Ameliorating Effects of Biochar Application in a Hard-Setting Subsoil Layer: Quality of Leached Water and Soil Chemical Properties

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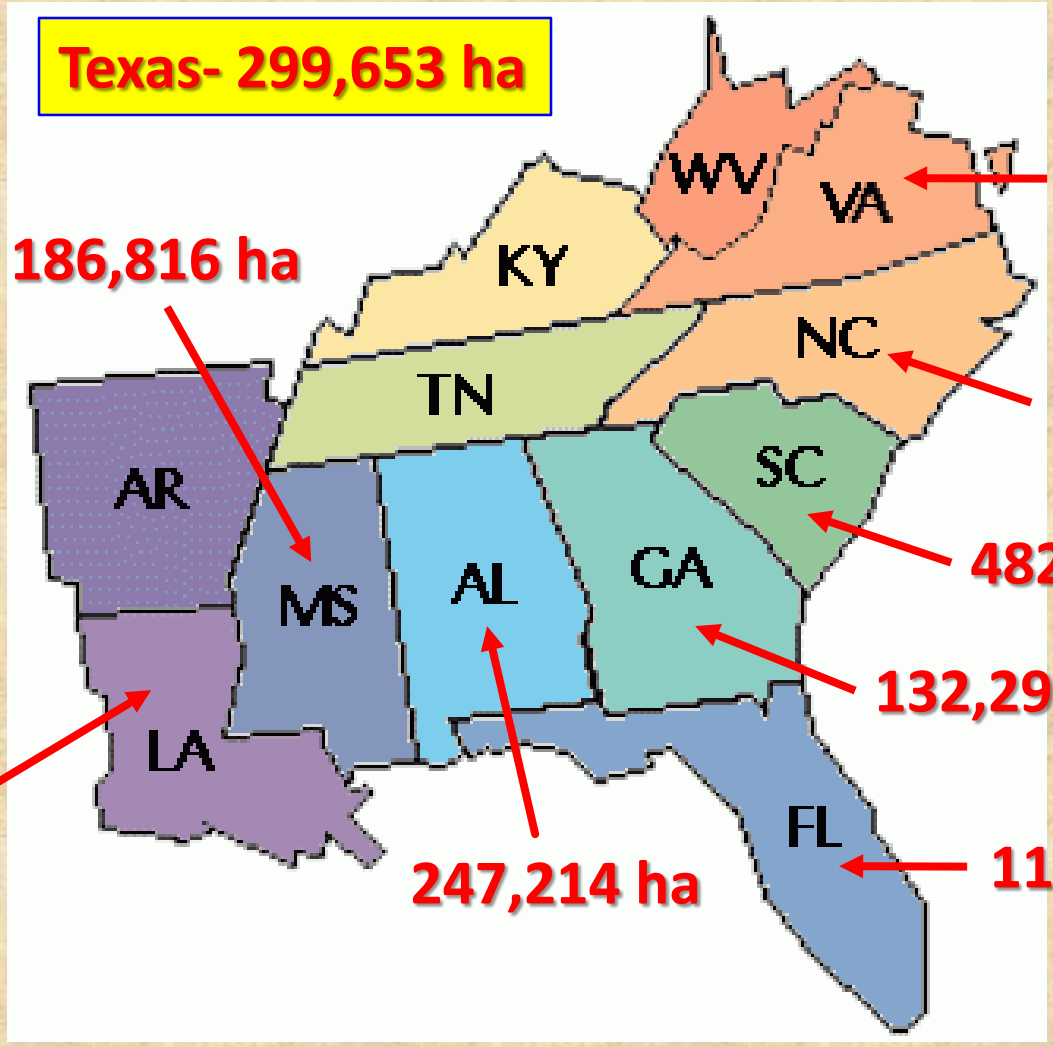
Hard-setting Subsoil Layer – Norfolk Sandy Loam in SE USA Coastal Plains Region 101

- Compacted subsoil horizons with limited soil water holding capacities.
- These horizons develop due to various pedogenic processess (e.g. eluviation-illuviation, wetting-drying, physico-chemical bonding of soil materials).
- Generally compacted subsoil horizons have lost soil organic matter due to eluviations, which allows closer arrangement amongst sand grains, oxides and other fine-size soil materials during wetting-drying cycles.
- Physico-chemical bonding between soil materials resulting in formation of a dense, structureless layer (E horizon) with bulk densities ranging between 1.41 to 1.82 g/cc and high penetration resistance.

