Biochar utilization for soil quality improvement, greenhouse gas reduction, metal, and nutrient sequestration

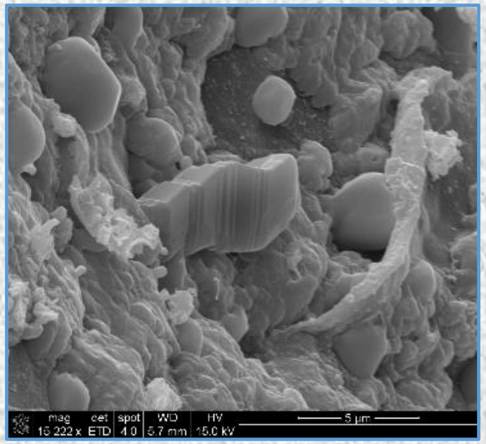
J.M. Novak, J.A. Ippolito, R.D. Lentz, H.L. Collins, R.S. Van Pelt, and K.A. Spokas

Biochar 2018 Conference

August 20th to 23rd 2018

Wilmington, DE

Biochar pellets



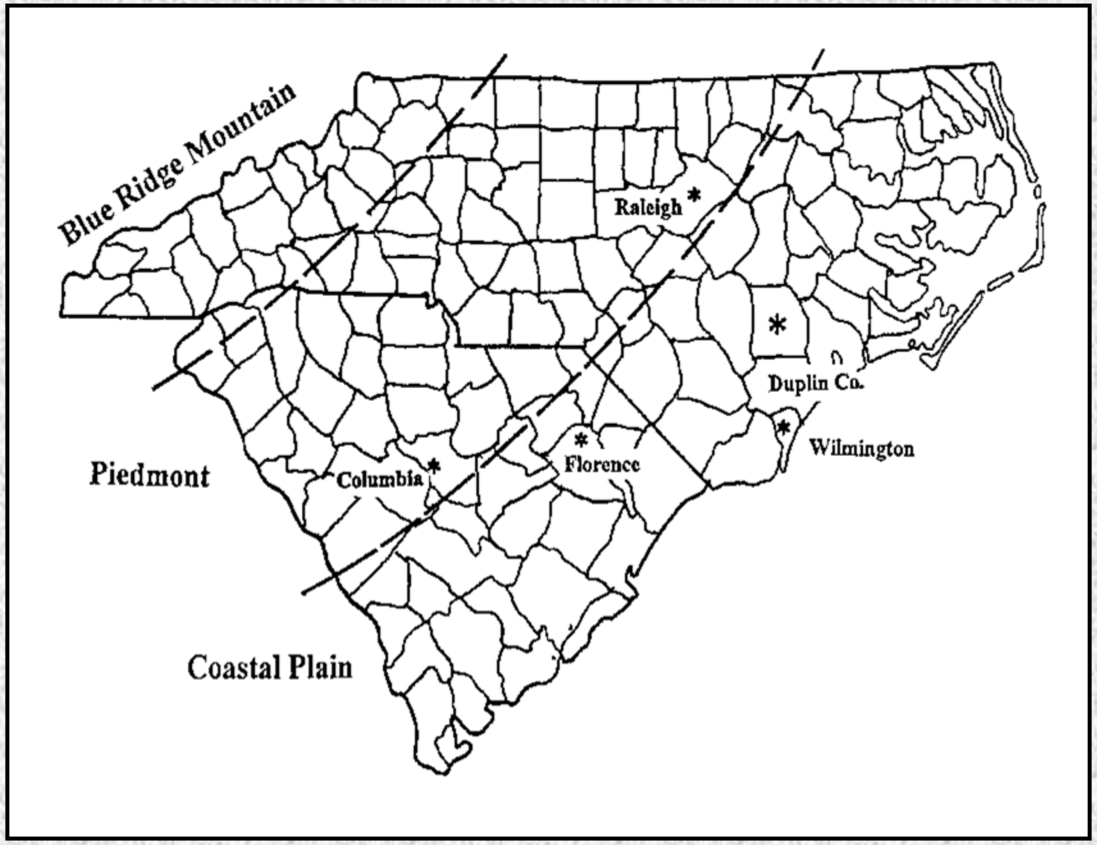
SEM of poultry litter biochar

USDA ARS
United States Department of Agriculture
Agricultural Research Service

Coastal Plain Physiographic Region of SE USA

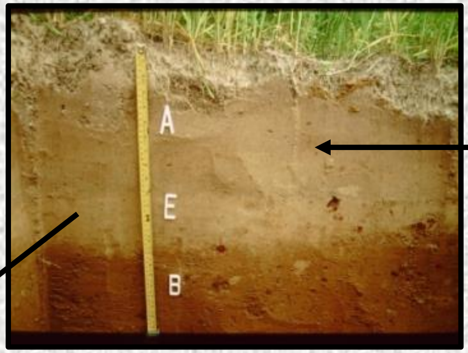
