

Sustainable Management of Forests for Bioenergy Production

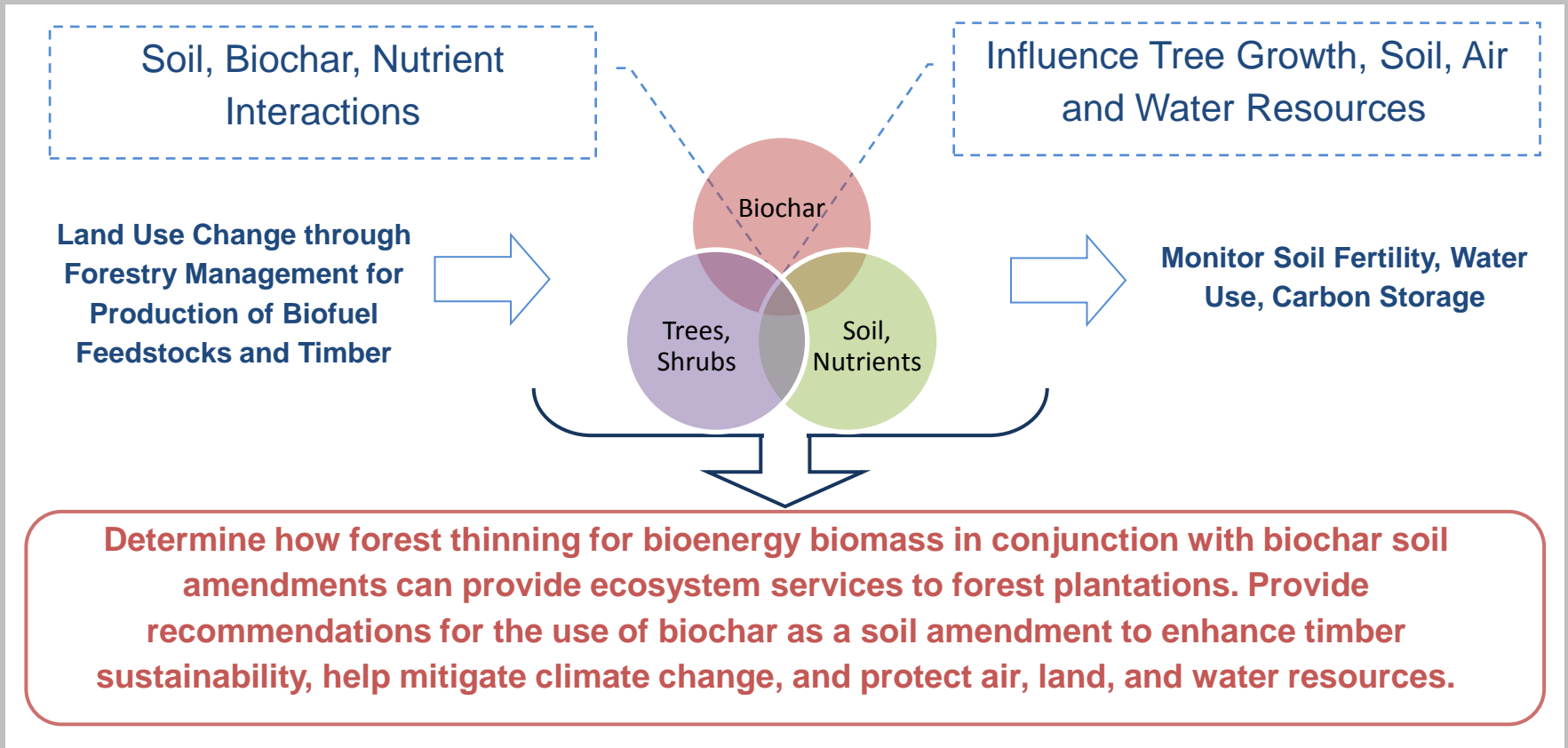
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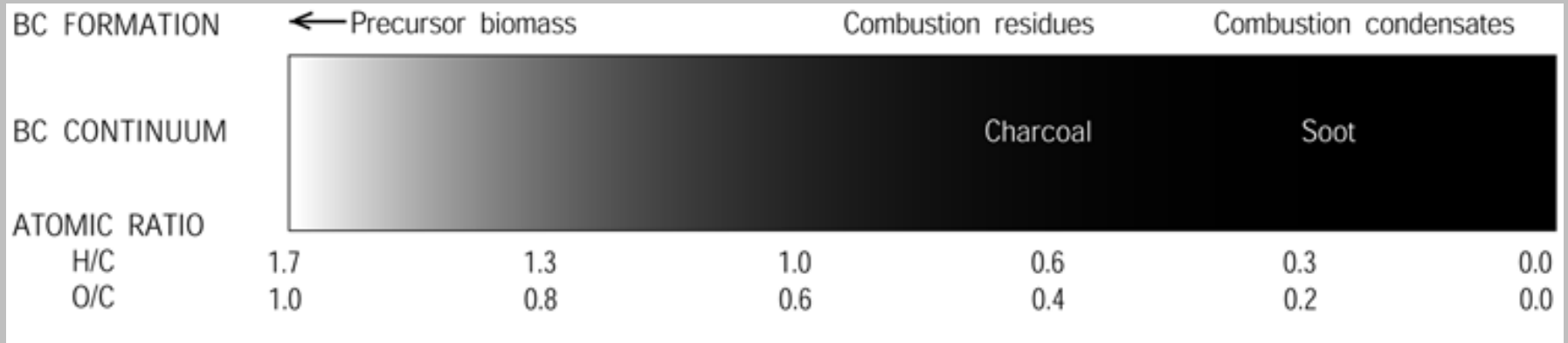
Project Objective

To determine if biochar soil amendments produced by pyrolysis of biomass from forest thinning for bioenergy can maintain, or enhance, the carbon storage in forest soils.



What is Biochar?

Black carbon (BC) is not a single entity, but exists as a chemical continuum.



Hammes et al., 2007 - Inspired by Hedges et al. (2000) and Masiello (2004).

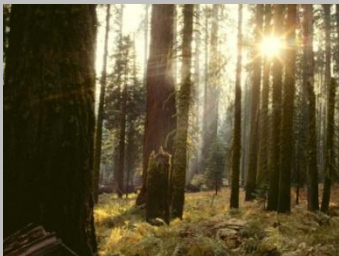
“ A solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment”

~ International Biochar Initiative.

Experimental Approach:

- **Produce biochar** from ponderosa pine at 300, 500, 700, and 900 °C using a Thermcraft pyrolysis unit (UC Davis, Department of Biological and Agricultural Engineering, Biomass laboratory).
- **Conduct saturate and unsaturated soil column leaching experiments** (using McCarthy Sandy Loam and acid washed quartz sand) to determine if additions of each the four biochars affected **retention of dissolved organic carbon (DOC)**.
- Using high pressure liquid chromatography with a diode array detector (**HPLC-DAD**), **quantify biomarkers**(benzopolycarboxylic acids -BPCA's) of the leachate and soil from column experiments to differentiate between native and non-native soil carbon pools.

Collect soils and duff



Prepare biochar and duff tea (DOC soln.)