Norfolk Soils in Southeastern USA

(based on early 90's Soil Survey: Total – 1,919,926 ha)



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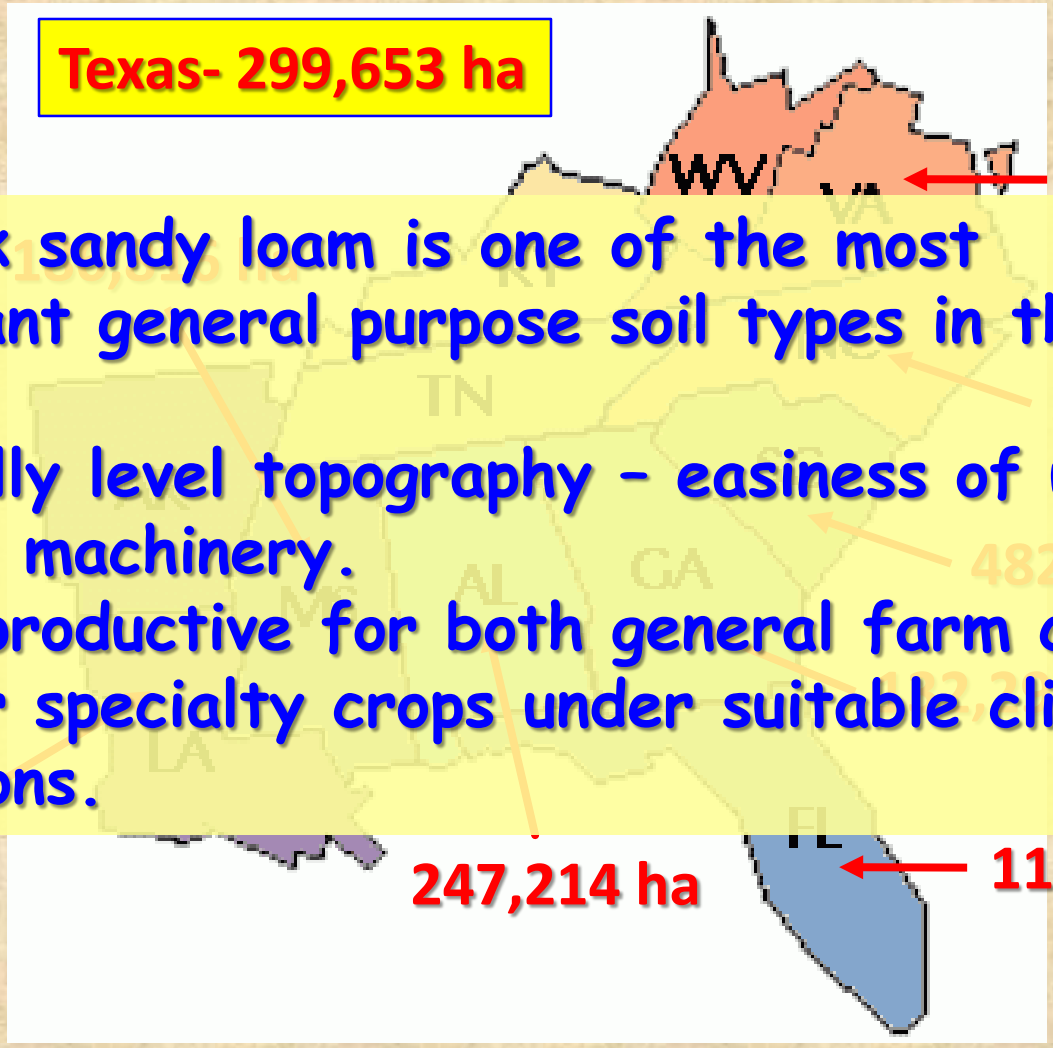


- Norfolk sandy loam is one of the most important general purpose soil types in the region.
- Generally level topography – easiness of using modern machinery.
- Quite productive for both general farm crops and for specialty crops under suitable climatic conditions.