- In the SE Coastal Plain, most of the agricultural soils formed in fluvial and marine sediments deposited 0.5 to 5 million yrs ago.

- The soils are sandy with poor fertility, acidic pH values, and low soil SOC contents.



Physiographic regions in NC and SC

Coastal Plain Soil Problems



Norfolk soil series

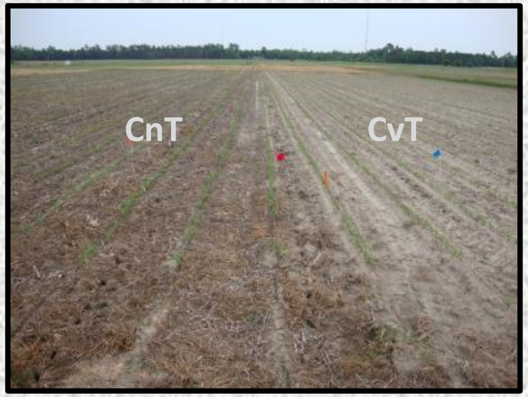
Low SOC contents in Ap horizon

E horizon forms hard layer

% SOC in Norfolk profile (eroded)

Depth (cm)	%SOC
0 to 15	0.39
15 to 30	0.18
30 to 45	0.13
45 to 60	0.14
60 to 75	0.16
70 to 90	0.14