Leach soil columns with duff tea



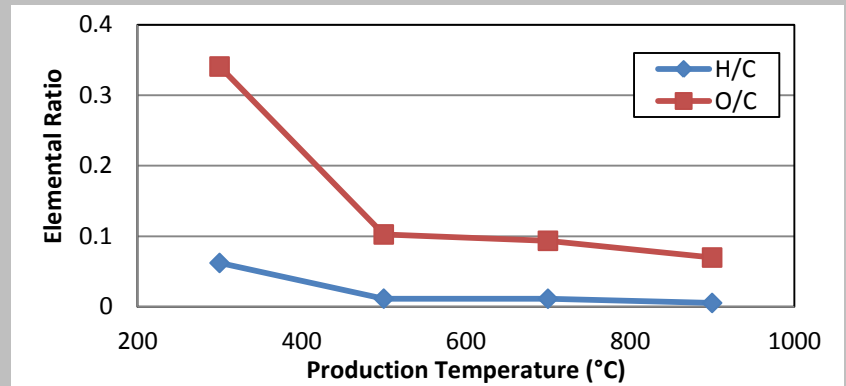
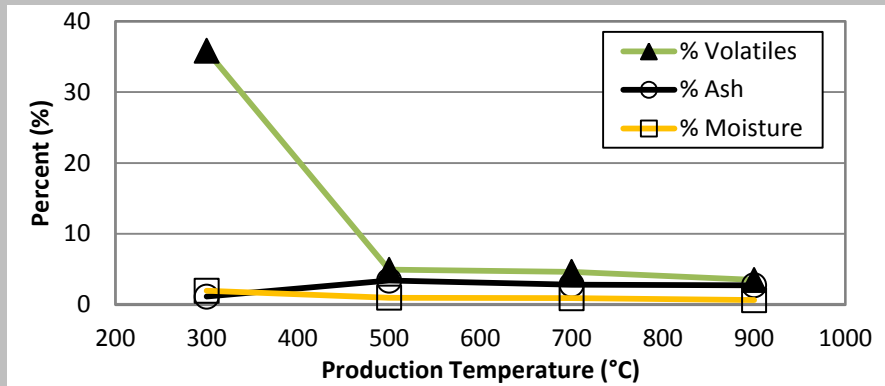
Quantify DOC



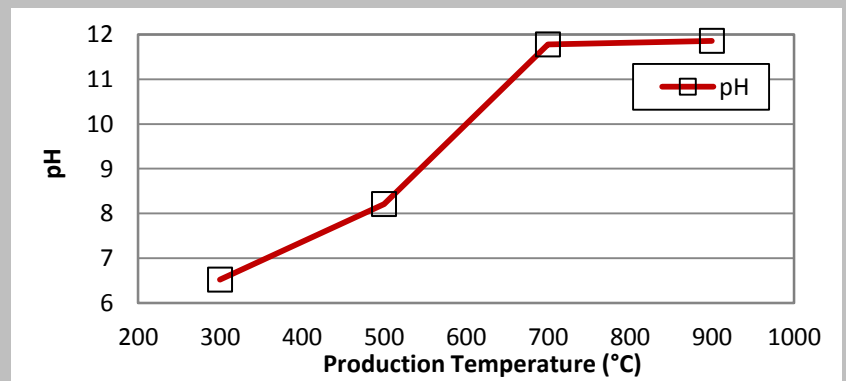
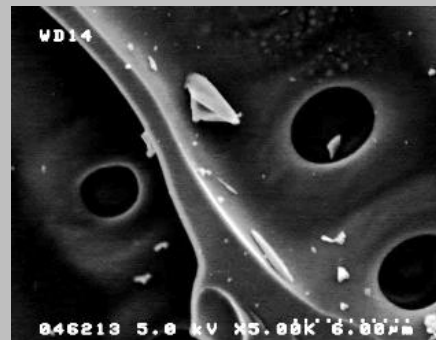
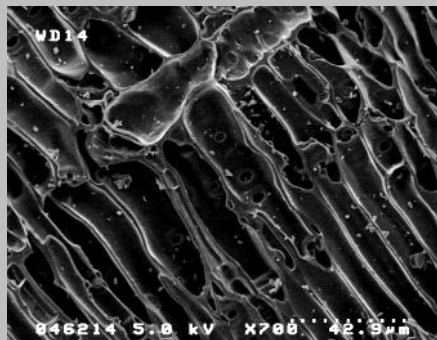
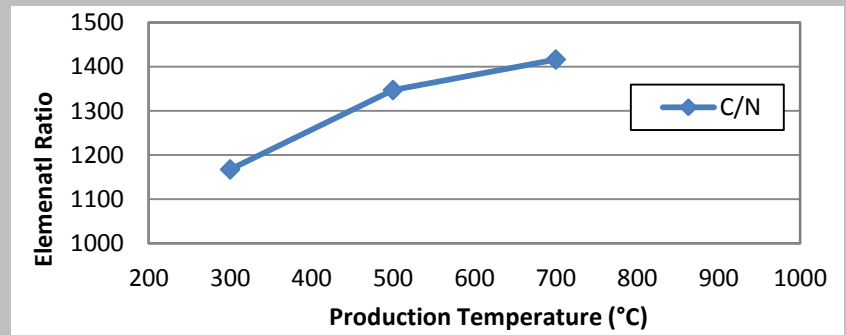
Quantify BPCA's



