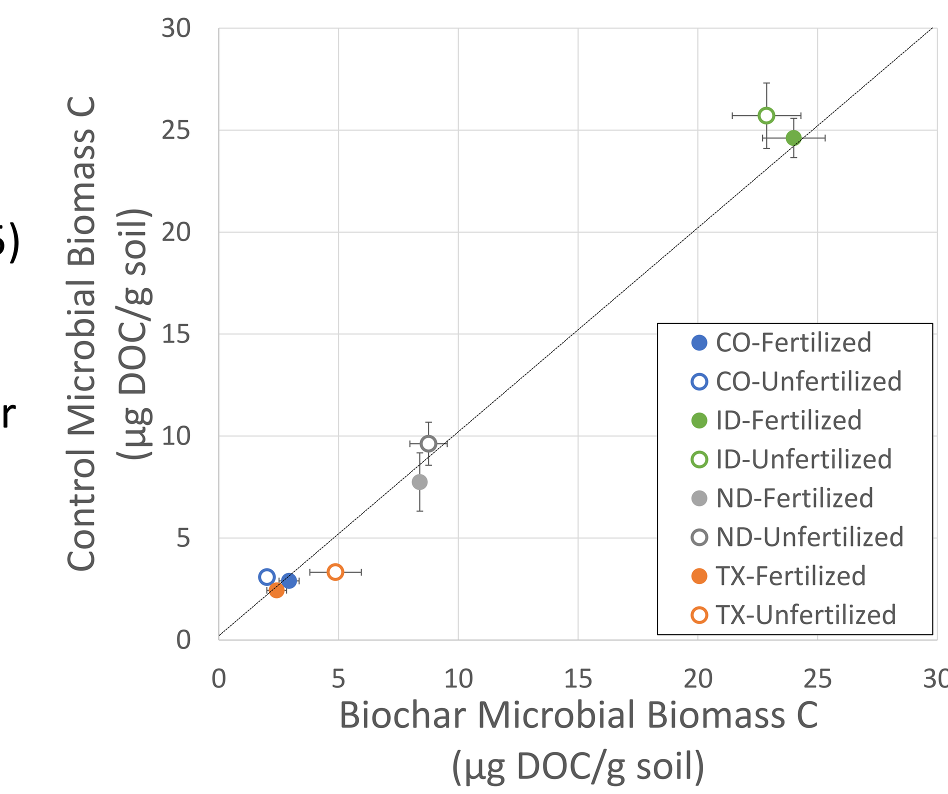


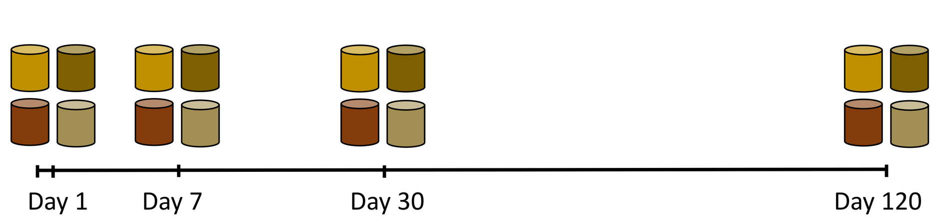
Fig 5: Microbial biomass from bulk soil at day 30

Materials and Methods

Experimental Design

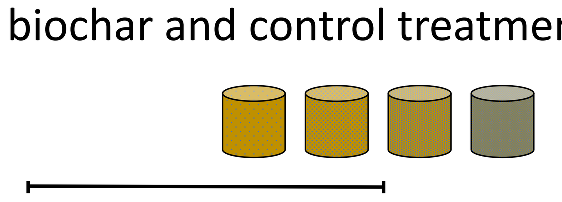
Full Experiment

Comparing 4 agricultural soils with biochar and fertilizer treatments across 4 harvest points in a 120 day incubation at 25°C, 60% WFPS (n = 4)



Soil Saturation Incubation

Comparing the effects of saturation on fertilized CO soils by adding the same amount of water to biochar and control treatments (n = 4)



Materials

- 0.5 mL 1M NH_4Cl fertilizer (7 mg N)

Soils

Location	pH	% C	% N	% Sand	% Silt	% Clay
CO	7.99	1.21%	0.13%	35%	32%	34%
ID	5.86	4.78%	0.45%	28%	54%	19%
ND	7.27	2.45%	0.24%	11%	60%	29%
TX	8.04	0.95%	0.12%	14%	50%	36%

Biochar

Description	Biochar Properties
Feedstock	Beetle-killed Lodgepole Pine
Pyrolysis	Slow Pyrolysis, 550°C
Particle Size	Sieved to between 2.8 – 2 mm
Application Rate	2% by mass (equivalent to 30 tonnes/ha)
C:N	255.3
pH	8.49

Methods

GHG Sampling

Mason jar headspace sampled using Picarro G2508 GHG Analyzer

Bulk Soil Mineral N

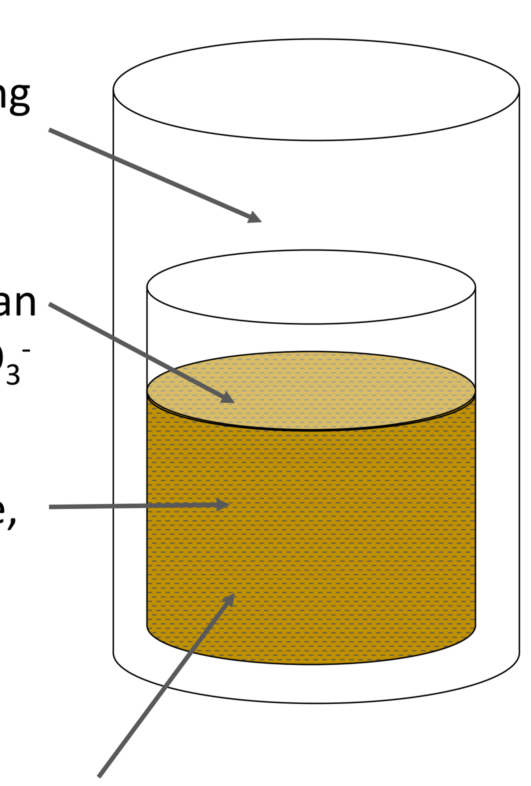
Extracted with 2M KCl and run on an AlpKem to determine NH_4^+ and NO_3^-

Biochar Mineral N

Biochar separated on a 2 mm sieve, rinsed with 800mL DI water then extracted like bulk soil

Microbial Biomass

Chloroform fumigation-extraction method (5 day) with DOC and TN measured on a Shimadzu TOC analyzer



Conclusion

C1) The biochar sorbed both NH_4^+ and NO_3^- with differing levels of retention compared to bulk soil. However such retention on the biochar did not prevent NH_4^+ losses due to microbial transformation.

C2) Biochar had no significant effect on the net transformation of N over the 30 day incubation, while soil type did have significant effects.

C3) N_2O flux data suggests that biochar's potential to aerate soils has a significant impact on the total N_2O emissions.

C4) Biochar did have a significant effect on microbial biomass but only in the unfertilized plots and there was no clear directional change across the gradient of soil types.

Acknowledgements

This project is supported by the Agriculture and Food Research Initiative Competitive Grant no. 2013-68005-21298 from the USDA National Institute of Food and Agriculture.