Norfolk Soils in Southeastern USA
(based on early 90's Soil Survey; Total – 1,919,926 ha)

- General Problem: Compacted soil, limited water holding capacity, low fertility >>>> Severely Impacting Crop Productivity.
- Deep tillage was used to rupture compact subsoil layer. Few issues involved: requiring large tractors; fuel consumption and needed annually to prevent re-setting of dense soil layer.
- To improve hydraulic properties: additions of composts, crop residues and fly ash >>> short term effect >>>> RECALCITRANT Effects
- Biochar has the potential to increase soil water holding capacities of sandy soils. Biochars impact have mixed results.

Benefits of the Designer Biochar Concept:

- may be used for improvement of selected soil properties;
- avoid applying a biochar that is unsuited for desired change in soil; and
- avoid creating another issue by applying an inappropriate biochar.

What are the targeted properties of a Norfolk soil that designer biochar can improve?

Norfolk loamy sand

- sandy, low water holding capacity
- acidic pH values (4.4 to 5.9)
- meager CEC levels (1 to 4 meq./100g)
- underlain by a E horizon that lacks structure and forms a hard layer (limits root penetration)

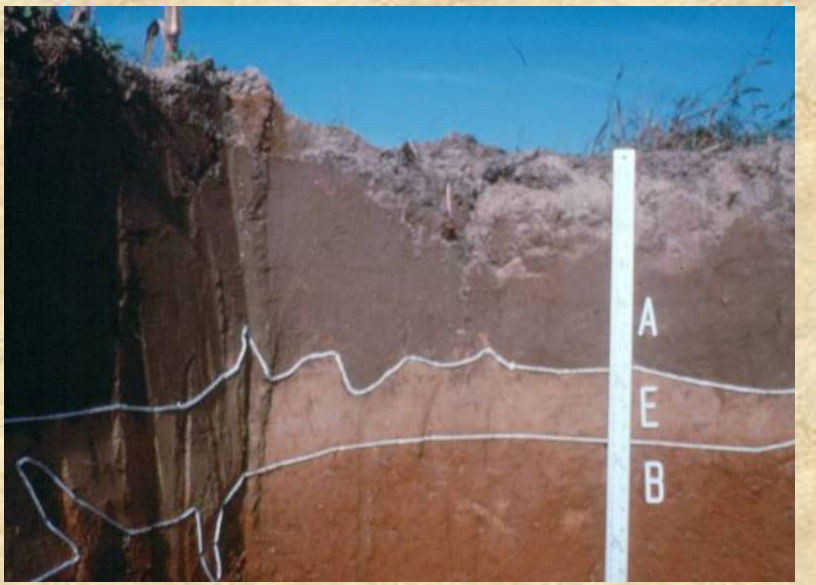

E horizon lack structure

% SOC in Norfolk profile	
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

How can a biochar be designed to improve targeted issues in the Norfolk soil?

Goals:

- improve water holding capacity;
- raise CEC, % SOC, pH, and other nutrients;
- reduce hard layer formation by creating aggregates; and
- improve soil fertility.



Objectives

- To investigate the contrasting effects of blended designer biochars on ameliorating chemical properties of hard-setting subsoil layer in Coastal Plain regions; and

- To examine weather applying blended biochars (PC + PL) to soil reduces nutrient leaching while improving soil water retention.