Results: Char Analysis

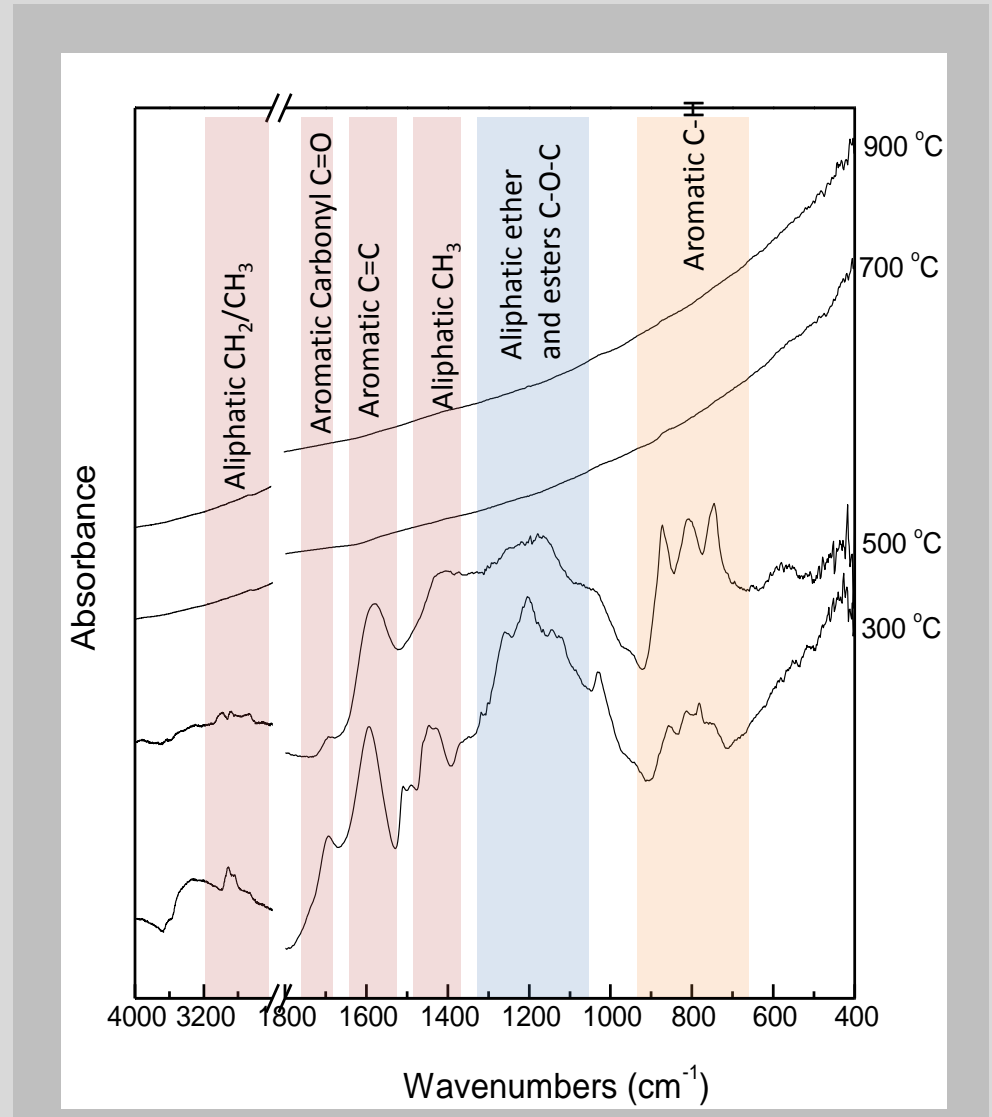


While % C, % ash, and pH increase with production temp., % H, % volatiles, and % moisture decrease. This and other data will be incorporated into the newly created UC Davis Biochar Database (biochar.ucdavis.edu).



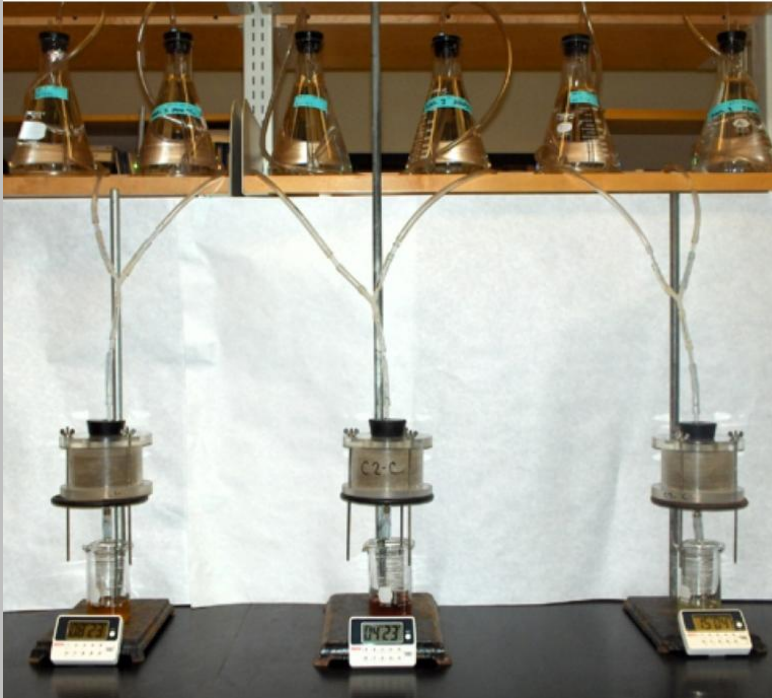
Results: Char Analysis

The FTIR spectra of the biochar thermosequence reveal a loss of IR bands with increasing pyrolysis temperature, indicative of loss of O-rich functional groups and an increase in aromaticity.



Methods: Soil Columns

- Pack soil columns, with char additions mixed into a layer of soil on the side of the column opposite the point of outflow. Wash soil columns with 1 L 0.1 M NaCl soln., leach with 1 L duff tea (~25 ppm DOC).
- Collect leachate in 250 mL fractions and analyze for pH, EC, **DOC**, NO_3^- , NH_4^+ , and **BPCA markers**.

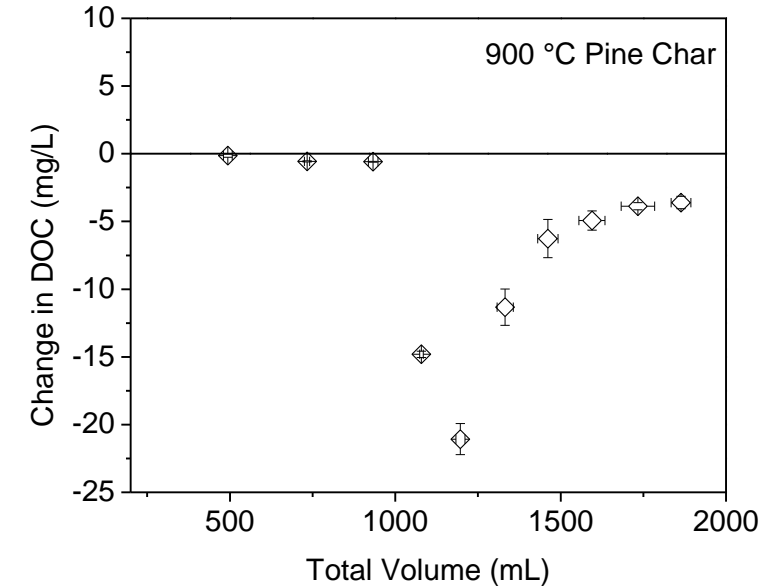
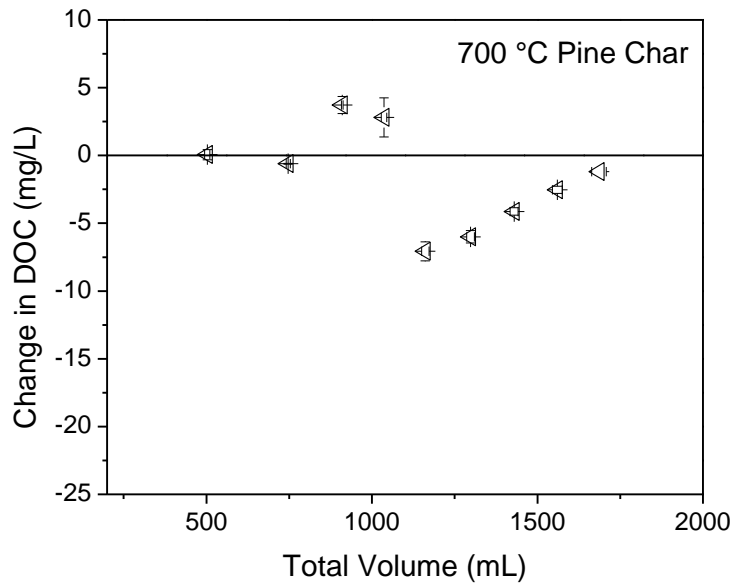
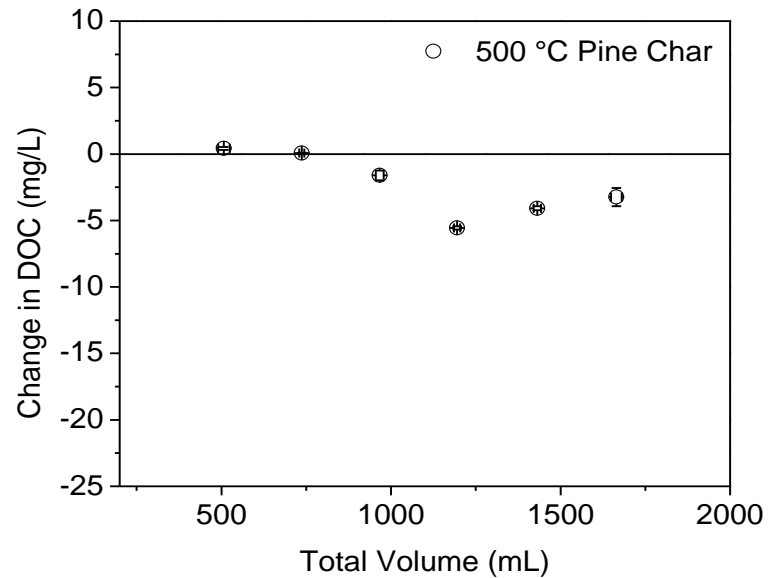
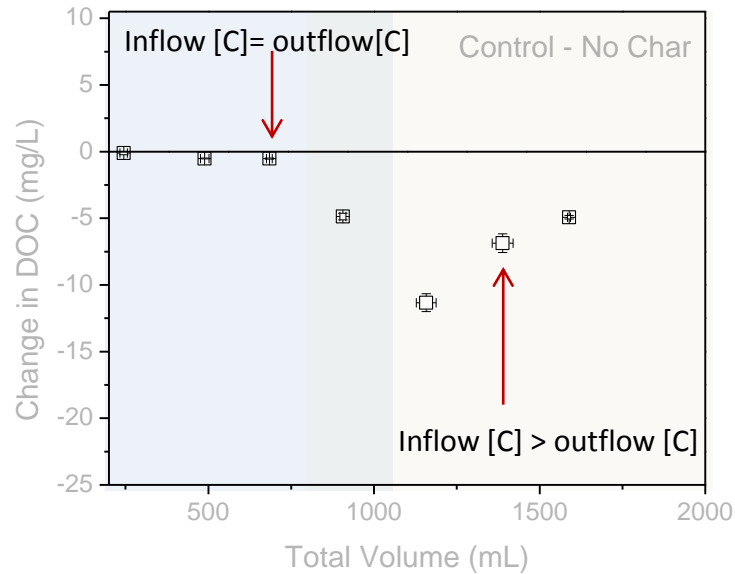


