Can Amending Soils with Biochar Improve Fertilizer Use Efficiency?

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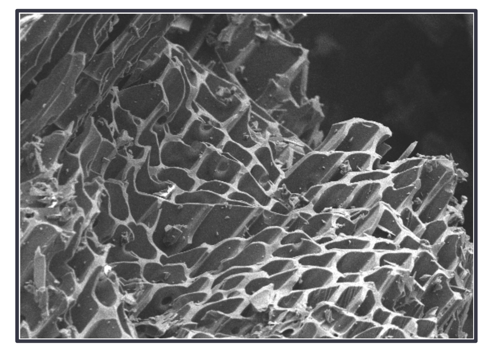
Background



What is biochar?

Biochar is a carbonaceous material created from the thermochemical conversion of biomass in an oxygen-limited environment.

Due to the high surface area, low bulk density, and aromatic molecular structure of biochar, it has many potential applications as an agricultural soil amendment.

What can biochar do?

Studies show mixed results on the ability of biochar to:

- Increase soil fertility
- Decrease nutrient leaching
- Increase soil carbon stocks
- Increase water holding capacity
- Close waste loops
- Generate renewable energy

Gaps in knowledge?

Recent meta-analyses show that **biochar literature is dominated by laboratory studies rather than those at field scale**. Additionally, studies are short-term, have small experimental plots, and do not use biochar that is commercially available.

Project Overview

Objective

The primary objective is to provide baseline data specific to California regarding **the suitability of biochar to address some of the most pressing agricultural issues**. These issues include nitrate leaching, low nutrient use efficiency, vulnerability of soils to drought conditions, depleted soil carbon stocks, and the accumulation of agricultural waste products.

Timeline

Project Phase	Year					
	1		2		3	
Phase I Produce and characterize biochar	✓	✓				
Phase II Laboratory and greenhouse trials		✓	✓	✓	✓	✓
Phase III Field trials in Davis and Fresno		✓	✓	✓	✓	✓
Phase IV Life cycle analysis of biochar use in CA.				✓	✓	✓

Project Phase I: Produce and Characterize Biochar

Objectives:

1) Produce/procure biochars from CA feedstocks, with an emphasis on agricultural or forestry waste products
2) Compare biochars produced at varying temperatures
3) Address limitations in current biochar literature by using biochars produced at commercial scale
4) Analyze physical and chemical properties of biochar, for use in project phases II and III

Results to Date:

ID	Temp (°C)	Feedstock	Pyrolysis	pH	EC (ms/cm)	Moisture (%)	Ash (%)
1	Raw	Almond shell	-	-	-	-	-
2	550-650	Coconut shell	Slow	7.8	278.0*	4.7	5.3
3	550-650	Pine	Slow	8.0	124.1*	4.1	4.5
4	400-500	75% Almond shell 25% Softwood	Hydro	9.3	3.2	4.0	19.0
5	400-500	Softwood	Hydro	7.9	2.6	4.1	4.5
6	400-500	Softwood (inoculated)	Hydro	10.4	2.1	4.1	9.2
7	800	Softwood	Mixed	10.3	2.7	5.5	31.5
8	700-800	Almond shell	Gasification	10.1	27.2	11.5	55.4

*µs/cm

Project Phase II: Laboratory and Greenhouse Trials

Objectives:

To evaluate if, and to what degree:

1) there is chemical sorption of NO_3^- and NH_4^+ to the biochars
2) biochar provides a physical mechanism to slow the movement of NO_3^- and NH_4^+ through the soil profile,
3) biochar increases porosity and pore connectivity in soils, and,
4) interactions between biochar and NO_3^- and NH_4^+ can lead to increased plant N uptake and decreased N leaching.

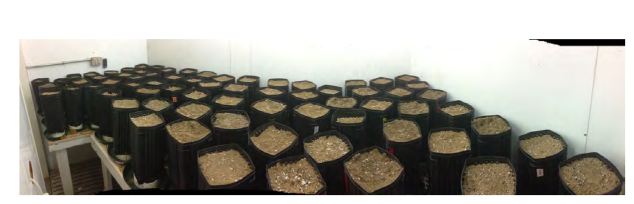
Experimental Approach:

1) Quantify NO_3^- and NH_4^+ sorption through biochar and substrate specific isotherms

2) Filter NO_3^- and NH_4^+ solutions through soil columns with and without biochar. Analyze the leachate for quantity of NO_3^- and NH_4^+ and measure the rate at which it's released

