Sustainable Management of Forests for Bioenergy Production

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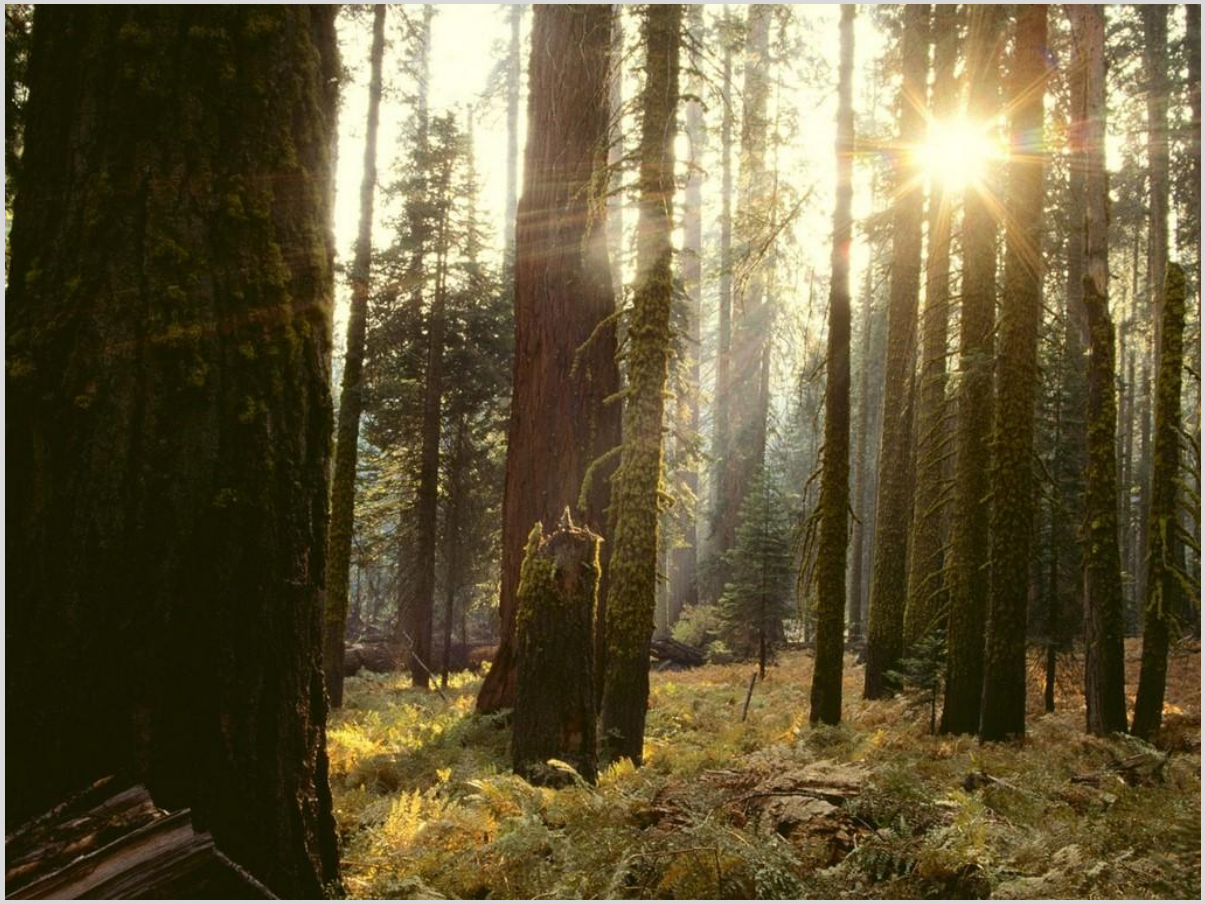
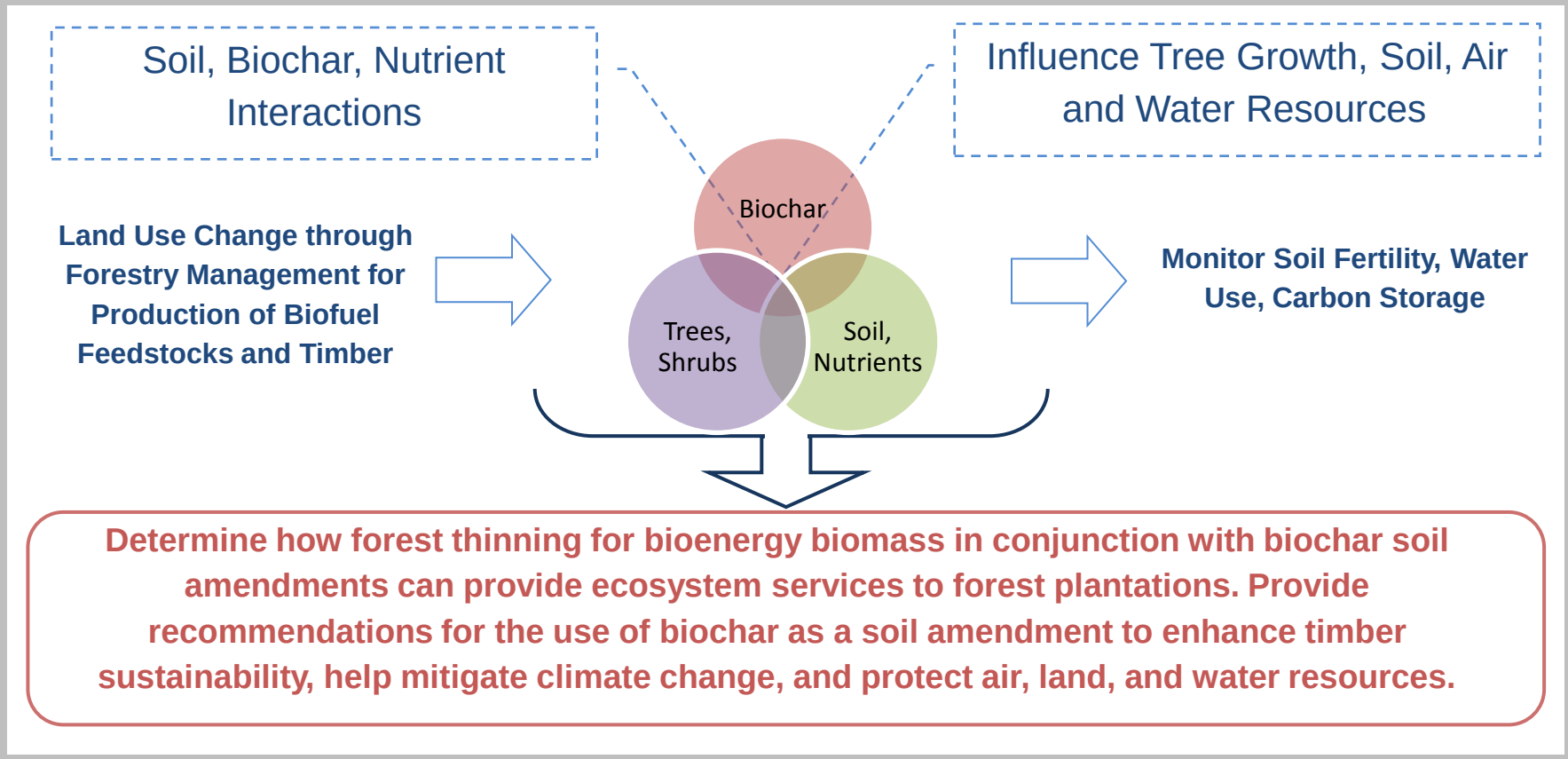