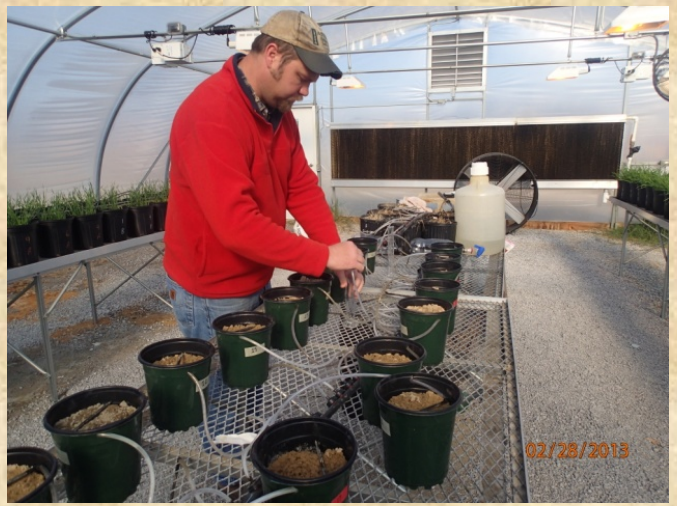
Experimental Design and Treatment

- Feedstocks: Pine Chips (PC); Poultry Litter (PL) and Hardwood (HW)
- Biochars (PC and PL) were pelletized (10-20 mm in length; 6-8 mm in dia) – slow pyrolysis at 500°C.
- Hardwood (oak + hickory sawdust): pyrolysis at 500°C - <0.5 mm

1. Pot Study with Winter Wheat
2. Leaching Study (Laboratory)

Experimental Design and Treatment

Study I. Pot Experiment (Greenhouse) with Winter Wheat (Pioneer Variety, 26R20)



- Norkfolk's E Horizon
- Experimental Treatments: control; 50:50 blends of PC and PL; 80:20 blends of PC and PL; 100% PL and 100% PC

- Biochar Rate of Application (2%) = 40 Mg/ha
- 4 replications; Completely Randomized Block Design
- Blanket Applications: 45 kg N/ha; 60 kg P/ha; 80 kg K/ha

Experimental Design and Treatment

Study II. Leaching Study

- Norkfolk's E Horizon
- Experimental Treatments: control; 50:50 blends of PC and PL; 80:20 blends of PC and PL; 100% PL and 100% PC

- Biochar Rate of Application (2%) = 40 Mg/ha
- 3 replications; 128 days
- 128 days; 4 Leaching Events
- PVC columns (16 cm height x 10 cm dia)

RESULTS: Study I

Biochar Treat	pH	EC (uS/cm)
Control	4.95d	19.5c
100% HW	6.28c	30.8c
50:50 PC:PL	8.42a	295.0a
80:20 PC:PL	7.05b	135.5b
100% PC	6.22c	17.7c
100% PL	8.28a	220.5ab
$LSD_{0.05}$	0.28	90.3

Source: Sigua et al. 2016 Chemosphere 142:168-175

- Soil pH and soil EC varied significantly ($p \leq 0.001$) with designer biochars.
- 50:50 PC:PL and 100% PL had the greatest soil pH and EC readings.
- Results have shown the beneficial effect of designer biochars on enhancing soil pH of highly weathered Norfolk soils.
- With the exception of 100% PC, application of other designer biochars resulted in significantly higher soil EC than the control.

RESULTS: Study I

- Overall, designer biochars had significantly affected the levels of soil TN, but not soil TC.
- On the average, 100% PL had the greatest TN while the least amount of TN was from HW.
- Application of 100% PL in terms of percent increase in soil TN was superior over all other designer biochars and the control.
- Our results show the beneficial effect of designer biochars on enhancing soil TN in a typical highly weathered Norfolk soil.