Tillage and crops management practices to increase profile SOC contents

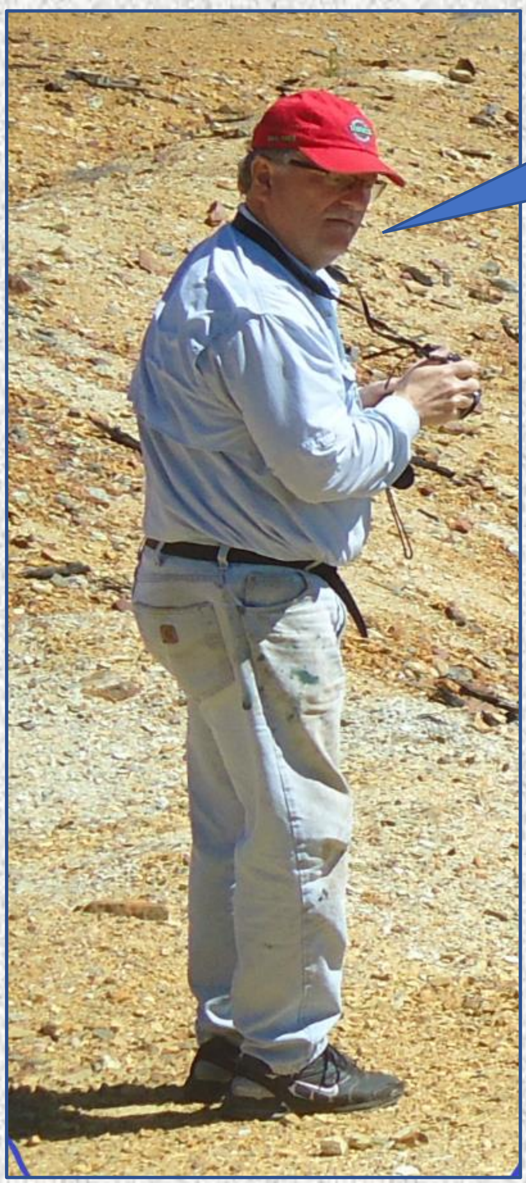


Soil organic carbon g/kg

Depth (cm)	Tillage	1979	1980-1983	1983-1991
0-5	conventional	6.3 (0.8)	7.2 (0.3)	7.2 (0.2)
	conservation	5.3 (0.2)	7.3 (0.4)	12.0 (0.5)*
5-10	conventional	5.2 (1.1)	7.1 (0.4)	5.6 (0.2)
	conservation	4.6 (0.3)	6.2 (0.4)	6.3 (0.3)
10-15	conventional	3.9 (0.7)	6.0 (0.5)	4.5 (0.1)
	conservation	4.5 (0.6)	5.3 (0.4)	4.8 (0.3)

It took almost 20 years to increase SOC under conservation tillage!

Hunt et al. JSWC (1996)



Mark G. Johnson (EPA)

Mike Bollman and Mark G. Johnson (EPA)

For over 10 years, scientists at ARS-Florence have designed biochars for soil health improvements and mine spoil remediation

Feedstock selection

Vary pyrolysis temperature

Vary biochar morphology

Bench-scale expt.

Greenhouse experiments

Field-scale biochar plots

Coordinating designer biochar selection

Establish soil/spoil deficiency

Select the appropriate designer biochar from the ‘biochar tool box’

Determine biochar application rate, morphology, and application method

Application rate

Pellet vs. dust

Application method

Designing relevant biochars

	Single feedstock/blend	Pyrolysis (°C)	Particle size	Soil impact
SE USA sandy soils	2008 Switchgrass	250 to 500	Dust (< 0.42-mm)	+ water storage
	Hardwoods	350 to 700	Dust (<0.42-mm)	+ water storage
	Pecan shells	700	Dust (< 0.42-mm)	+nutrients/lime
	Loblolly pine chips	350 to 700	Dust, pellets (> 2-mm)	C sequestration
	Pine chips/poultry litter	350 to 700	Dust, pellets (> 2-mm)	C sequestration & balance soil [P]
Mine spoils/soils	2015 Miscanthus	500	Flakes (2-6 mm)	Metal binding & enzymes
	‡Lodge pole pine	500	Flakes (2-6 mm)	Metal binding
	‡Poultry litter & beef cattle manure	500	Flakes (2-6 mm)	Metal binding, liming & soil microbiology

Novak et al., 2009; Novak and Busscher, 2012; Novak et al., 2014, Sigua et al., 2016, Novak et al. 2018; ‡current studies

USDA ars
United States Department of Agriculture
Agricultural Research Service

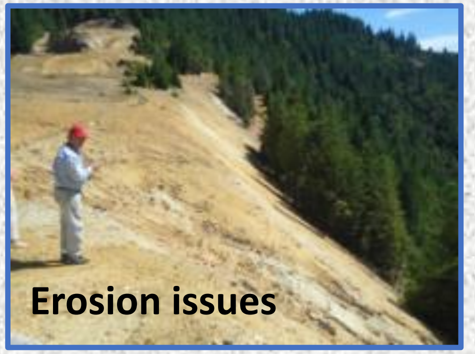
Mine spoil remediation:

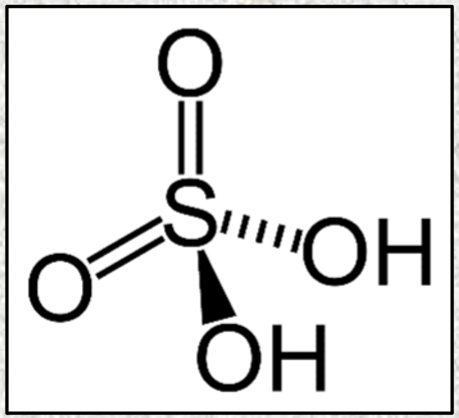
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Formosa mine site