Soil column leaching



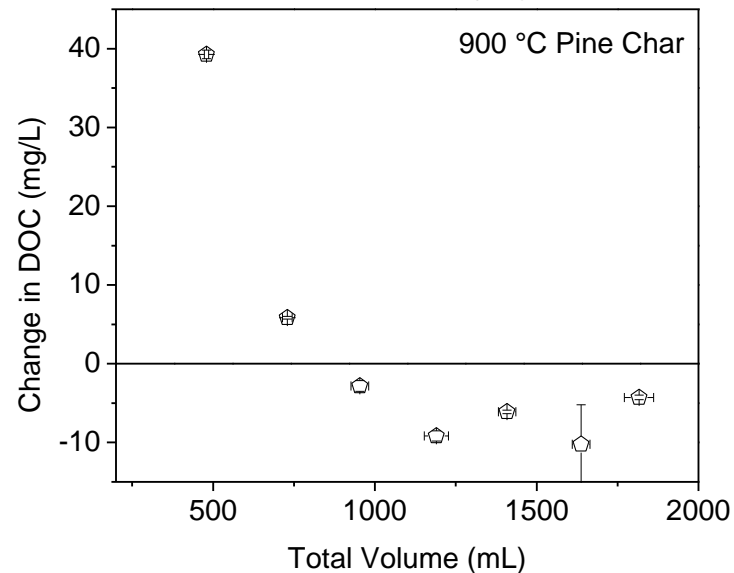
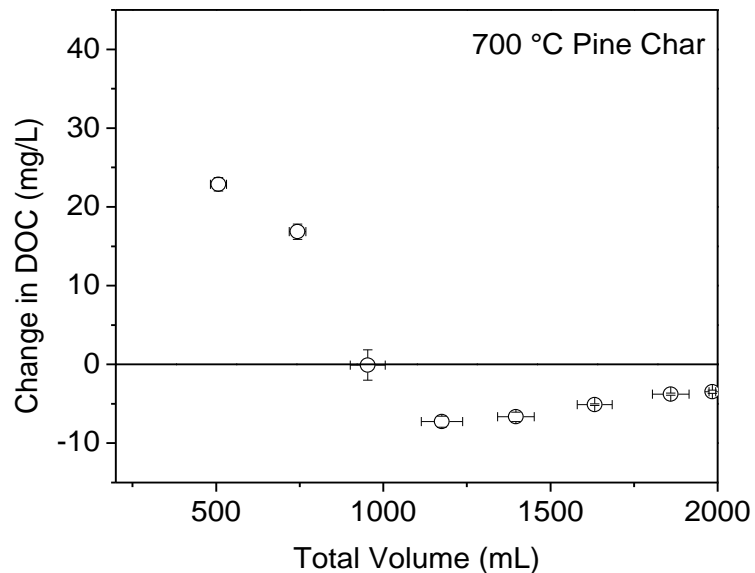
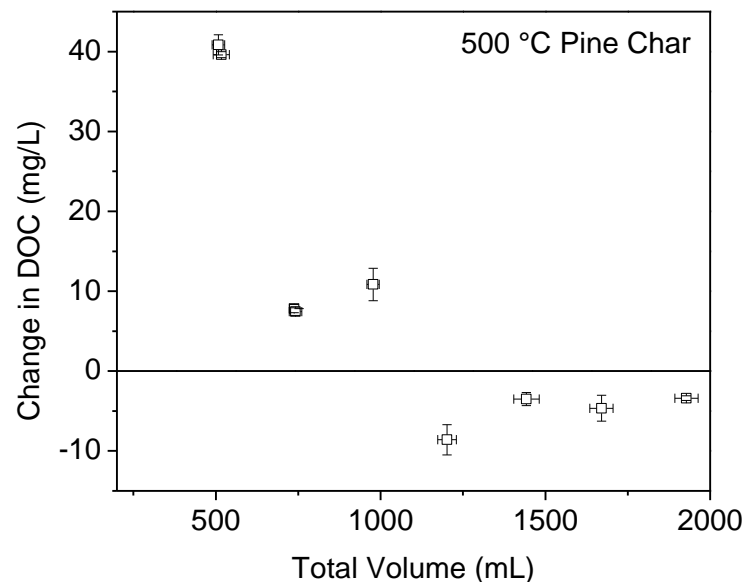
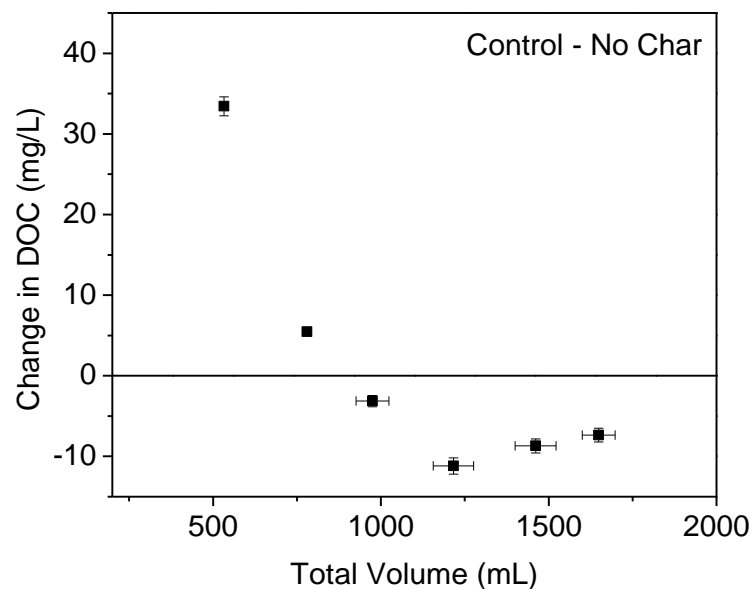
- Sample soil in columns before and after leaching and analyze for total C and N.

