Influence of pecan-derived biochar on chemical properties of a Norfolk loamy sand soil

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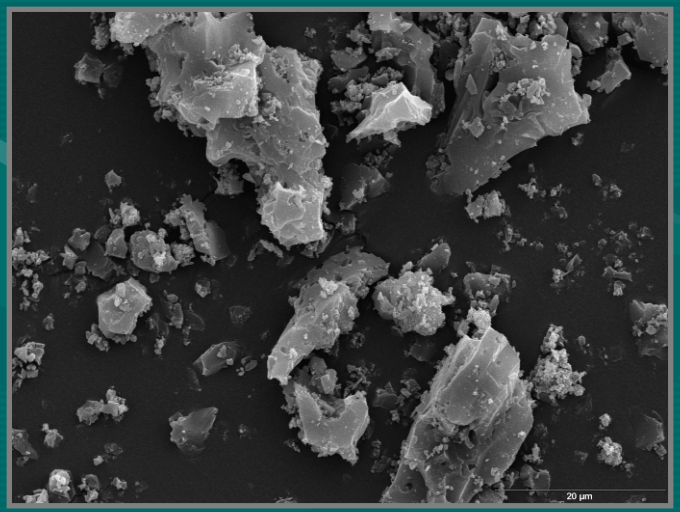
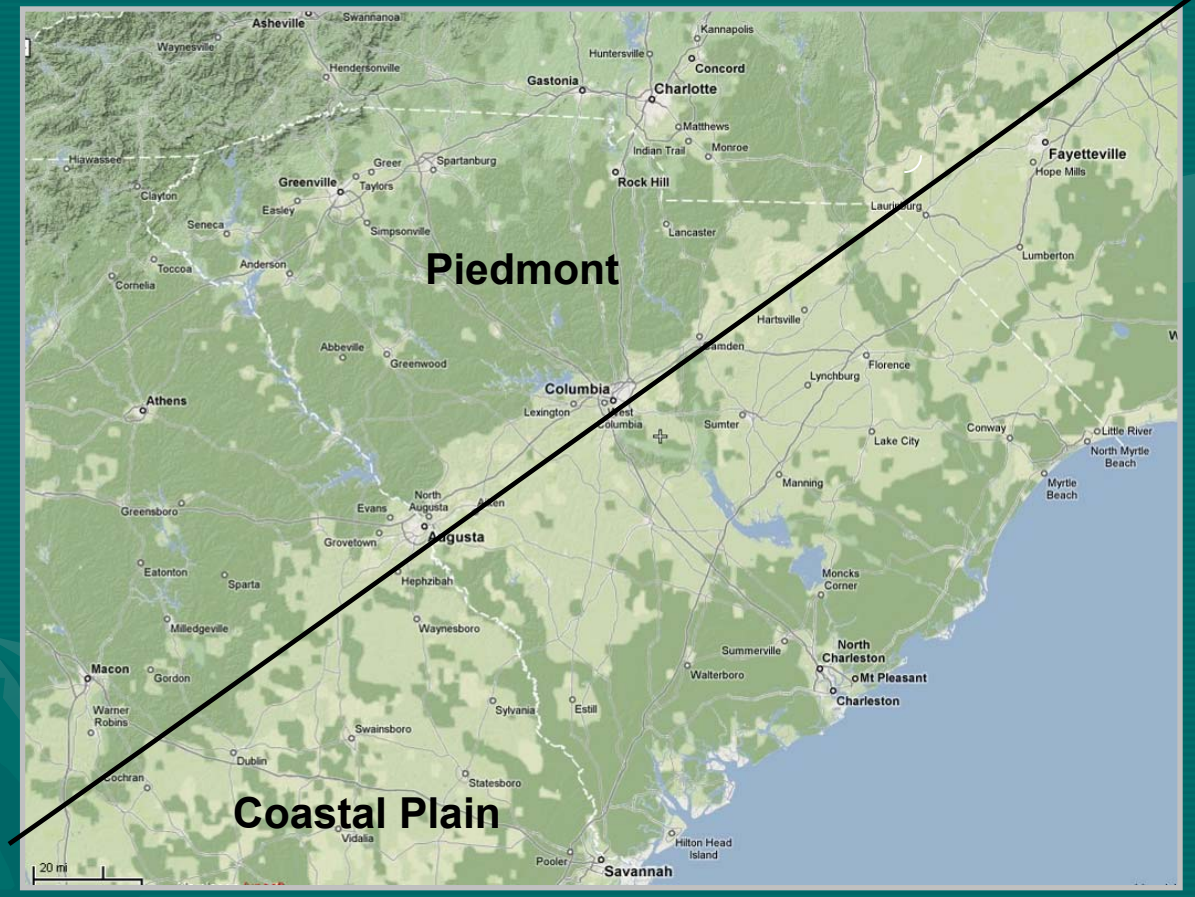