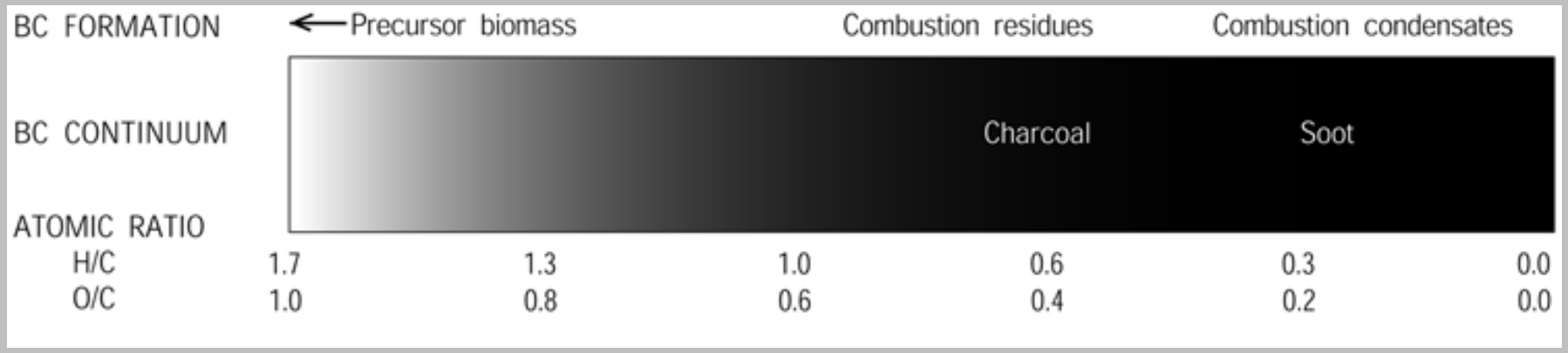
Project Objective

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.

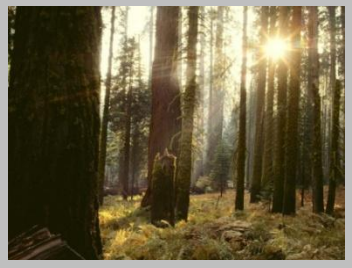
Experimental Approach:

- **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**(benzepolycarboxylic 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



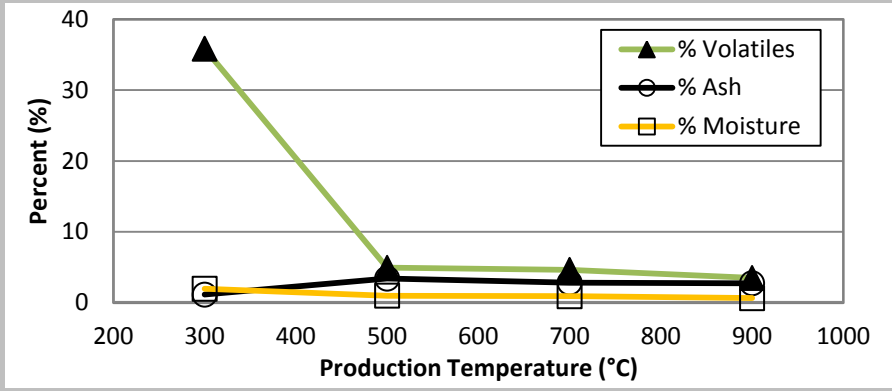
Prepare biochar and duff tea (DOC soln.)

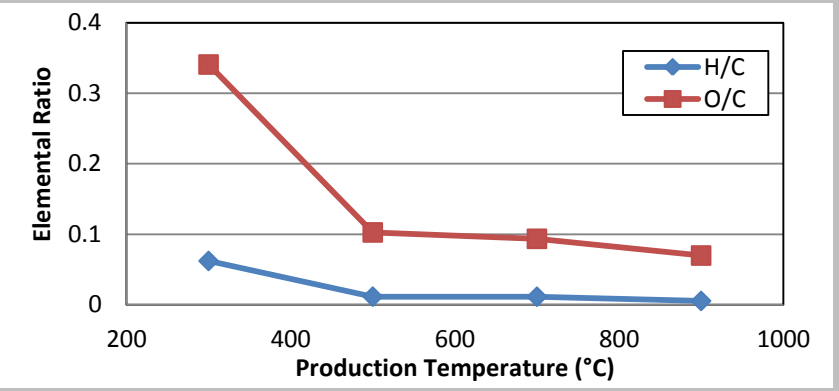
Leach soil columns with duff tea

Quantify DOC

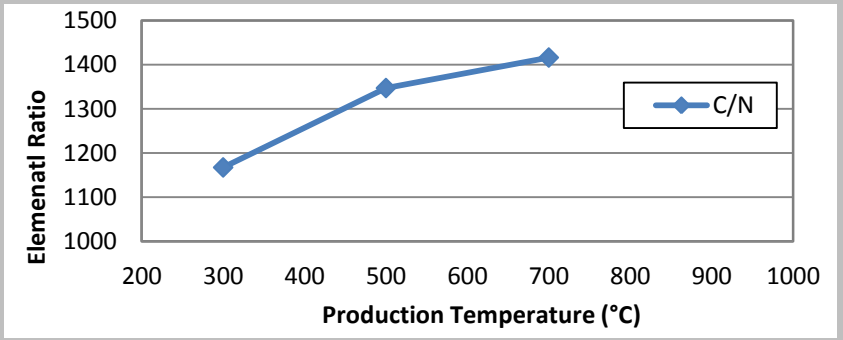
Quantify BPCA's

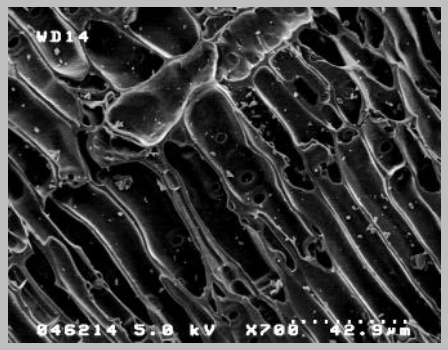
Results: Char Analysis

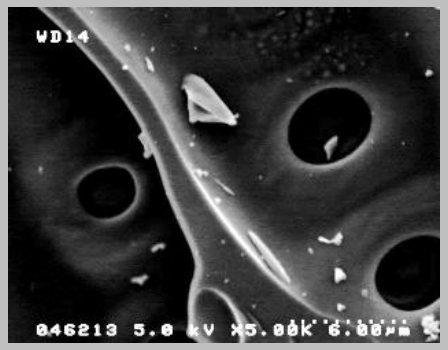


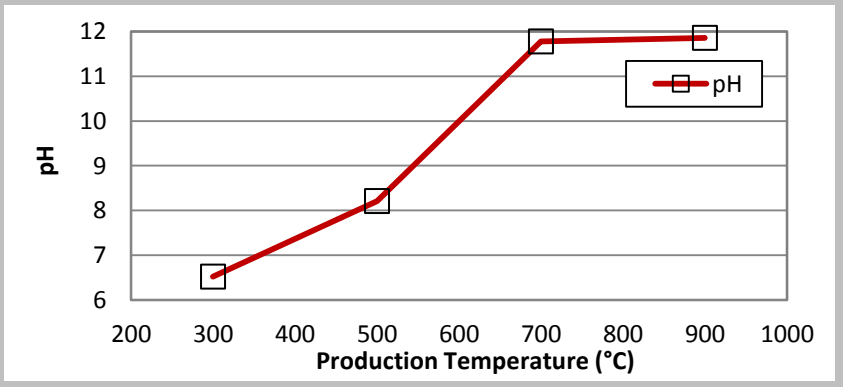


While % C, % ash, and pH increase with production temp., % H, % volatiles, and % moisture decrease. This and other data will be incorporated into the newly created UC Davis Biochar Database (**biochar.ucdavis.edu**).