Acid mine drainage


Poor microbial colonization


Erosion issues




Poor soil:plant relationships

Tri-State mine site


Spoil stored on surface


Surface after spoil removal


Sporadic plant cover


Chemical & physical issues

30 Zn 65.41	48 Cd 112.41

HEAVY METAL

USDA ars
United States Department of Agriculture
Agricultural Research Service

Remediation of the Formosa mine site

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Phase 1 (2017-2018)

120 holes dug

Biochar + biosolids + lime added

Pine trees planted

Establish a pine tree plantation

Phase 2 (2018-2019)

Soil preparation for biochar

Grasses/Forbes will be planted

EPA & ARS ground crew

Collaborative projective funded through an Interagency Agreement.

TSM remediation: Establishing background soil properties

Physical issues

Soil supplied to ARS-Florence is unweathered C horizon with many coarse fragments.

Soil contains pockets of silts/clays exhibiting distinct redoxymorphic features (mottling).

Sieving soil reveled that almost 30% of material was > 12.7 mm coarse fragments.

Chemical issues

$CaCl_2$ extr (0.01 M)	mg/kg
Cu	0.93
Cd	21
Zn	376

Material	pH (H_2O)
Clay (8 mm)	4.71
All soil (8 mm)	5.12
All soil (12 mm)	4.92
Rocks (> 12.7 mm)	4.88

Coordinate biochar types for use in a Switchgrass growth experiment with Tri-State Mine soil (2018)

% Application rate (w/w)	
Biochar	Manure compost
0	0
0	2.5
0	5
2.5	0
2.5	2.5
2.5	5
5	0
5	2.5
5	5