Biochar Treat	TN (%)	TC (%)
Control	1.42b	42.6a
100% HW	1.04c	43.9a
50:50 PC:PL	1.44b	42.3a
80:20 PC:PL	1.37b	42.7a
100% PC	1.37b	44.1a
100% PL	1.94a	39.8a
$LSD_{0.05}$	0.32	4.42

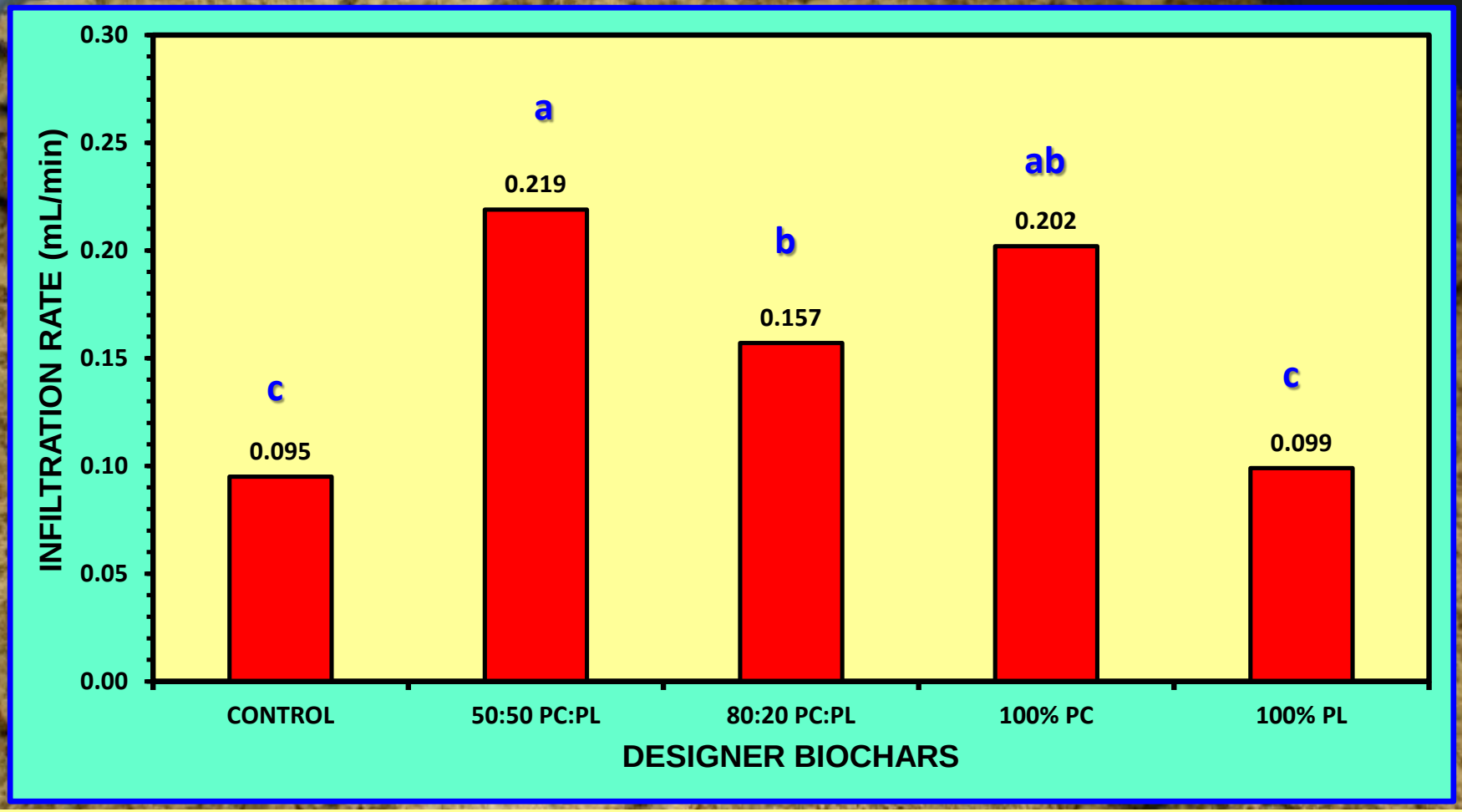
Source: Sigua et al. 2016 Chemosphere 142:168-175

RESULTS: Study I

Biochar Treatments	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
Control	15.4c	46.5c	42.5c	8.2c
100% HW	11.3c	80.2c	68.7bc	9.2c
50:50 PC:PL	118.9a	439.4b	172.7a	64.7a
80:20 PC:PL	37.2c	154.4c	81.9bc	21.2c
100% PC	12.3c	41.2c	57.9c	8.6c
100% PL	66.8b	673.2a	106.9b	38.1b
$LSD_{0.05}$	27.8	115.3	43.2	14.1