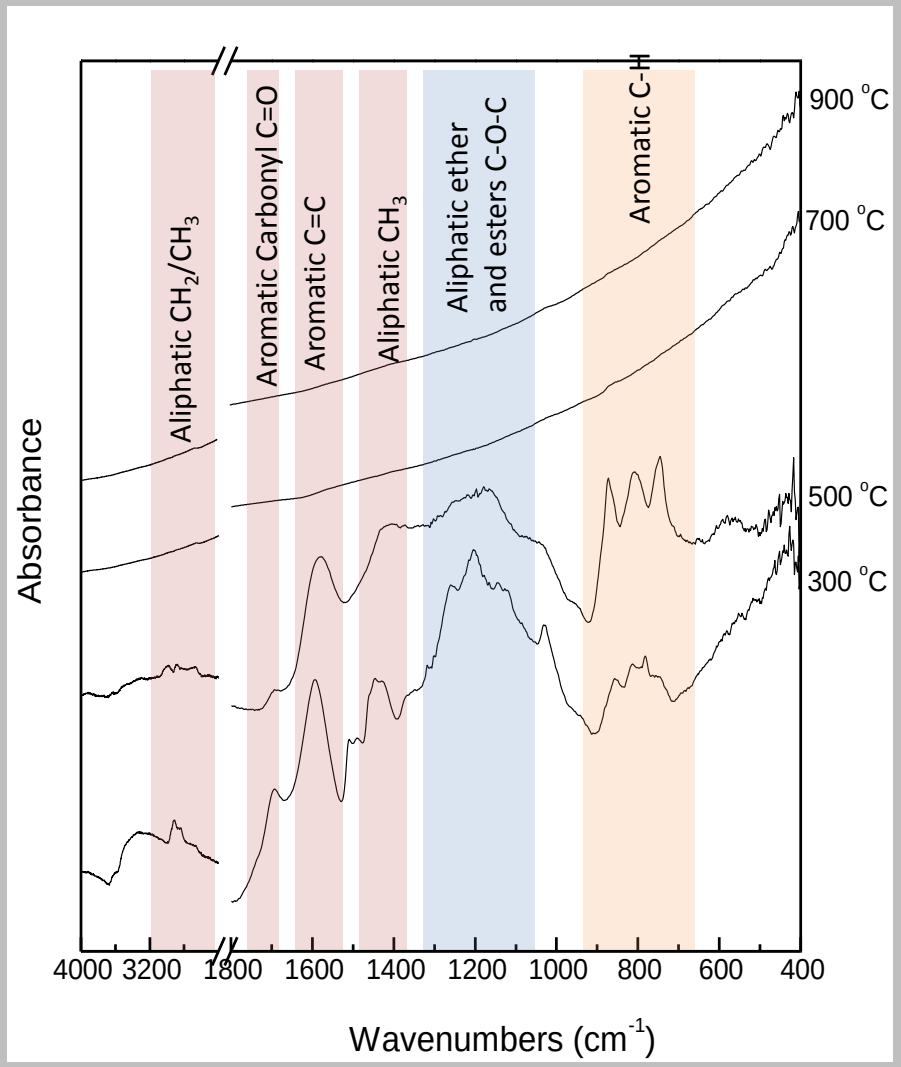






Results: Char Analysis

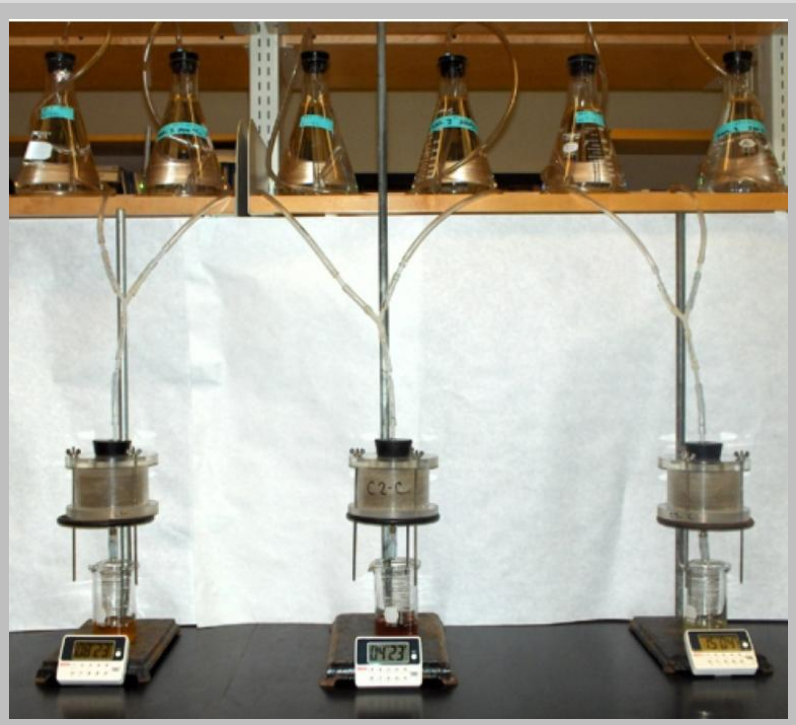
The FTIR spectra of the biochar thermosequence reveal a loss of IR bands with increasing pyrolysis temperature, indicative of loss of O-rich functional groups and an increase in aromaticity.



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).

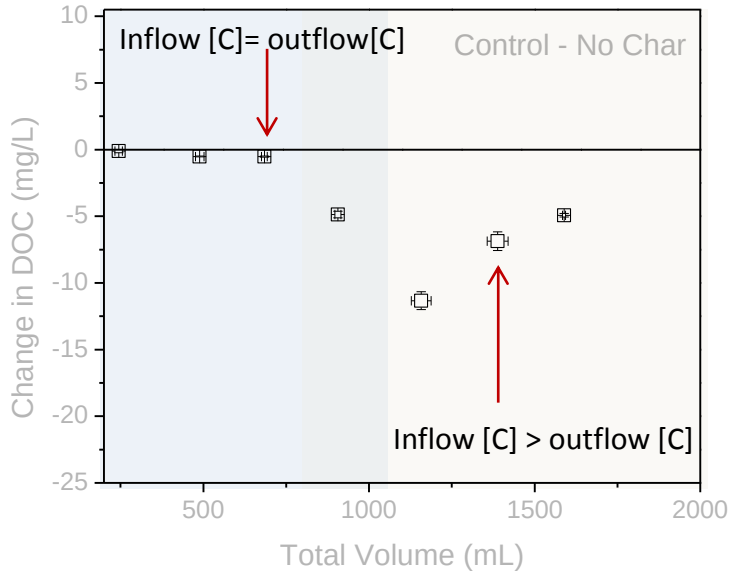
- Collect leachate in 250 mL fractions and analyze for pH, EC, **DOC**, NO_3^-, NH_4^+, and **BPCA markers**.