Results: Retention of DOC in Sand Columns



Change in DOC in leachate fractions of sand columns, compared to initial concentrations, show increased retention of DOC in columns with addition of 900 °C Pine biochar. Error bars represent the standard error of three replicates.

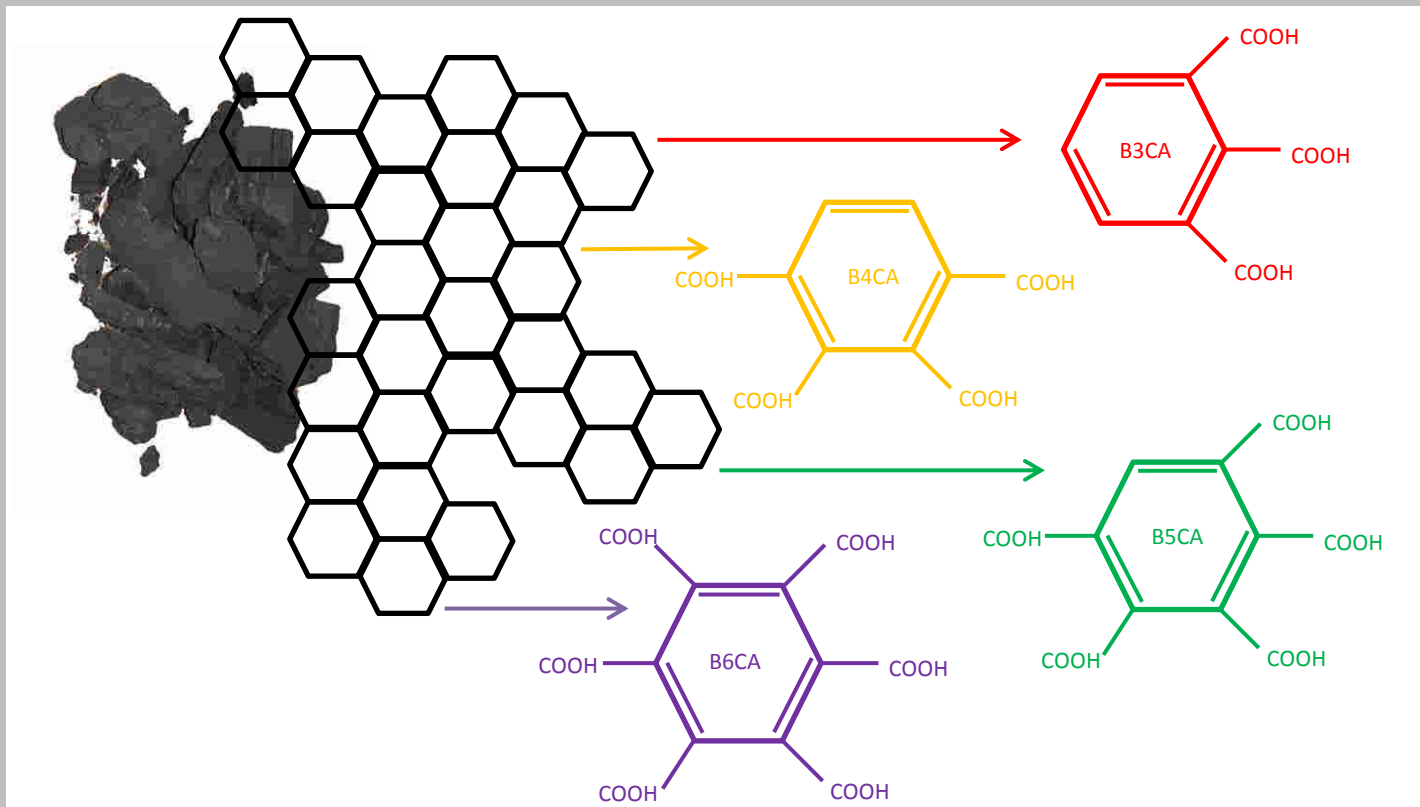
Retention of DOC in McCarthy Soil Columns



Change in DOC in leachate fractions of Wallace soil columns do not show increased retention of DOC in columns with addition of biochar. Error bars represent the standard error of three replicates.