Physiography of SE USA Coastal Plain

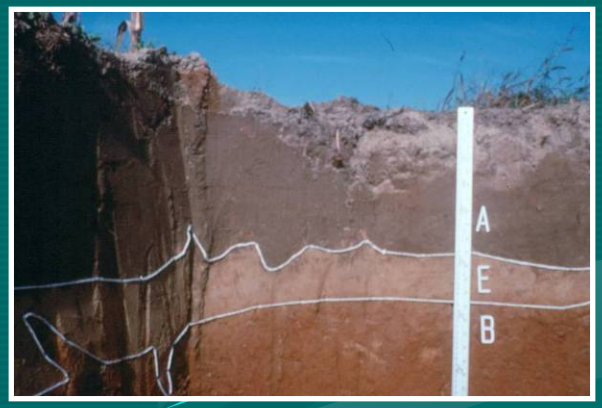
- In the SE Coastal Plain, most of the agricultural soils formed in fluvial and marine sediments deposited 0.5 to 5 million yrs ago.
- The soils are sandy with poor fertility, acidic pH values, and low soil organic carbon contents (SOC).



Coastal Plain Soil Properties

Norfolk loamy sand

- well-drained, sandy Ap horizon
- underlain by a E horizon that lacks structure and forms a hard layer (limits root penetration)



E horizon from Norfolk loamy sand

% 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

Previous efforts to rebuild SOC contents

- Using conservation tillage, it can take between 5 to 10 years to detect significant SOC changes.
- The SOC increase is depth dependent.

Median SOC contents in sandy soils after 6 yrs of conservation tillage under a corn-cotton rotation (3.3 ha field, n = 50; Novak et al., 2008).

depth	1998	2004	Δ	Residue OC input	As SOC
- cm -	Mg ha^{-1}				%
0 to 3	2.04a	2.67b	+0.63	14.8	4.3
3 to 15	10.66a	8.27b	-2.39	---	---

Bottomline: It takes a long time and a lot of crop residue to increase SOC content

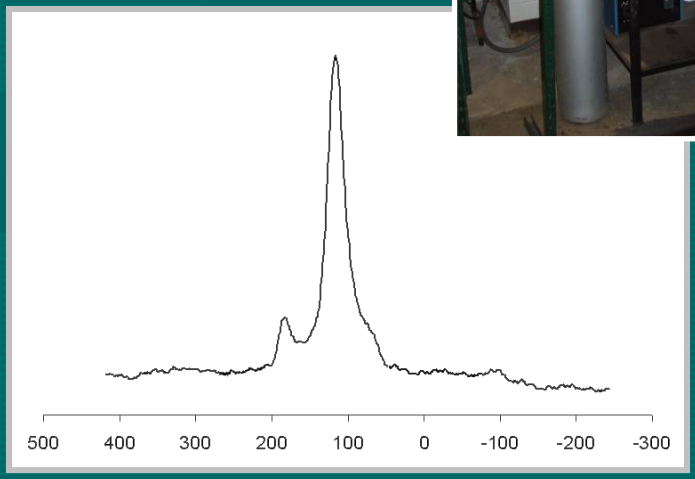
Our quest

How are we going to increase SOC contents and improve fertility in sandy soils, Jeff?

Terra Preta profile showing biochar with soil depth (courtesy of Wikipedia.org)

Pecan shell-based biochar

- Colleagues at NC A&T made biochar from pecan-shells by pyrolysis at 700°C
- Biochar is 88% OC, 0.4% N (220:1, C:N ratio), pH of 7.5
- Most of C (58%) is distributed in polymerized aromatic ring structures
- Inorganic components are Ca, K, Mg, Na, P and Si



Biochar incubation with Norfolk Ap horizon (methods)

Creating Norfolk soil + biochar mixtures (0, 0.5., 1.0 and 2.0%)

Columns with soil and biochar (SOC, CO_2, aggregates, and strength measured)

Leaching of columns (DOC, cation, N conc.)