Lodgepole pine biochar

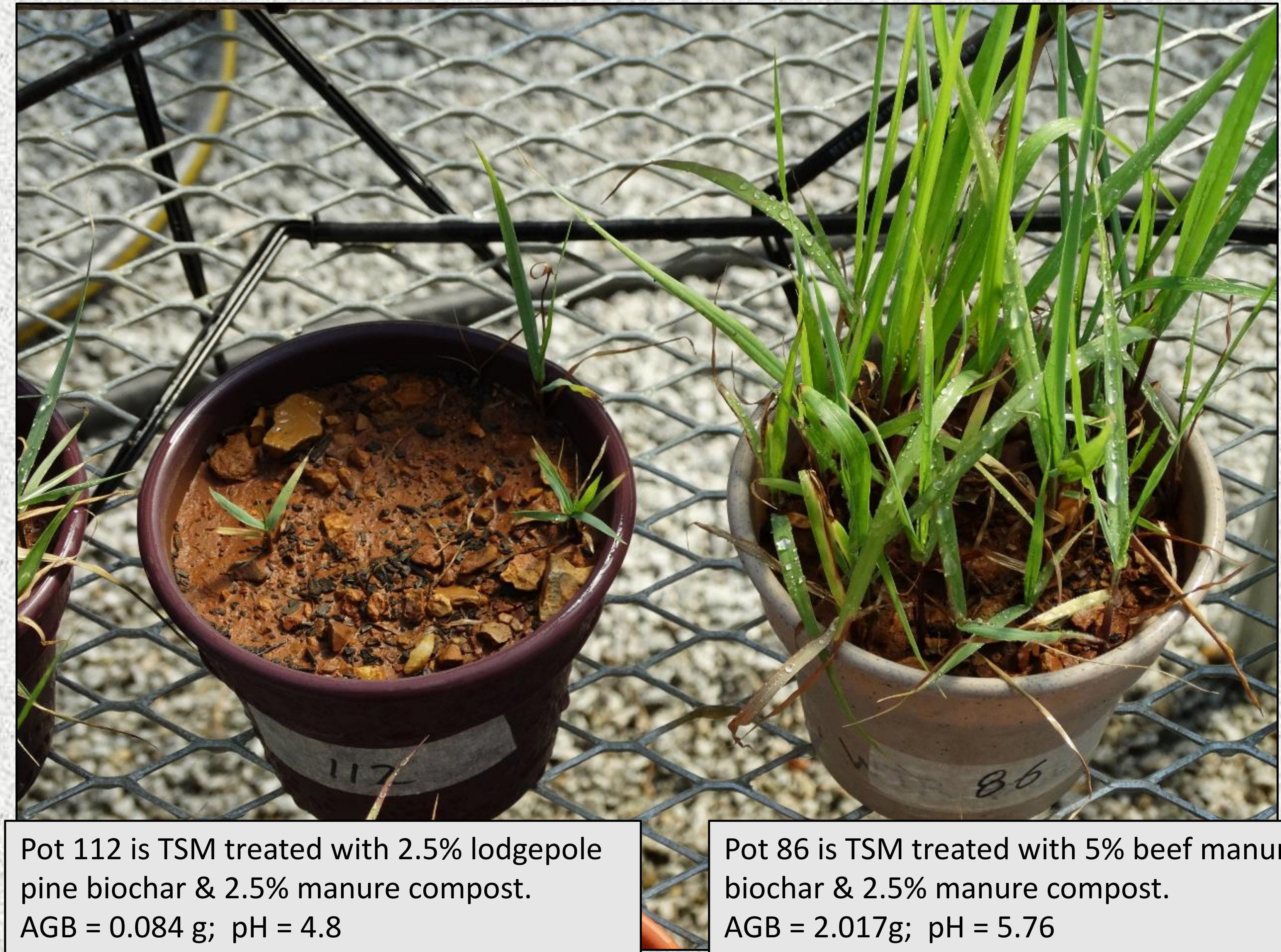

Switchgrass


Poultry litter biochar


Beef cattle manure biochar


Beef cattle manure compost

What did we find?