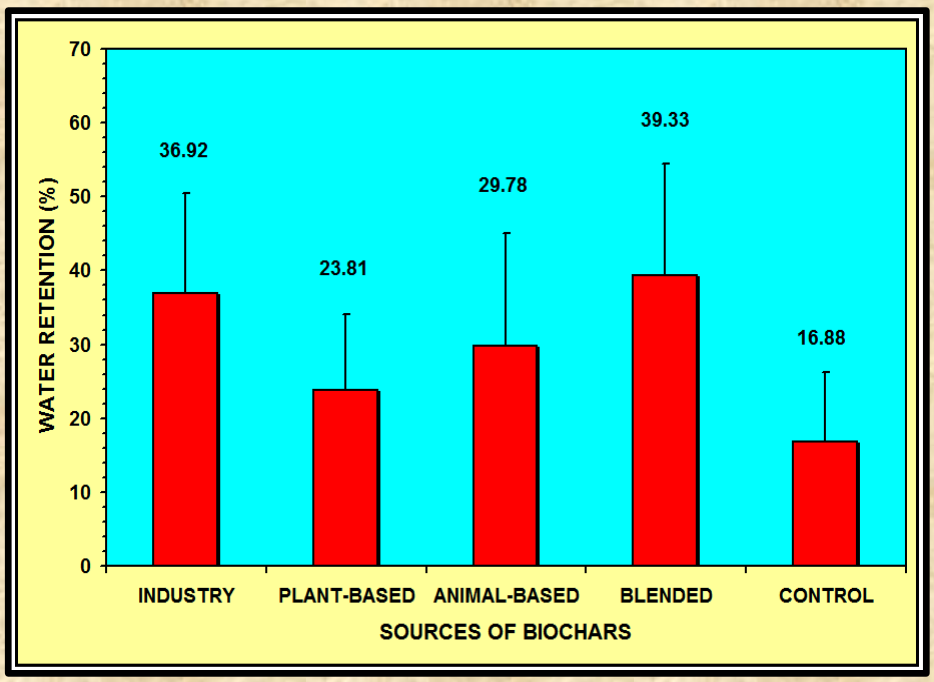
- Mehlich extractable P, K, Ca and Mg varied significantly ($p \leq 0.0001$) with designer biochars.
- There was a much greater increase in the concentrations of P, K, Ca and Mg for treatments with 50:50 PC:PL and 100% PL compared with the control soils.
- Application of 50:50 PC:PL increased concentration of P, K, Ca and Mg by 669%, 830%, 307% and 687%, respectively when compared with the control treatment.

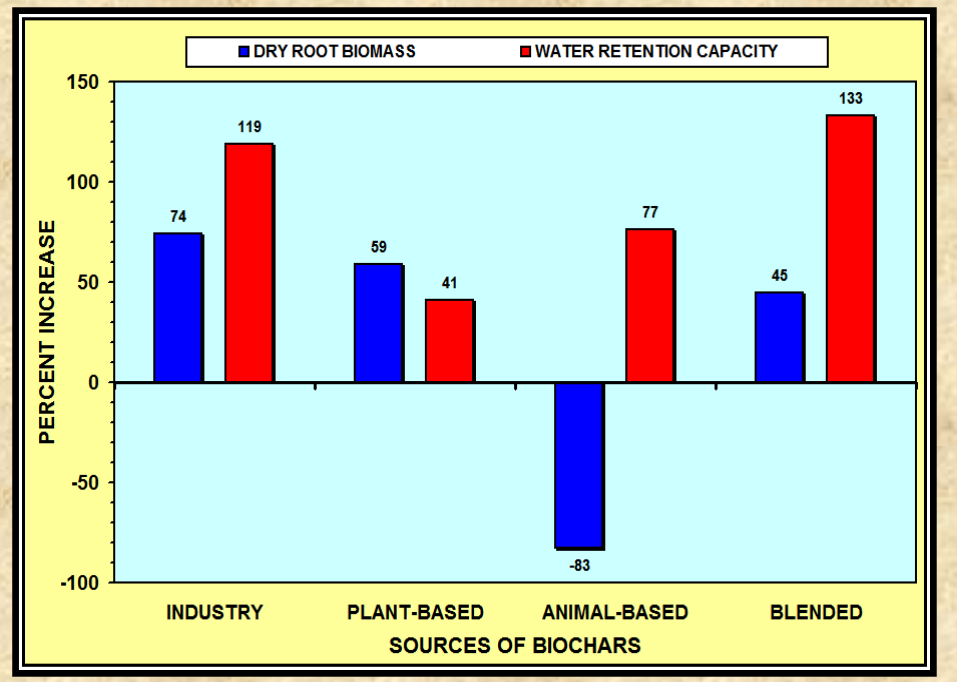
RESULTS: Study II (Leaching)