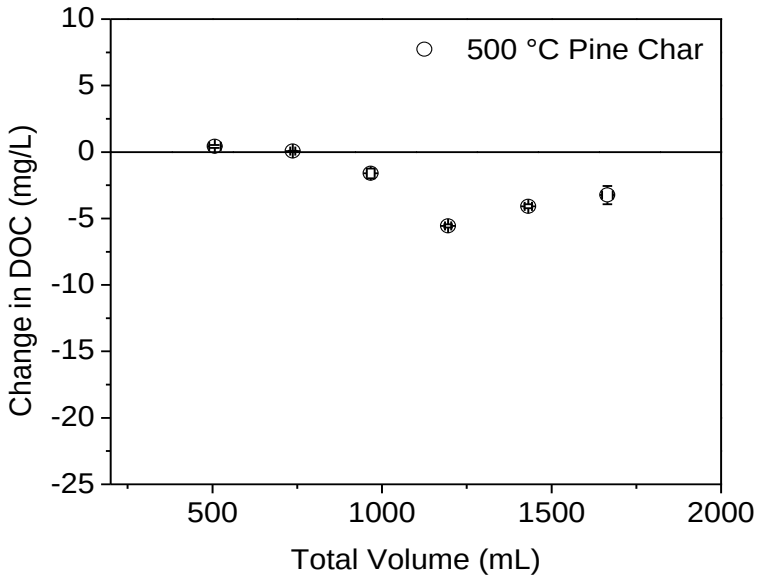


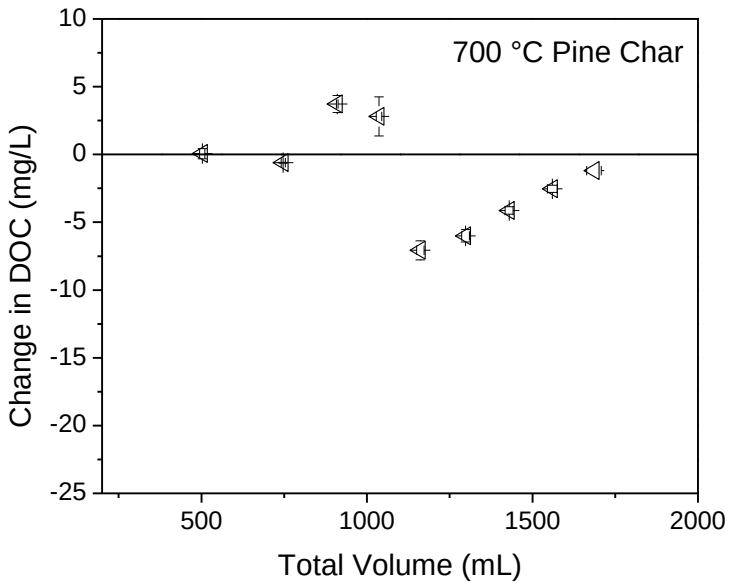
Soil column leaching

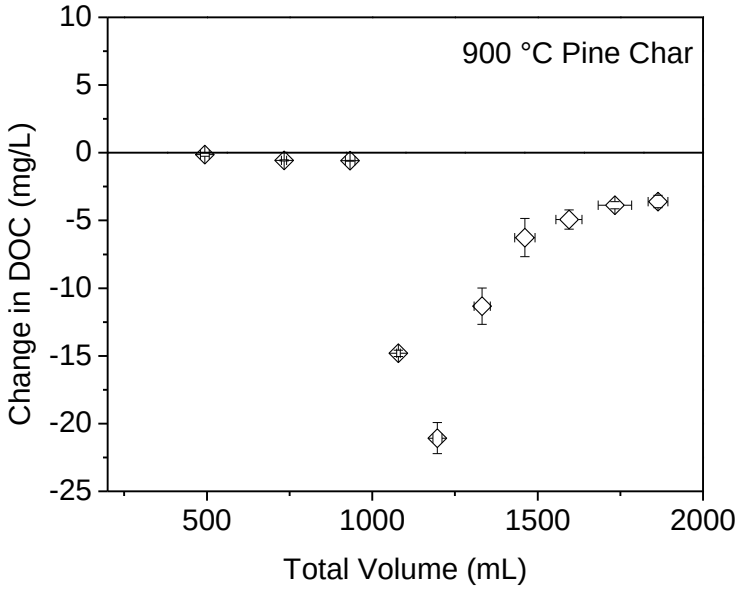
- Sample soil in columns before and after leaching and analyze for total C and N.

Results: Retention of DOC in Sand Columns



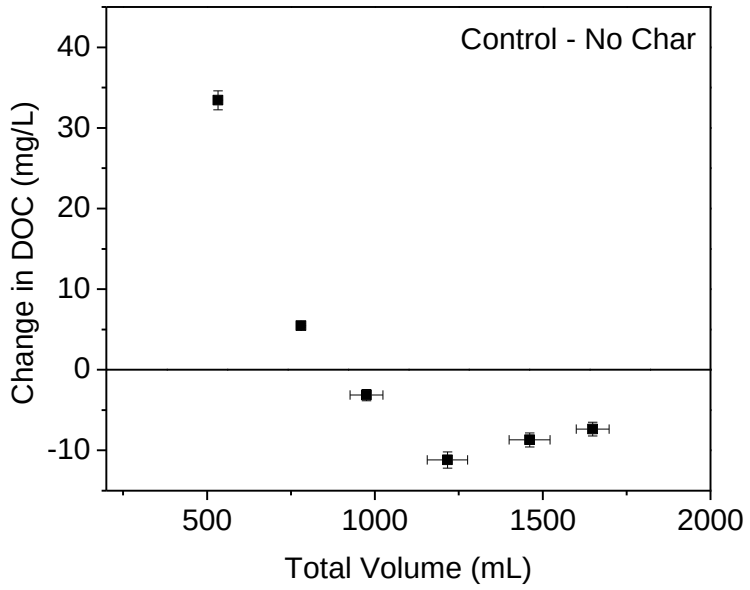


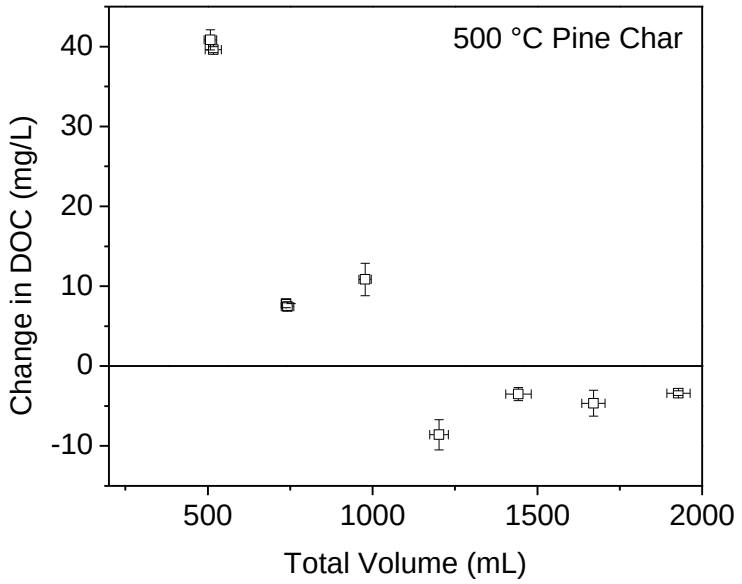


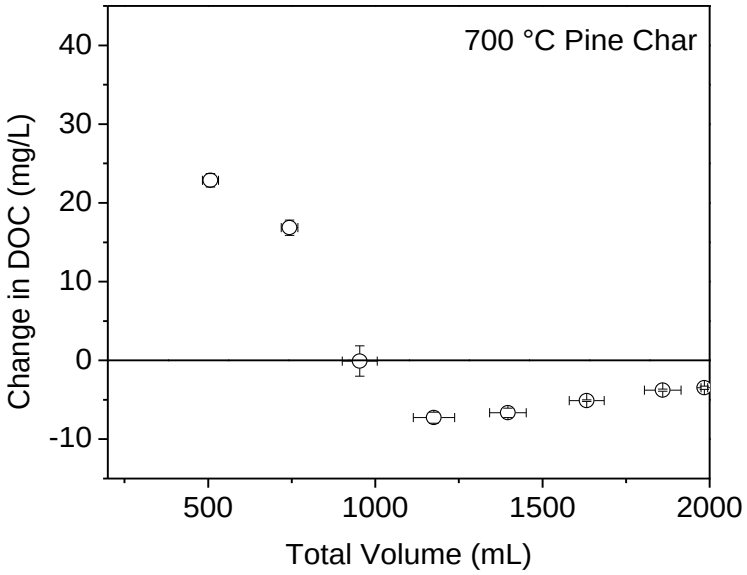


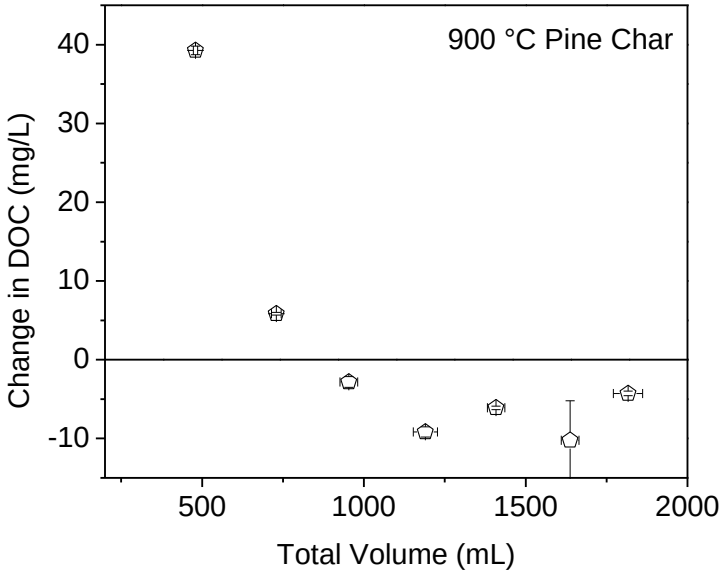
Change in DOC in leachate fractions of sand columns, compared to initial concentrations, show increased retention of DOC in columns with addition of 900 °C Pine biochar. Error bars represent the standard error of three replicates.