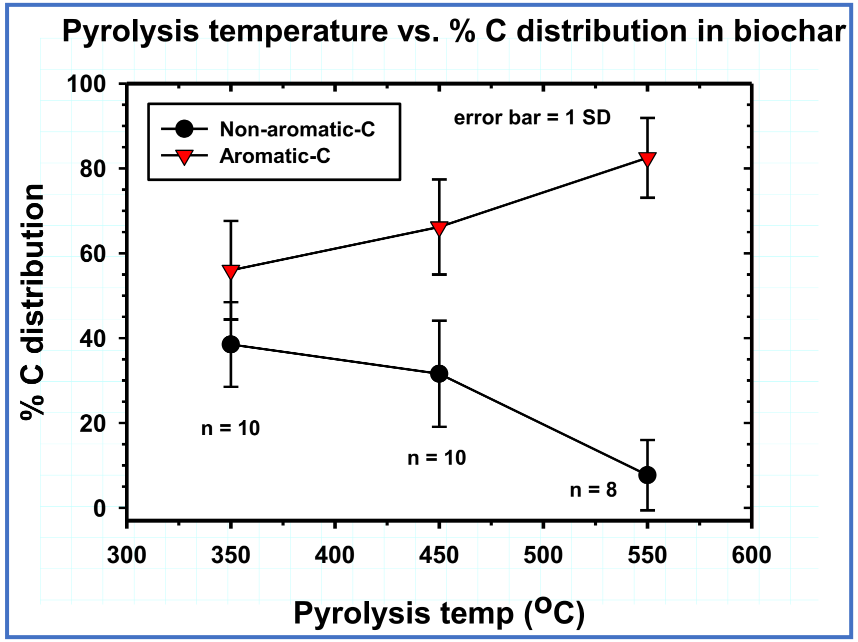


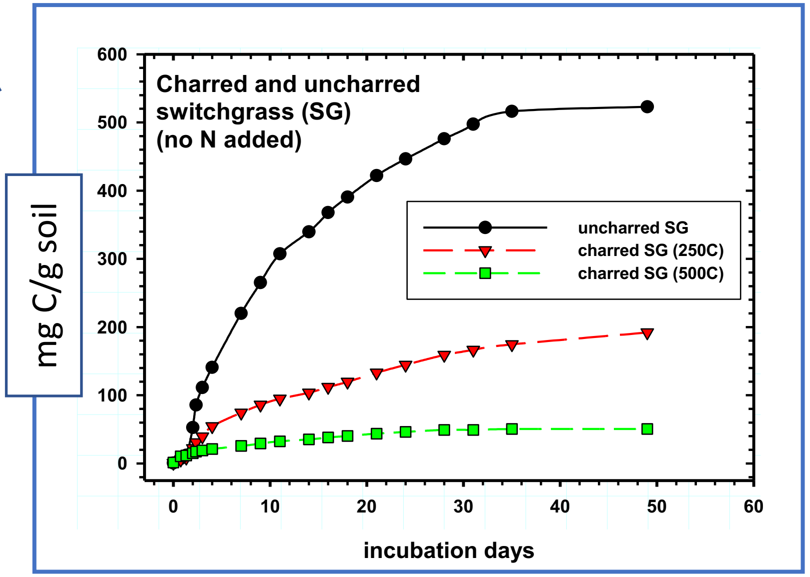
Pot 112 is TSM treated with 2.5% lodgepole pine biochar & 2.5% manure compost.
AGB = 0.084 g; pH = 4.8
Salt-Cd = 135 mg/kg; Salt-Zn = 270 mg/kg
Shoot-Cd =135 mg/kg; shoot-Zn=2,961mg/kg

Pot 86 is TSM treated with 5% beef manure biochar & 2.5% manure compost.
AGB = 2.017g; pH = 5.76
Salt-Cd = 8.4 mg/kg; Salt-Zn =150 mg/kg
Shoot-Cd= 44.5 mg/kg; shoot-Zn= 761mg/kg

Biochars & greenhouse gas production (CO_2)

- Higher pyrolysis temperatures (> 500°C) causes more C distribution in aromatic-C structures (less decomposable).
- Consequently, a high temperature produced biochar incubated in soil is more resistant to microbial oxidation and conversion to CO_2.
- Biochar's structural make up is one factor that determines its C contribution as CO_2 to the atmosphere and as C to the soil organic matter pool.