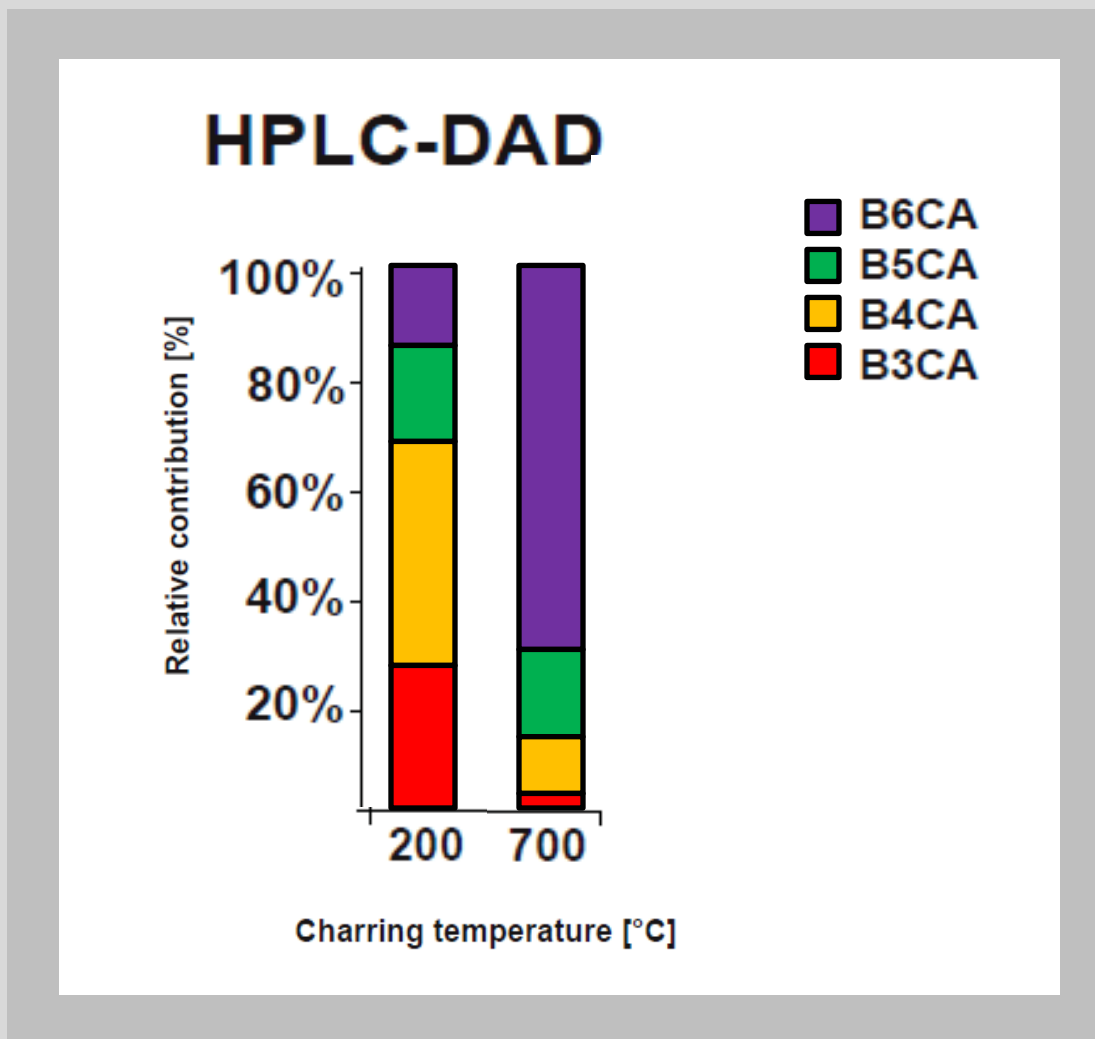
Black Carbon Molecular Markers

- C:N, aromaticity, surface area, etc., have been shown to be correlated to BC production temperature and feedstock.
- Nitric acid oxidation of aromatic rings in BC form specific molecular markers (Benzenepolycarboxylic acids, BPCA).



(Adapted from Schneider et al., 2009)

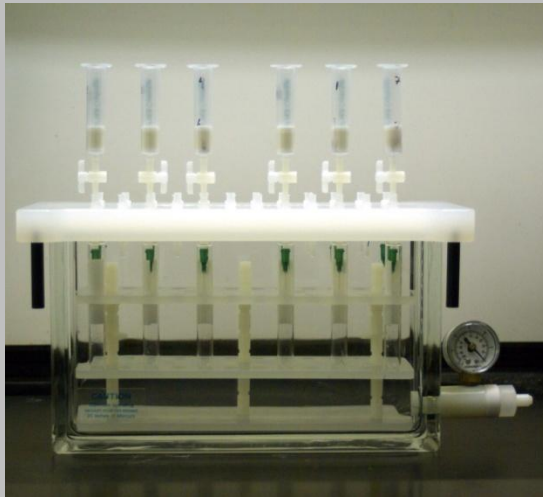
Shifts in BC Molecular Markers



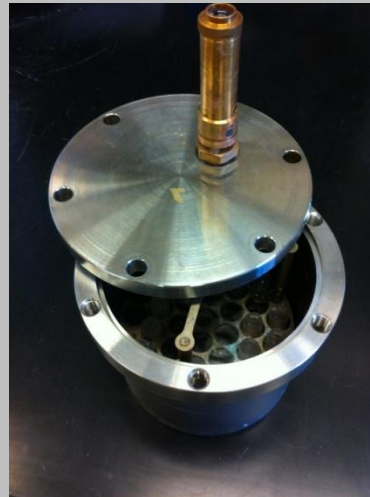
Relative contribution of different BPCA's to total BPCA-C content of wood char derived from *Castanea sativa* pyrolyzed at increasing temperatures. BPCA detection by HPLC-DAD (Adapted from Schneider et al., 2009).

Methods: BPCA for Soil Column Leachate

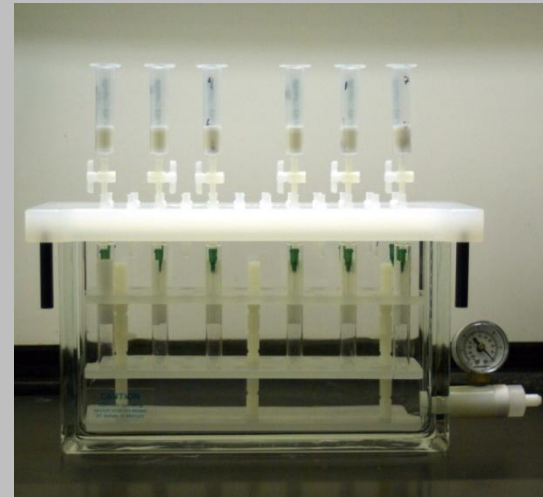
- **1 - Isolate** dissolved black carbon from soil column leachate via solid phase extraction (SPE), or use whole soil or char sample.
- **2 - Oxidize** sample with nitric acid in a high pressure digester (8 hrs @ 170 °C).
- **3 - Remove** interfering ions using cation exchange resin and SPE.
- **4 - Separate** and **quantify** BPCAs with high-performance liquid chromatography and diode-array detection (HPLC–DAD).



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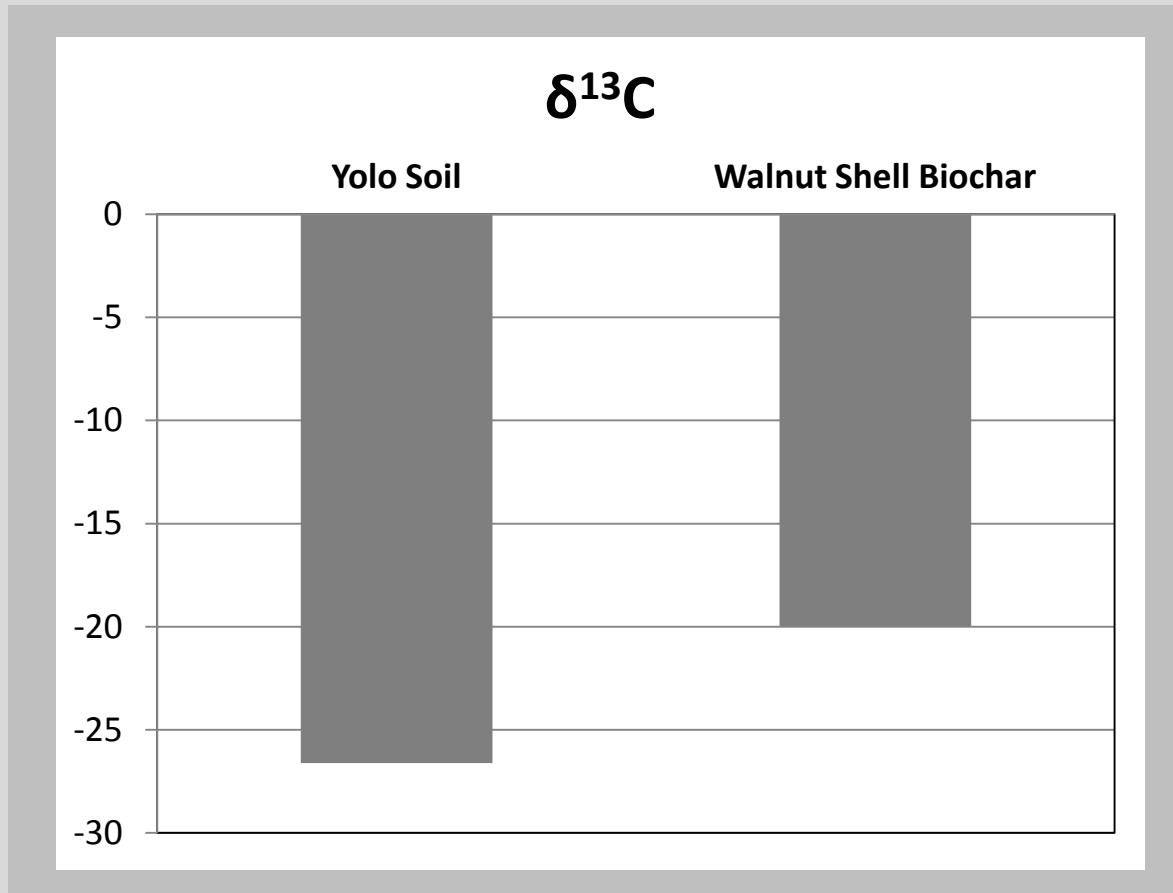
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4