Retention of DOC in McCarthy Soil Columns





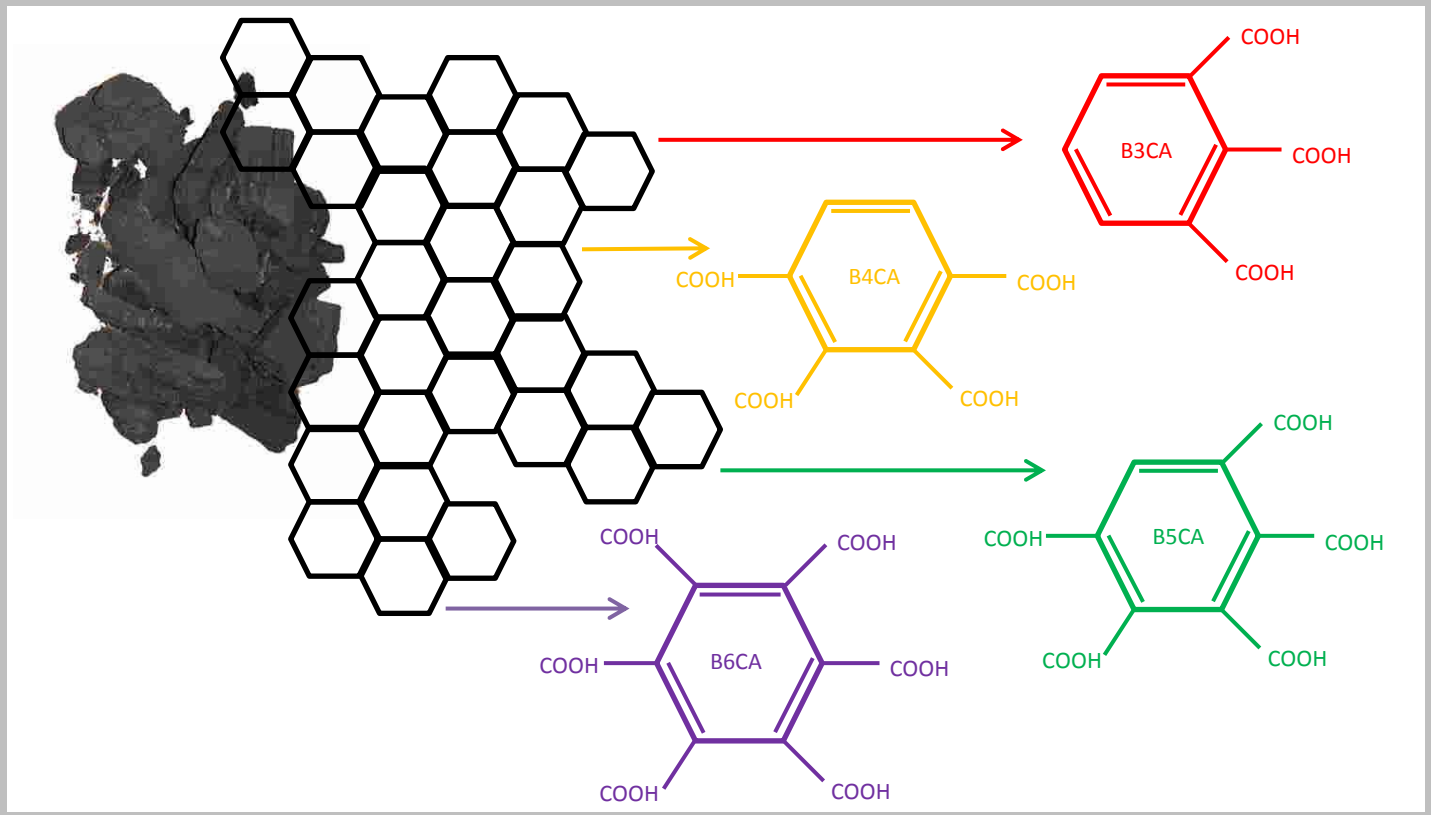




Change in DOC in leachate fractions of Wallace soil columns do not show increased retention of DOC in columns with addition of biochar. Error bars represent the standard error of three replicates.

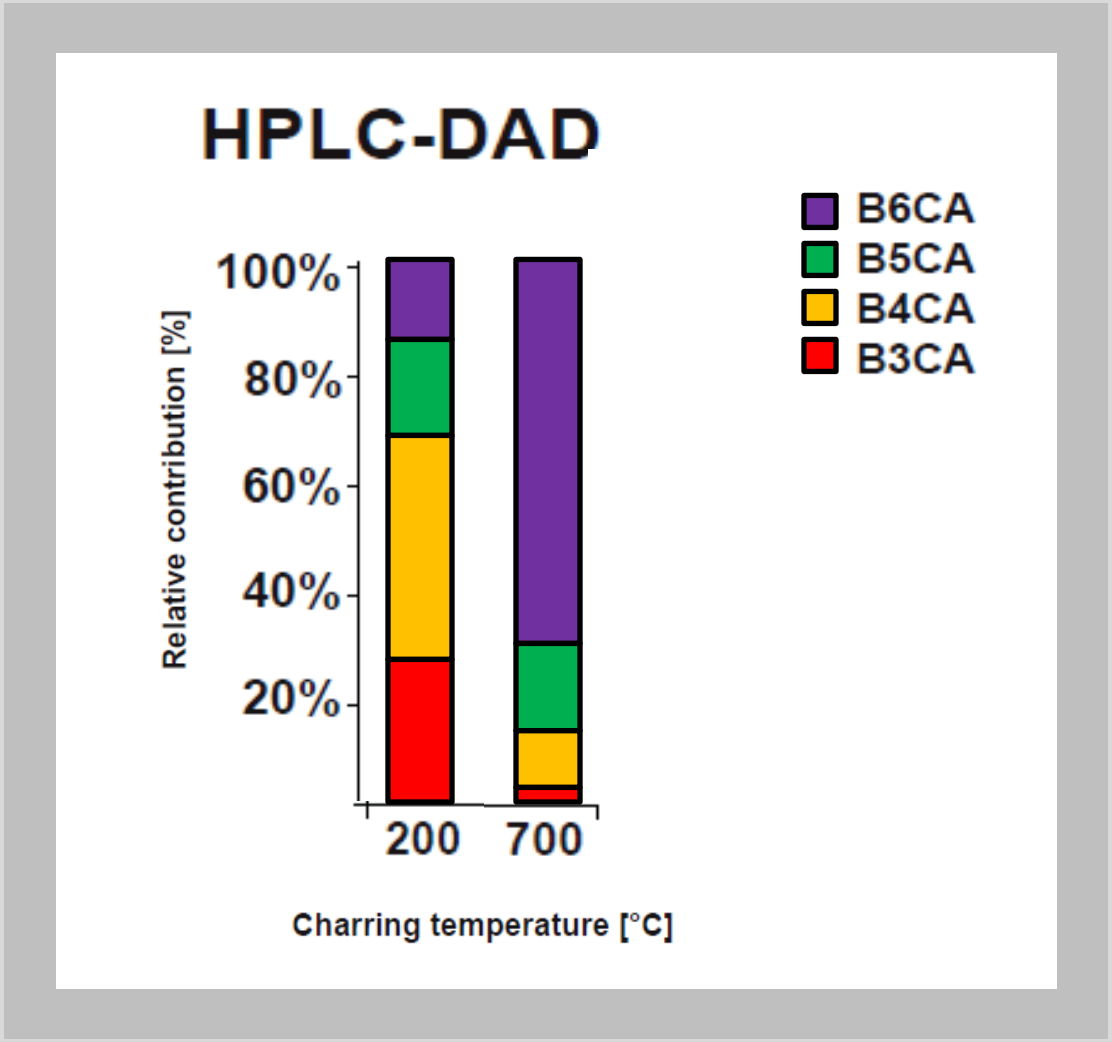
Black Carbon Molecular Markers

- 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)