Biochar incubated in a Norfolk soil

	Mean SOC content (g kg^{-1})	
Soil + biochar (%)	0 days	67 days
0	17.0a	17.4a
0.5	18.1a	18.3a
1.0	22.2b	21.9b
2.0	31.2c	29.2c

(Novak et al., 2008; *in review*)

Norfolk mean fertility (after 67 d)

	Norfolk soil + % biochar			
Soil property	0	0.5	1.0	2.0
pH	5.2a	5.6b	5.9c	6.4d
K (mg kg^{-1})	26a	47b	49c	69d
Ca (mg kg^{-1})	392a	462b	537c	692d
CEC ($cmol_c$ kg^{-1})	5.2a	5.4a	5.6a	5.9a
Ex. Acid ($cmol_c$ kg^{-1})	2.4a	2.1a	2.0a	1.5b

(Novak et al., 2008; *in review*)

Cumulative CO_2 fluxes (at 67 d)

	Cum CO_2 (µmol m^{-2} s^{-1})	
Soil + biochar (%)	Mean	SD
0	22.8a	5.2
0.5	20.8a	1.4
1.0	20.9a	2.5
2.0	14.5a	3.4

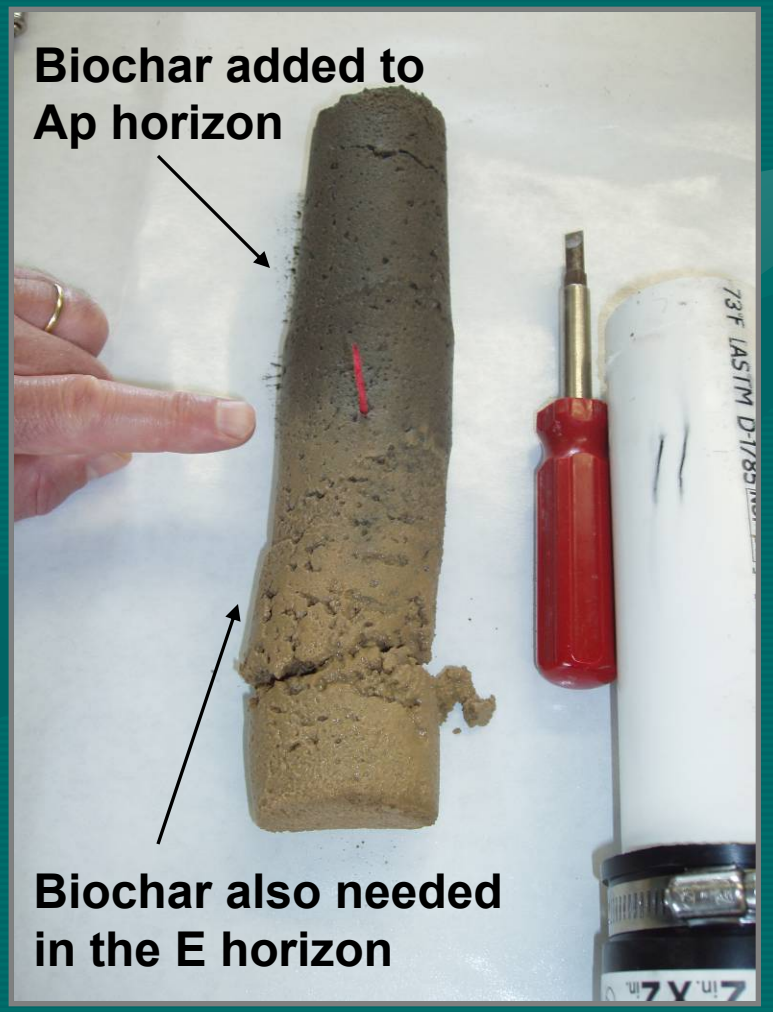
(Novak et al., 2008; *in preparation*)

Mean DOC conc. in leachates

	Leachate DOC (mg/L)	
Norfolk soil + % biochar	25 days	67 days
0	71a	45a
0.5	58a	37a
1.0	61a	46a
2.0	76a	58a