Isotopic Signature

- $\delta^{13}\text{C}$ value of DOC solutions (natural abundance) derived from soil and char are different and therefore stable isotopes could be used to evaluate origin of carbon pools contributing to DOC in leachate.



(Unpublished work by Daoyuan Wang and Kate Scow)

Future Work

- Employ BPCA method to identify different carbon pools in the column leachate as well as to track changes in soil carbon.
- Explore isotopic analysis as possible method for differentiating origin of fractions of DOC.
- Measure changes in soil carbon: TC measurements before and after application of leaching.



UC Davis Biochar Database


biochar.ucdavis.edu

UC DAVIS BIOCHAR DATABASE

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HOME

Welcome to the UC Davis Biochar Database. The database serves as an open-access tool for biochar users, manufacturers, and researchers. This database was initially released on May 1, 2013 and we will continue to work to increase the number of biochars which are included. We hope you see the value in this resource and will contribute and participate in this community centered biochar project.



Biochar is charcoal created from pyrolyzed biomass, and differs from charcoal only in the sense that its primary use is not for fuel but rather as a soil amendment.

REASON FOR DATABASE

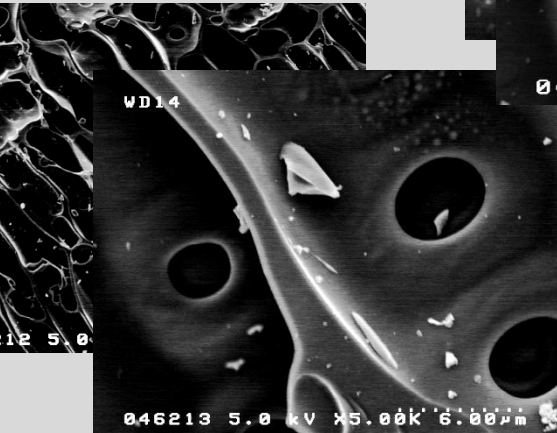
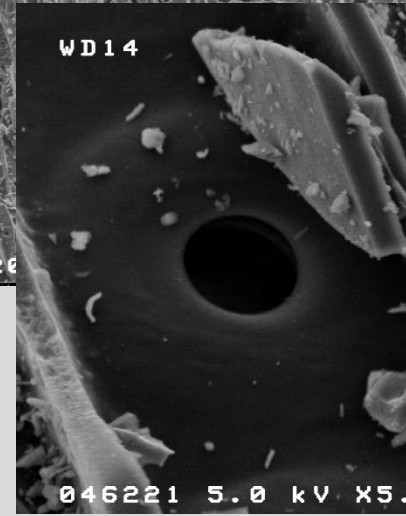
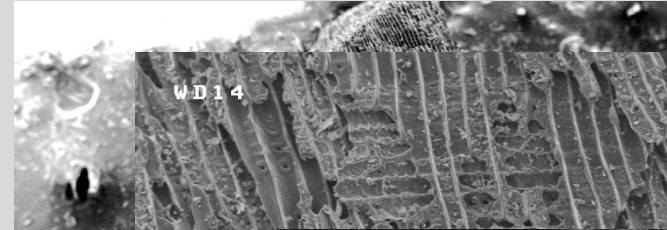
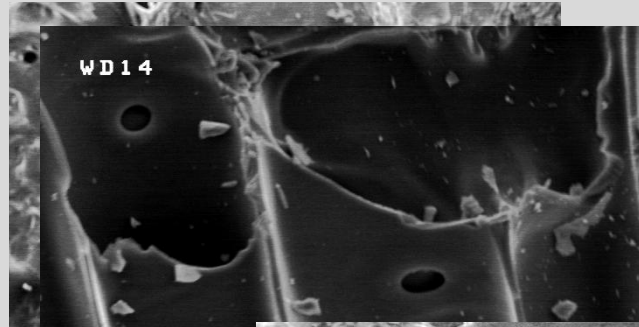
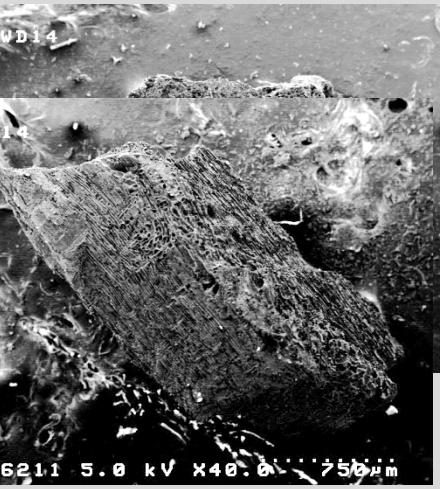
Biochar research, although still in its infancy, has generated much interest as a soil amendment due to its potential for increased soil fertility, water holding capacity, greenhouse gas reduction and carbon sequestration. The relatively low entry barrier to biochar manufacturing has resulted in many suppliers producing boutique biochars which make use of a variety of feedstock materials. Even with the current public interest in this material, our understanding of how biochar properties impacts the potential benefits is largely inadequate. This deficit in basic biochar science makes it difficult for biochar end users to make informed decisions regarding the specific biochar properties to consider when selecting a particular biochar for their use. The idea for this database arose from this research conducted in the [Pankh Environmental Soil Chemistry Laboratory](#) at University of California, Davis which aimed to determine trends in biochar physical and chemical properties based on feedstock source. The UC Davis Biochar Database was launched as an open-access resource to facilitate bridging this gap.