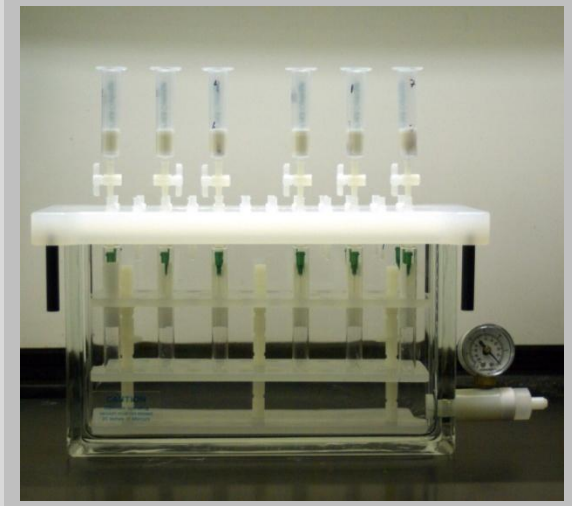
Shifts in BC Molecular Markers



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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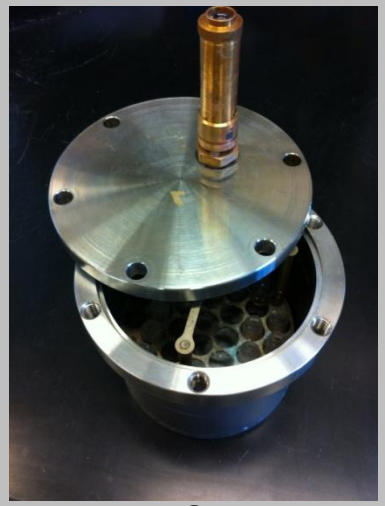

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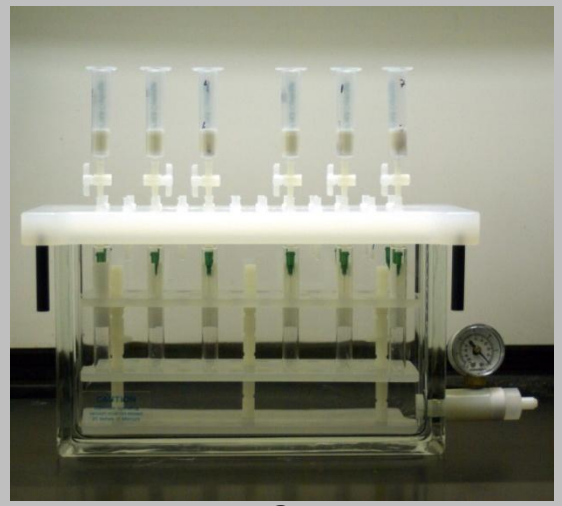

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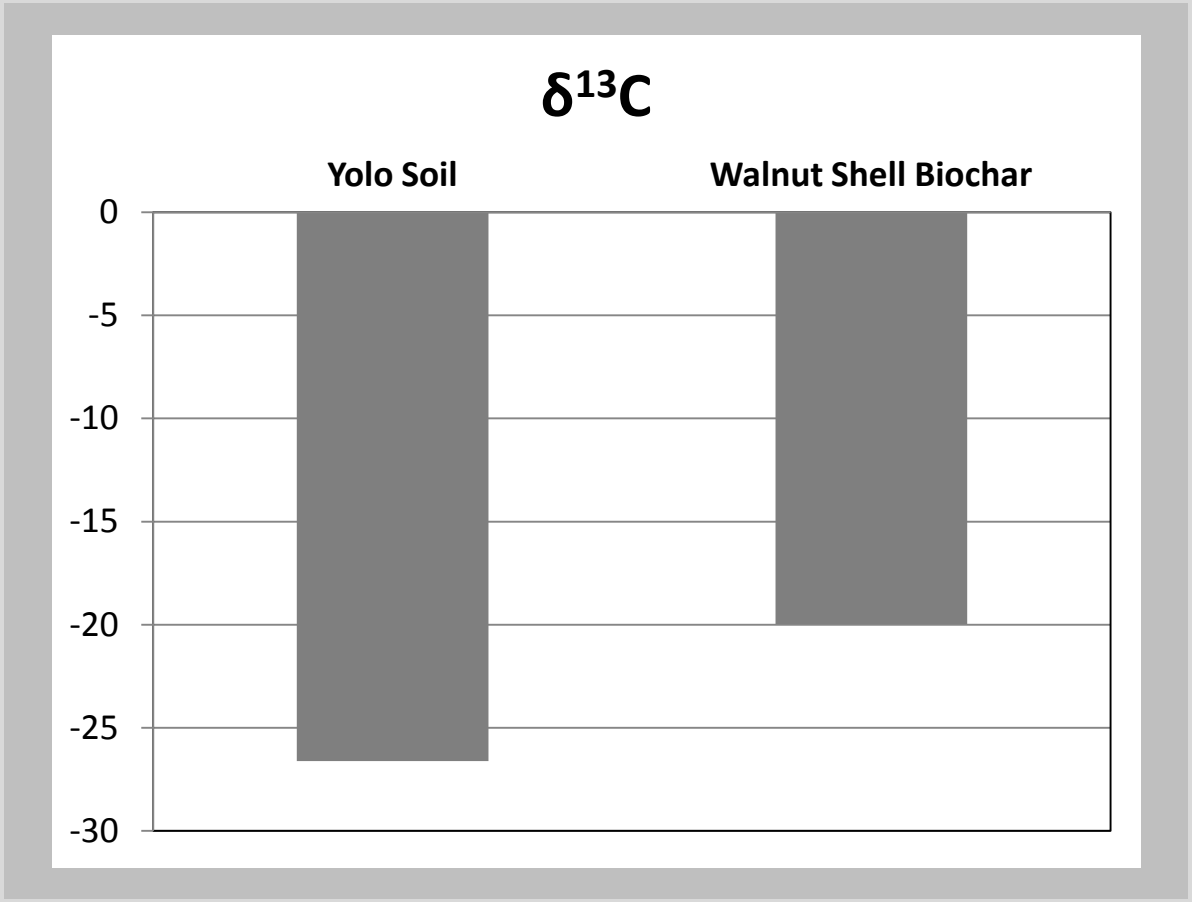
BPCA derivation and quantification