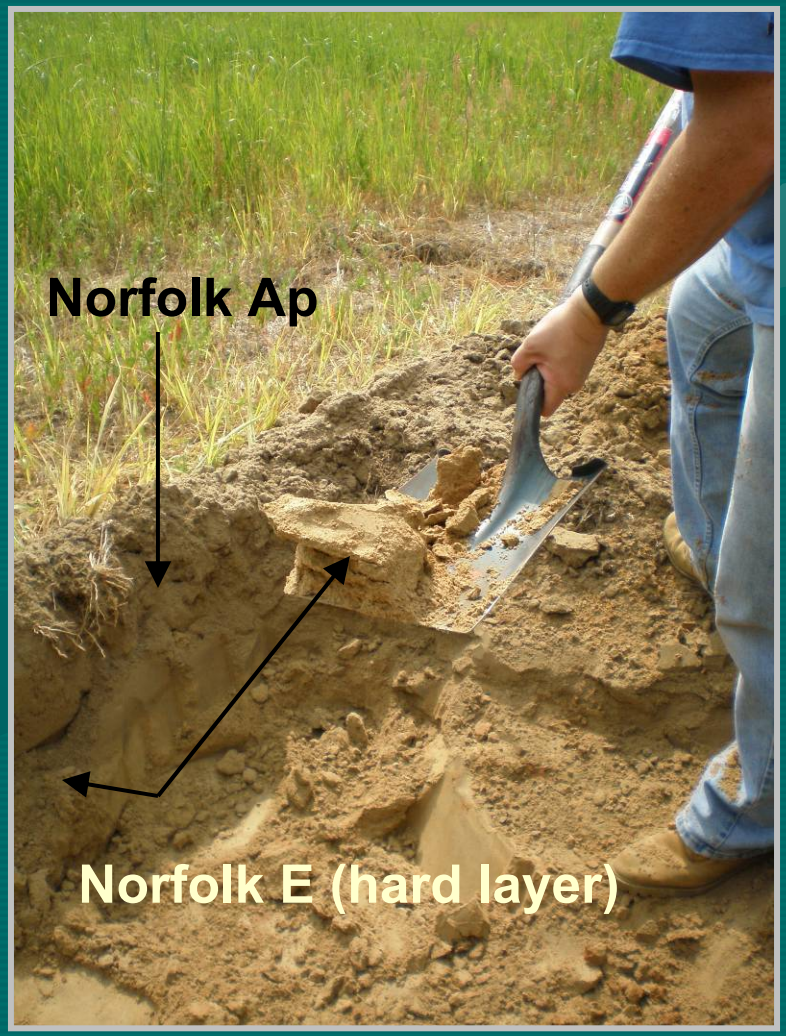
(Novak et al., 2008; *in preparation*)

Biochar application to surface soil and its movement in the profile



What we need to achieve is biochar in Ap and E horizons:

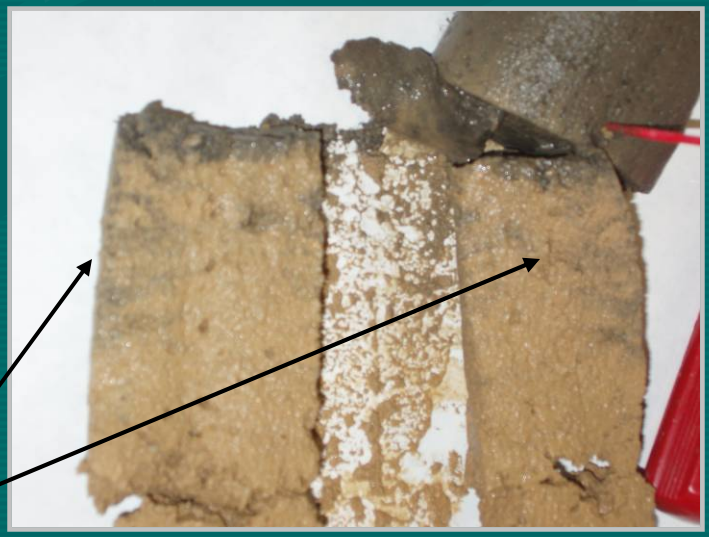
- Biochar that can be surface applied, disked in, and then migrates through soil into subsurface hard layers
- Can biochar chemistry be designed to promote leaching to E horizon?
- Collaboration with NC A&T scientists to create "designer biochar"



Biochar leaching experiment

Column packed with Norfolk E

Norfolk Ap/E ± biochar leached with di. H_2O



Dark bands are leached biochar

DOC (g) collected from biochar (BC) treatments

Norfolk Ap/E Soil + biochar	DOC (g)	
	Mean	SD
Control (no BC)	4.67a	1.71
BC 1	2.24a	0.83
BC 2	1.53a	1.63
BC 3	29.82b	10.51
LSD (0.05)	11.51	

Goal: Creating biochars with specific characteristics for targeted purposes

- **For C sequestration:**
  - highly recalcitrant

  -- high aromatic content with wide C:N ratio
- **For soil fertility improvement:**

  -- less aromatic character; lower C:N ratio

  -- some cellulose, complex sugars, COOH, etc.
- **For movement in soil profile**

  -- more water soluble C structures

  --sugars, amines, ROHs, amines, COOHs, etc.