Visit the database at: biochar.ucdavis.edu

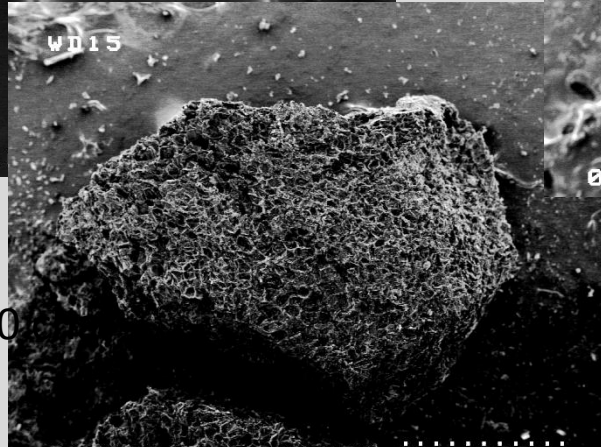
900 char

Results: Char Analysis

900 char



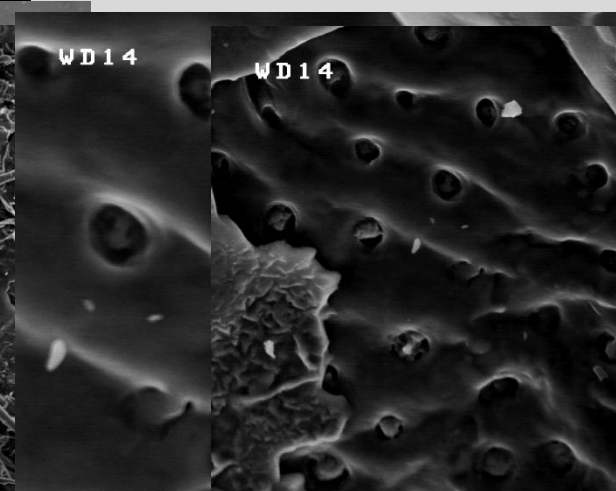
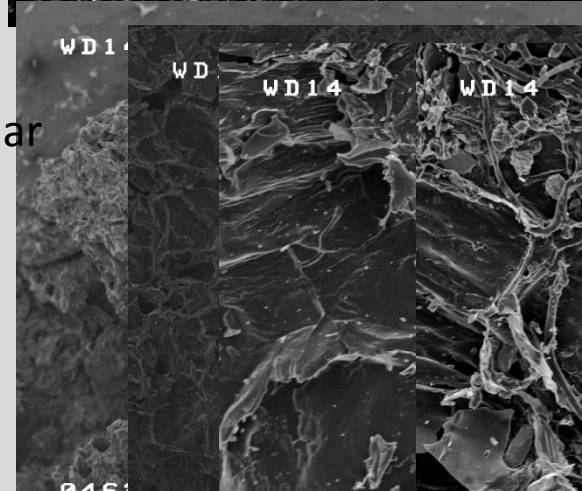
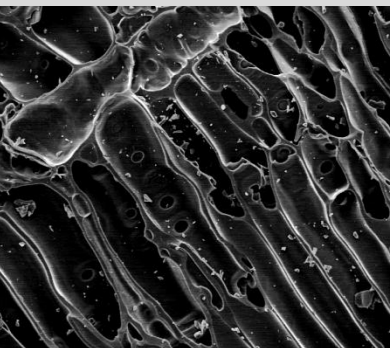
046217 5.0



700

0462 046220

300 char



Results: Char Analysis

Figure 9 shows the impact of temperature on biochar pH and its corresponding C:N ratio. This and other data will be incorporated into the newly created UC Davis Biochar Database (biochar.ucdavis.edu).

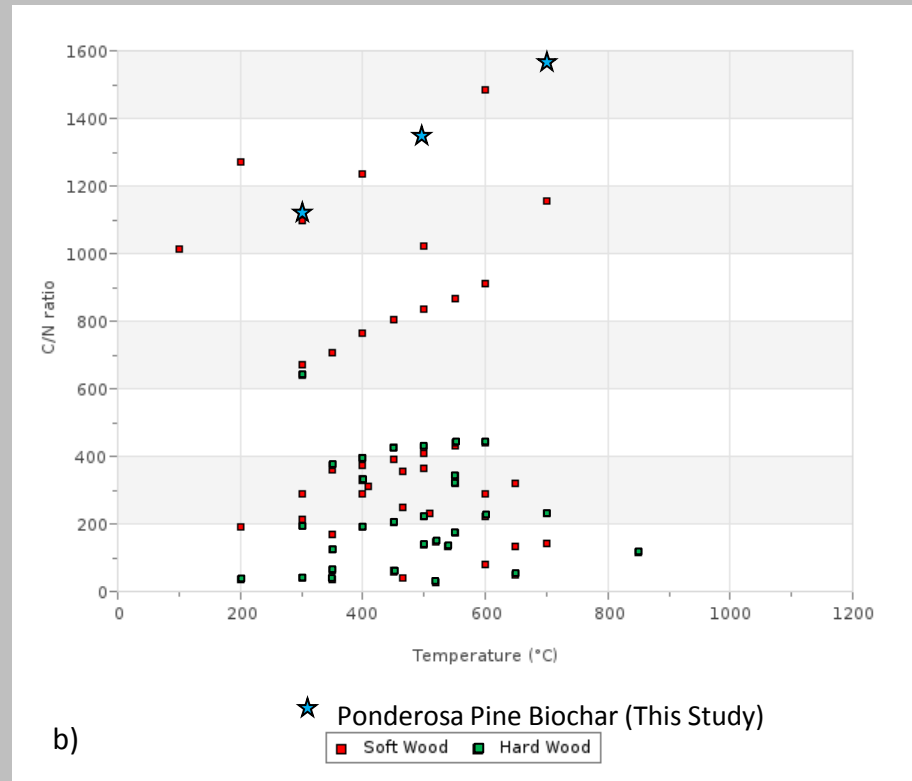
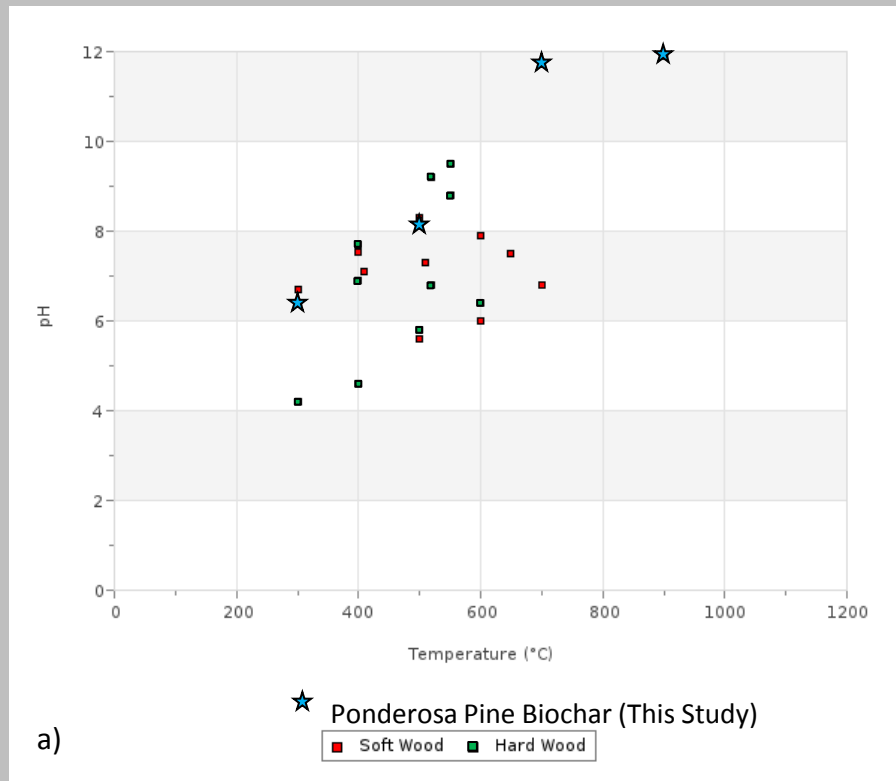


Figure 11. Data points for a) pH and b) C:N have been overlaid on plots created using the UC Davis Biochar Database to demonstrate the similarities of these biochars with others made from hard and softwood feedstocks.