Isotopic Signature

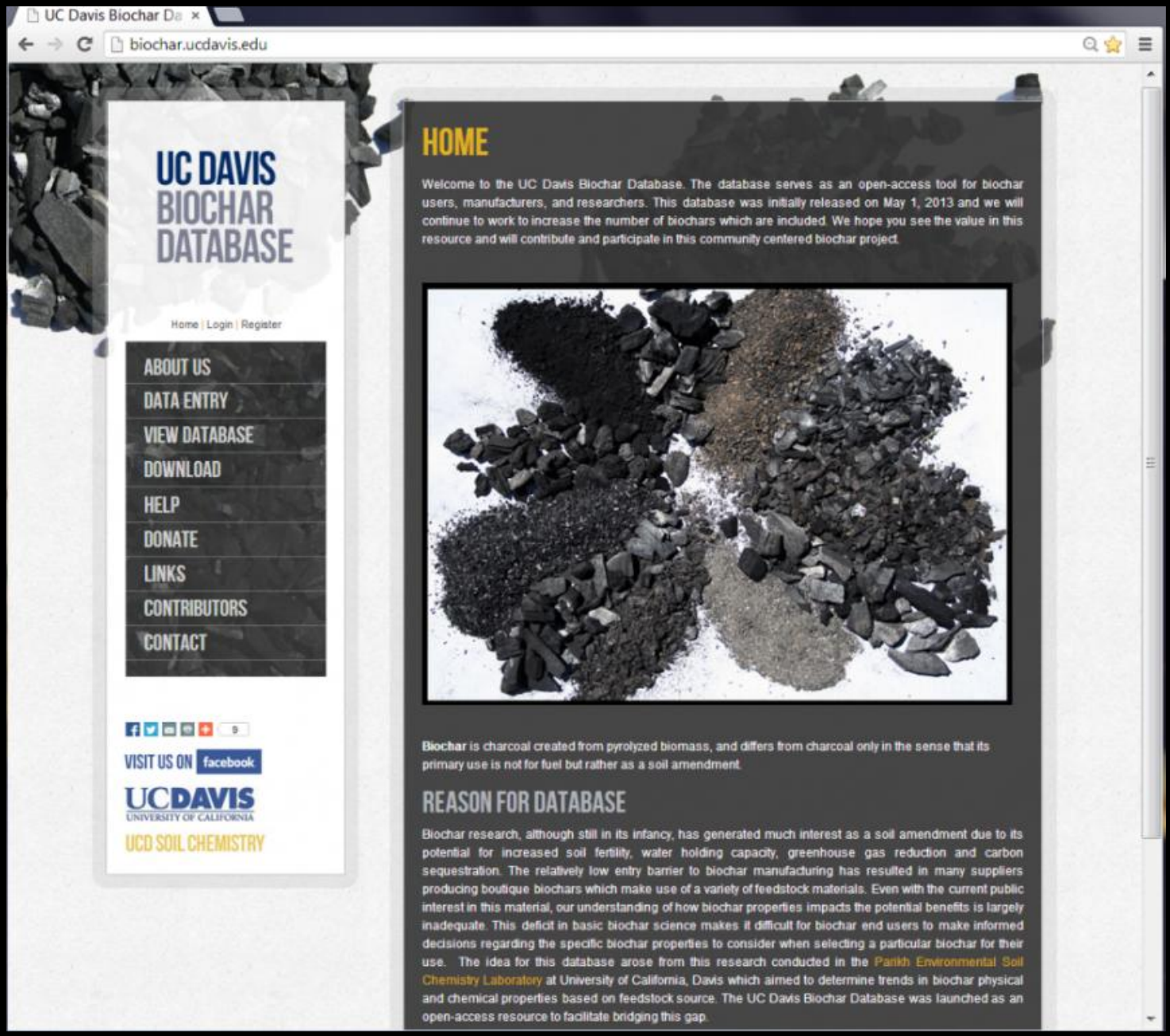
- $\delta^{13}C$ value of DOC solutions (natural abundance) derived from soil and char are different and therefor stable isotopes could be used to evaluate origin of carbon pools contributing to DOC in leachate.



(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.