- There was significant differences in water infiltration when results were pooled from 4 Leaching events (32, 67, 95 and 128 days).
- Water infiltration was enhanced by about 1.5 to 2-times in the 50:50 PC:PL, 100% PC and 80:20 PC:PL when compared to 100% PL and the control.

RESULTS: Study II (Leaching)





The water retention capacity of Norfolk soils that were treated with 50:50 PC:PL, 100% PL, and 100% PC when compared with the untreated soils were increased by 133%, 77% and 41%, respectively. This implies that soil moisture content is improved by adding these biochars.

Results: Study II (Leaching)

Biochar Treat	pH	EC (dS/m)	NO_3 (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Na (mg/L)
Control	5.9c	0.1d	6.0a	0.1c	2.0d	6.0d	4.0d
50:50 PC:PL	8.0a	2.3b	5.0b	54.0a	55.0b	385.0b	163.0b
80:20 PC:PL	7.3b	0.8c	5.0b	10.0b	20.0c	110.0c	53.0c
100% PL	8.0a	4.5a	4.0c	63.0a	160.0a	799.0a	246.0a
100% PC	6.5b	0.2d	5.0b	0.1c	3.0d	8.0d	5.0d

Source: Novak et al. 2016 Chemosphere 142: 160-167

Leaching Day	pH	EC (dS/m)	NO_3 (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Na (mg/L)
32	6.8c	4.3a	2.0c	16.0c	160.0a	970.0a	1059.0a
67	7.3a	0.9b	8.0a	33.0a	18.0b	55.0b	228.0b
95	7.1b	0.6c	7.0b	28.0b	7.0c	13.0c	140.0c
128	7.4a	0.4c	3.0c	24.0b	6.0c	8.0d	107.d

Source: Novak et al. 2016 Chemosphere 142: 160-167

Summary (Take Home Message)

- Our results proved our hypothesis by showing that application of most biochars (except 100% PL) to the Norfolk E horizon resulted in significant increases in water retention.
- 50:50 blend of PC:PL was the most resilient biochar treatment in the compact soil, since after multiple leaching, it is still had consistently higher soil water retention value.
- Results showed favorable and beneficial effects of different biochars on improving soil chemical properties of Norfolk soils with hard setting subsoil layer.

Summary (Take Home Message)

- Again, the 50:50 blend of PC and PL was found to be superior compared to other biochars because of their favorable effect on soil fertility.

So,

- Overall, our results showed promising significance of designer biochars for improving soil fertility and water retention of an Ultisols soil with hard setting subsoil layer in Coastal Plain, USA.

Outlook

Long-Term Field Experiment: Designer Biochar Applications
USDA-ARS, Coastal Plains Soils, Water and Plant Res. Center
Florence, South Carolina

Treatments: 100% Pine Chip biochar; 100% Poultry litter biochar; 100% Switchgrass biochar; Pine chip + Poultry litter (3:1); Pine chip + Switchgrass (3:1); and Control.

Questions… Thanks!!!

6.16.2016