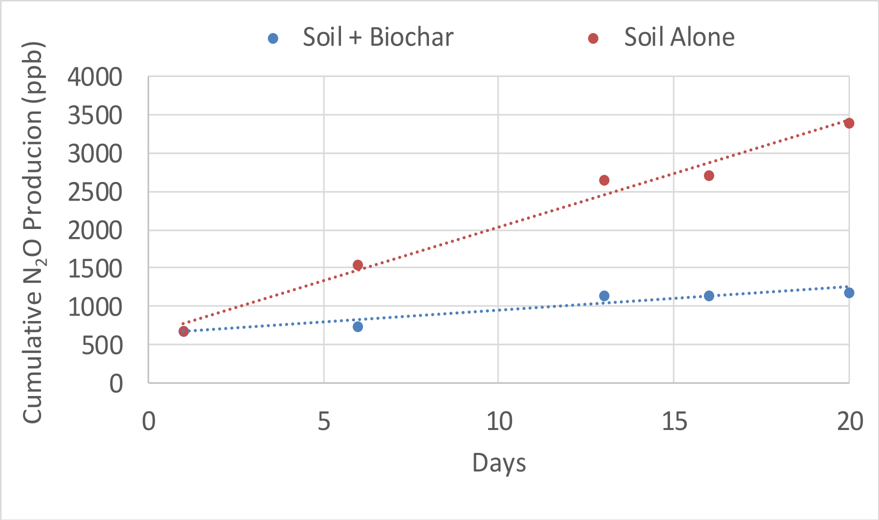




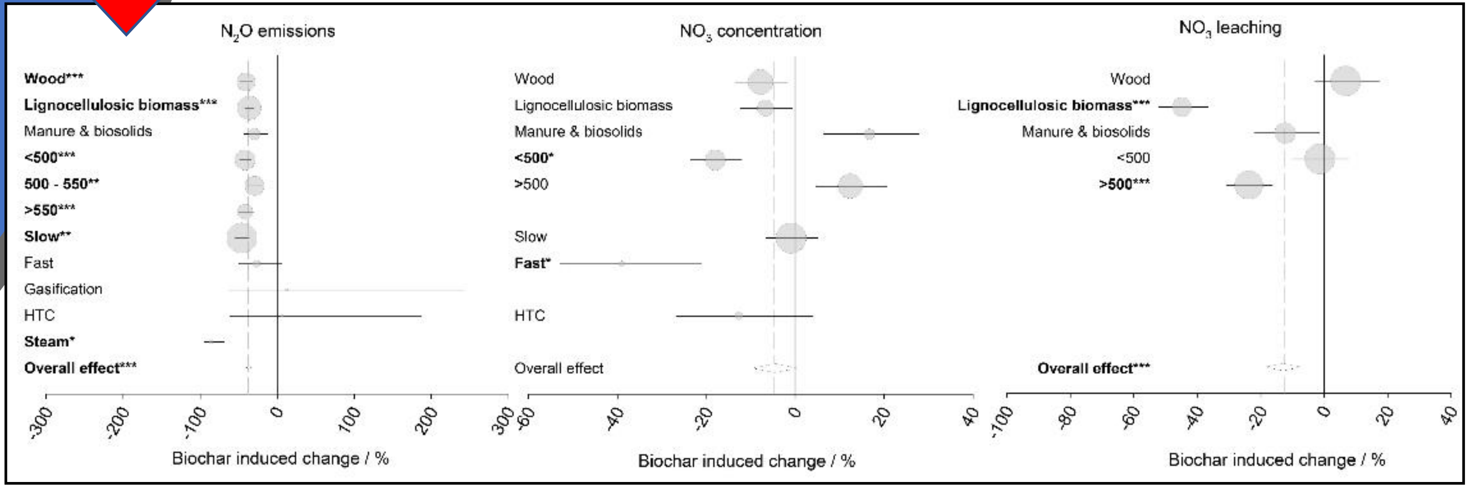
Sigua et al. (2016)

Biochar & greenhouse gas production (N_2O)

- In a laboratory study, Thomazini et al. (2015) reported a suppression of 63% of N_20 production after biochar addition to several soil-types.
- In a meta-analysis of biochar:denitrification studies (n = 88), the overall N_2O emission reduction was 38%, NO_3 concentrations were unaffected while NO_3 leaching was reduced by 13% (Borchard, 2018, manuscript in preparation).
- Overall, the literature reports that biochars role with increasing/decreasing denitrification and conversion of N as nitrous oxide (N_2O) is mixed.



Thomazini et al. (2015), courtesy of K.A. Spokas



Borchard et al. (2018), used with permission (Funded through a USDA-NIFA/FACCE-JPI project)

United States Department of Agriculture
Agricultural Research Service

Activated Biochars for P sorption in Waste Streams

United States Environmental Protection Agency

Water treatment residuals, Mg and Fe-acid mine solids

Pelletize and pyrolyze

Targets

Heavy metals in mine spoils

Interagency Agreement just established between ARS and EPA (Philly office)

Conclusions

- Biochars can be designed to target their chemistry to a specific soil/spoil deficiency.
- The background soil/spoil deficiency must be well established prior to designer biochar production.
- The designer biochar technology will be applied to counter poultry related soil and environmental issues in the Delmarva area (2018-2020).