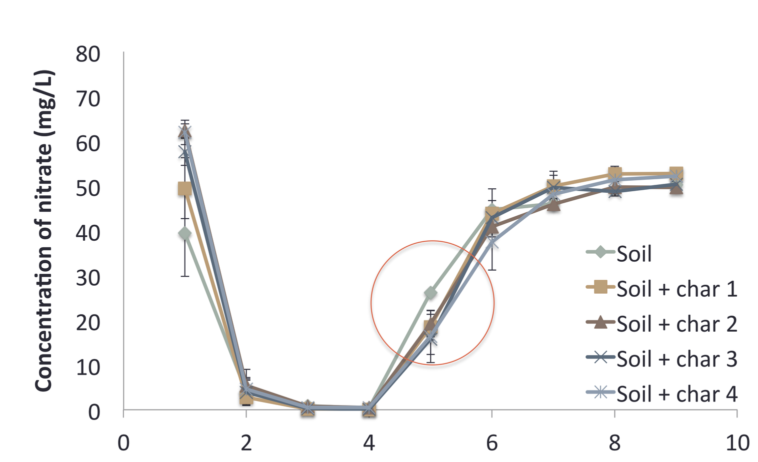
3) Quantify porosity, mean pore size, and pore connectivity of soils with and without biochar using micro-X-ray computed tomography (micro-CT).

4) Conduct growth chamber trials in which lettuce is grown in soils with and without biochar, and leaching is induced every two weeks. Analyze leachate for NO_3^- and NH_4^+. At the conclusion of each trial, analyze final plant biomass and soil to understand the fate and transport of NO_3^- and NH_4^+ in soils with and without biochar.



Results to Date:

- Preliminary sorption trials suggest no chemical binding between NO_3^- and biochars
- Preliminary column studies suggest there may be a physical delay in the movement of NO_3^- through the soil profile in the presence of biochar

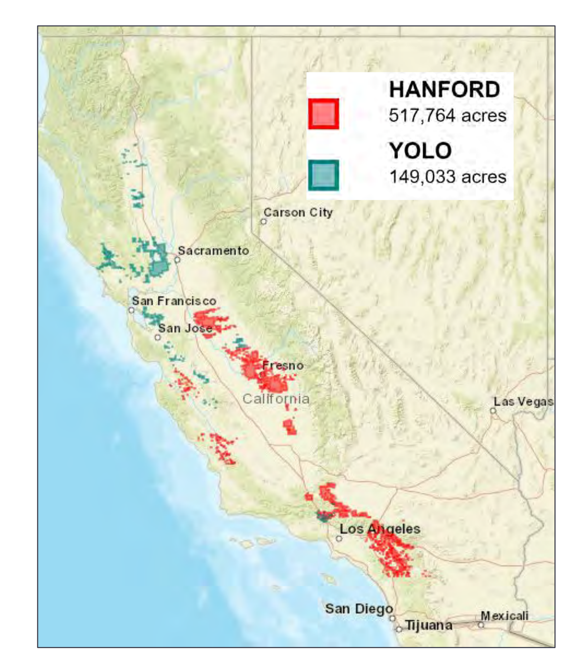


Circled region shows where NO_3^- is released sooner from soil columns not amended with biochar

Project Phase III: 3-yr field trials in Davis and Fresno

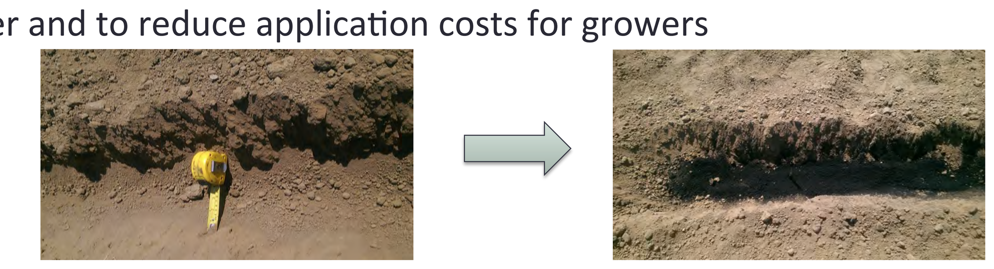
Objectives:

1) Inform the use and regulation of biochar in CA by providing baseline data relevant to CA soils and grower conditions
2) To address gaps in literature by providing long-term, field-scale data on cropping systems amended with commercially available biochar



Experimental Approach:

- Three year tomato-grain rotation
- One acre plots in 2 locations with 2 soil types (representing over 500,000 acres of CA soil):
  - Kearney ARE Center (Hanford Sandy Loam)
  - UC Davis' Campbell Tract (Yolo Silt Loam)
- Seven biochars and two controls (no biochar and unpyrolyzed almond shell) in triplicate, at three application rates
- Biochars banded above the drip tape, to maximize contact with irrigation and fertilizer and to reduce application costs for growers



- Two NPK fertilizer rates (high and low end of recommended range for each crop)
- Treatments analyzed for:
  - Crop yield and plant nutrition
  - Soil properties (pH, EC, macro and micro nutrients, soil-water measurements)
  - Spatial distribution of nitrogen and other nutrients
  - Spatial migration of biochar over time

Project Phase IV: Life Cycle Analysis and Outreach

Results from earlier phases will be assessed alongside yield and cost data to conduct a life cycle analysis that considers **the economic and environmental feasibility of widespread biochar adoption in California**. Results will be shared through the California Biochar Initiative (CBI), UCCE, at conferences, and in publications.

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