Visit the database at: biochar.ucdavis.edu

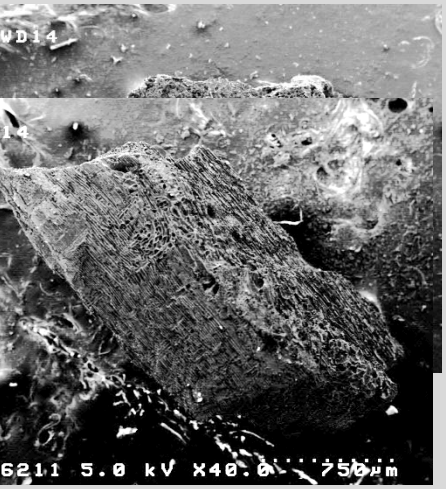
Results: Char Analysis

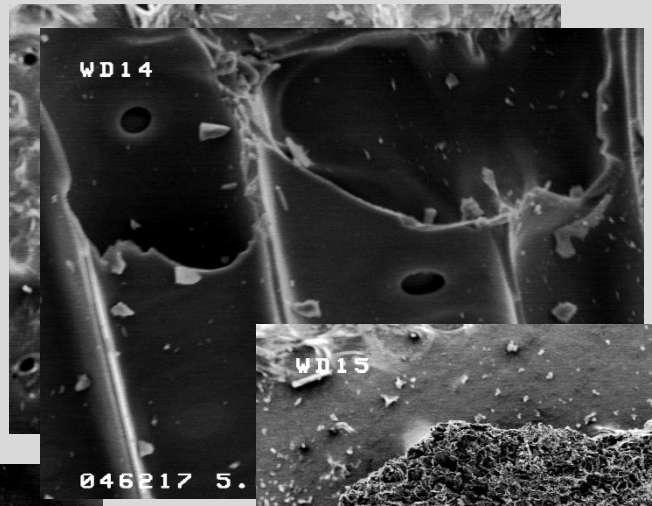
500 char

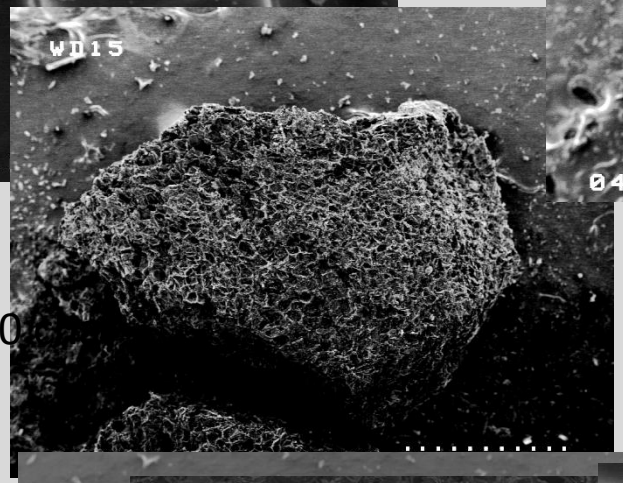
900 char

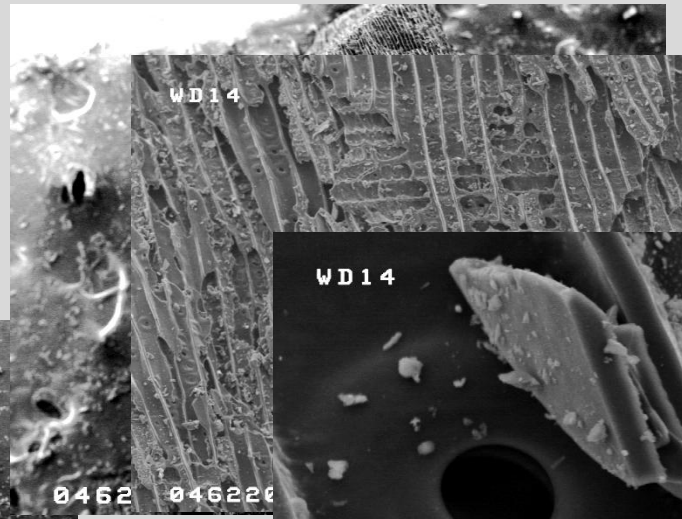
700

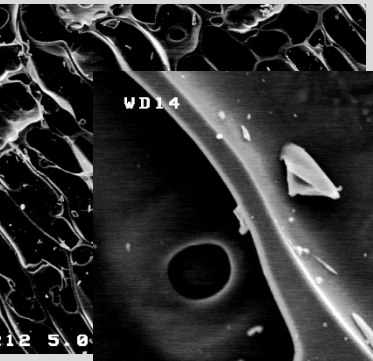
300 char

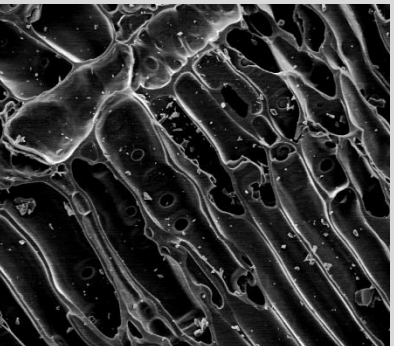


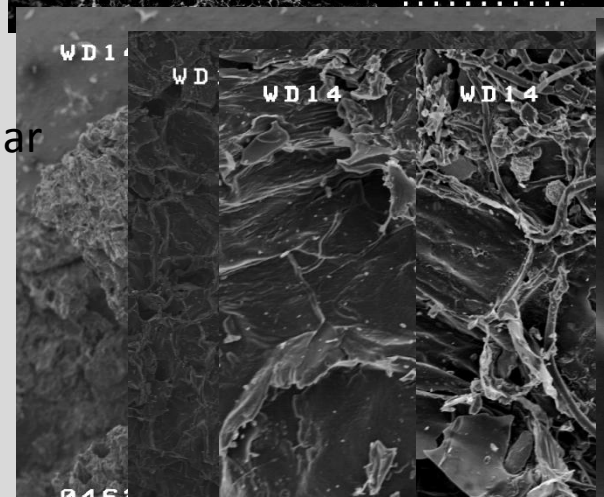


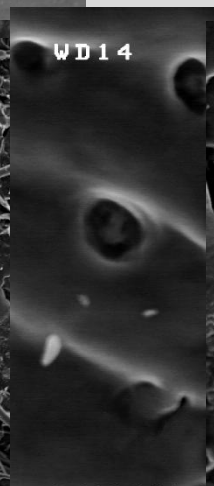


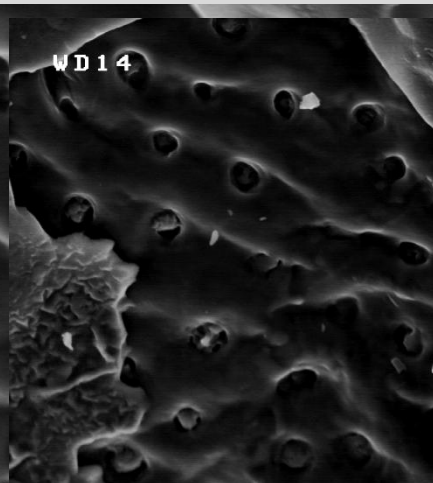






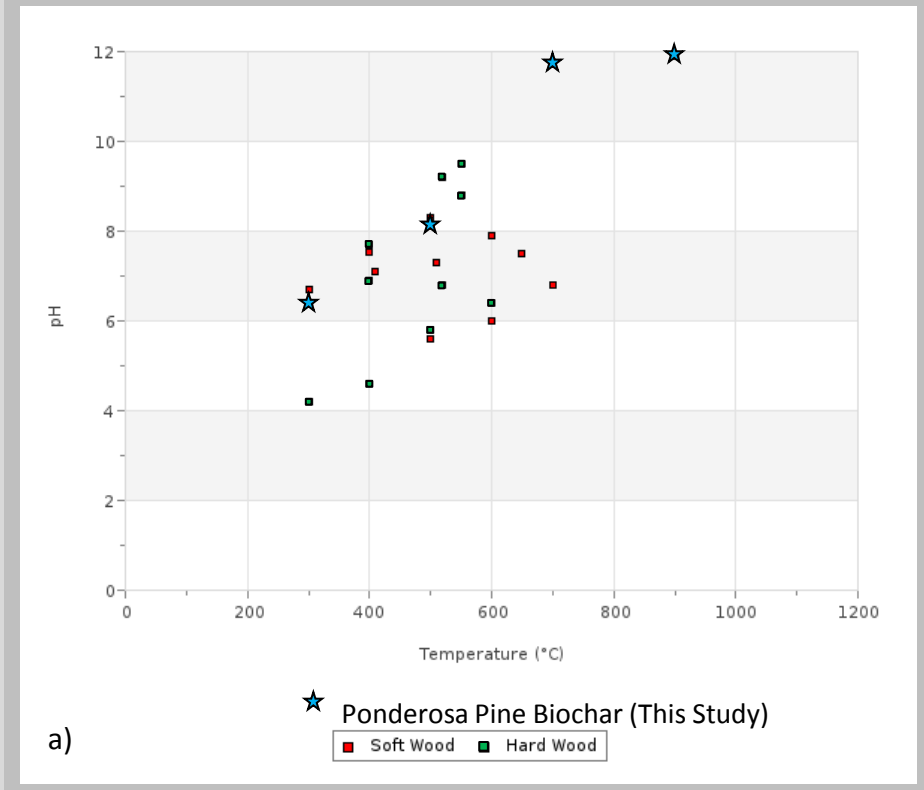






Results: Char Analysis

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).



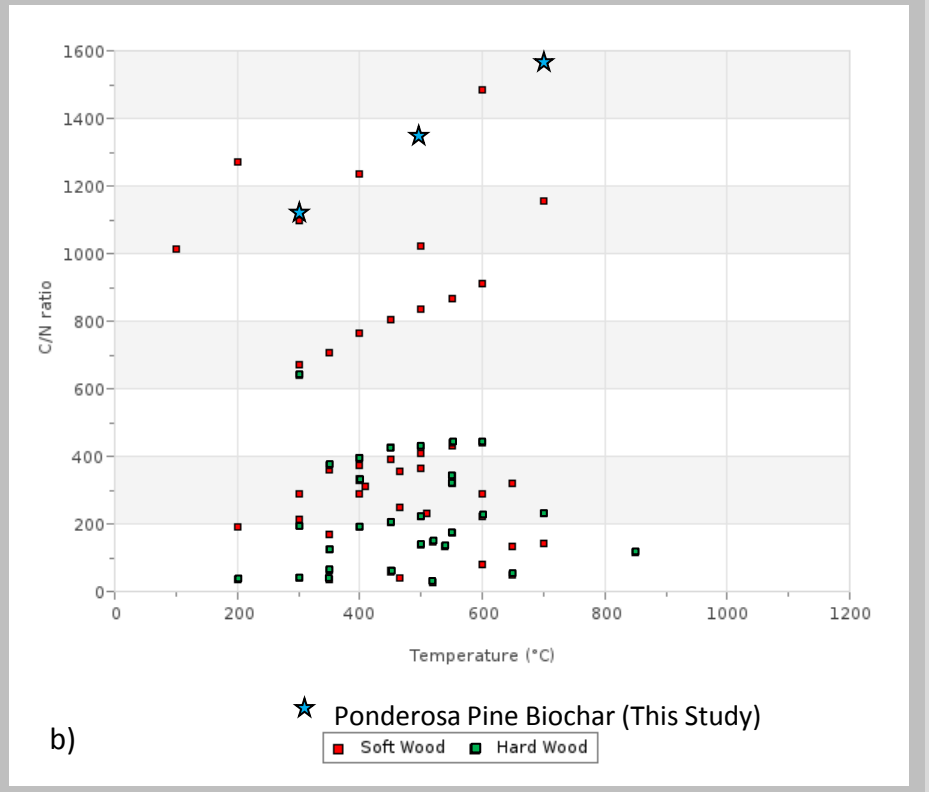


Figure 11. Data points for a) pH and b) C:N have been overlaid on plots created using the UC Davis Biochar Database to demonstrate the similarities of these biochars with others made from hard and softwood feedstocks.