Evaluation of Biochar for On-Farm Soil Management in California

Biochar Field Day
Dani Gelardi
June 6th, 2018

Presentation Outline

1. What is biochar?
2. Current biochar literature
3. Project overview
   - Objectives
   - Specific activities
4. Status and future direction for project tasks

What is biochar?

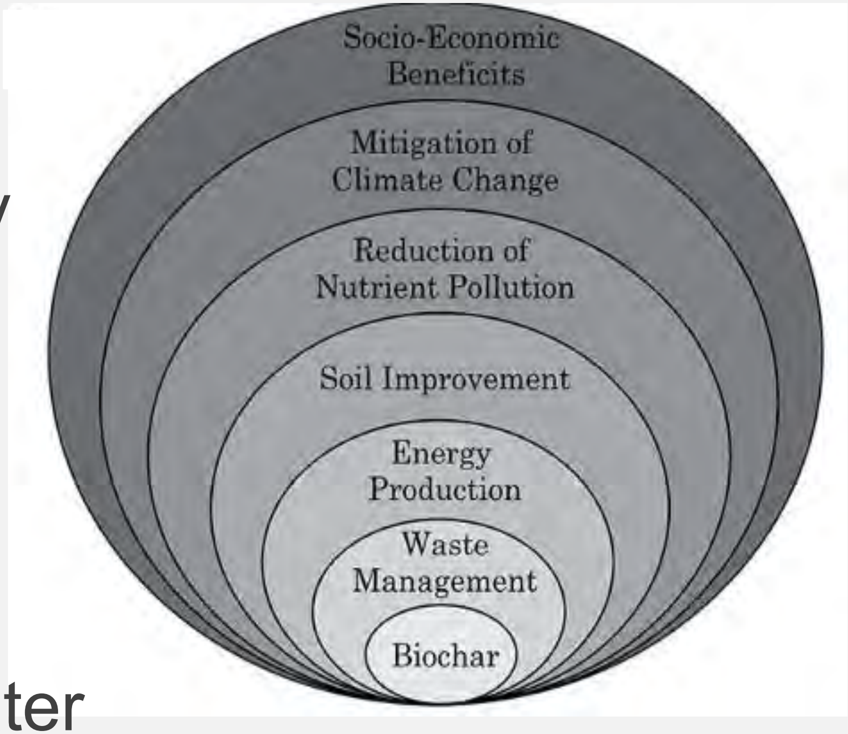
Charcoal created from the thermochemical conversion of biomass at high temperature in the absence of oxygen

Biochar varies by:

- Production temperature
- Production method
- Feedstock

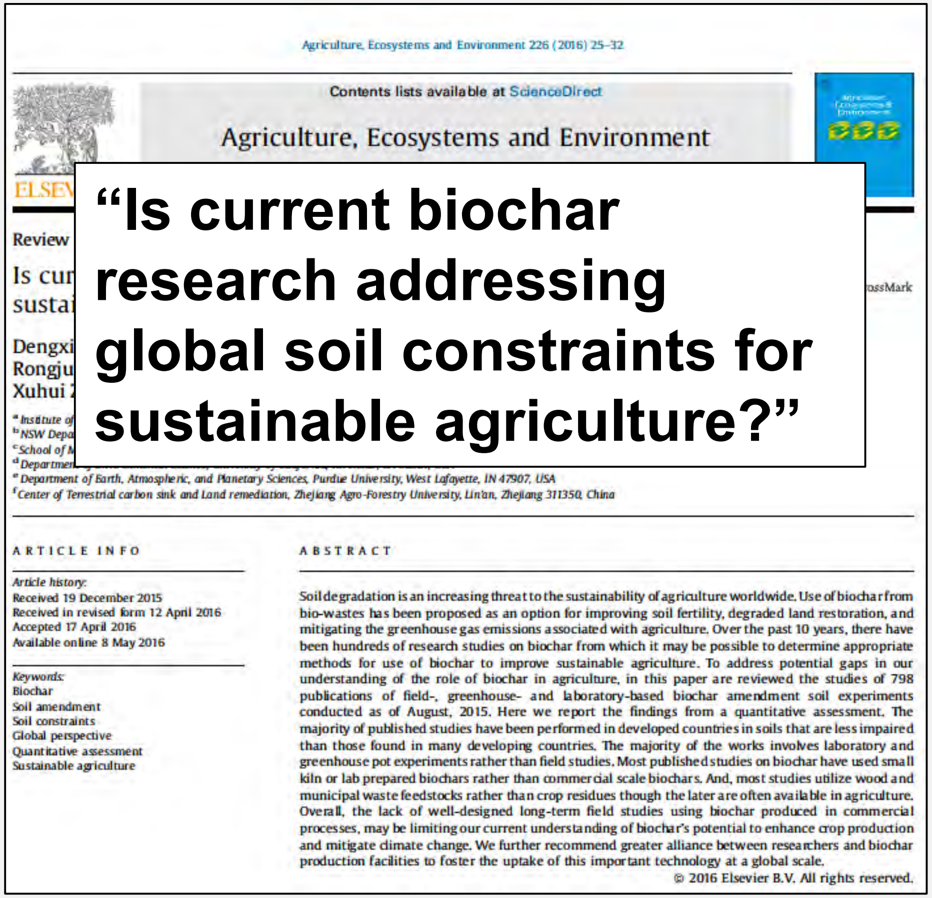
What *can* biochar do?

- Close waste loops
- Generate renewable energy
- Sequester carbon
- Retain soil nutrients and water



Novotny 2015

What *does* biochar do?



Agriculture, Ecosystems and Environment 226 (2016) 25–32

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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ARTICLE INFO

Article history:
Received 19 December 2015
Received in revised form 12 April 2016
Accepted 17 April 2016
Available online 8 May 2016

Keywords:
Biochar
Soil amendment
Soil constraints
Global perspective
Quantitative assessment
Sustainable agriculture

ABSTRACT

Soil degradation is an increasing threat to the sustainability of agriculture worldwide. Use of biochar from bio-wastes has been proposed as an option for improving soil fertility, degraded land restoration, and mitigating the greenhouse gas emissions associated with agriculture. Over the past 10 years, there have been hundreds of research studies on biochar from which it may be possible to determine appropriate methods for use of biochar to improve sustainable agriculture. To address potential gaps in our understanding of the role of biochar in agriculture, in this paper are reviewed the studies of 798 publications of field-, greenhouse- and laboratory-based biochar amendment soil experiments conducted as of August, 2015. Here we report the findings from a quantitative assessment. The majority of published studies have been performed in developed countries in soils that are less impaired than those found in many developing countries. The majority of the works involves laboratory and greenhouse pot experiments rather than field studies. Most published studies on biochar have used small kiln or lab prepared biochars rather than commercial scale biochars. And, most studies utilize wood and municipal waste feedstocks rather than crop residues though the later are often available in agriculture. Overall, the lack of well-designed long-term field studies using biochar produced in commercial processes, may be limiting our current understanding of biochar's potential to enhance crop production and mitigate climate change. We further recommend greater alliance between researchers and biochar production facilities to foster the uptake of this important technology at a global scale.

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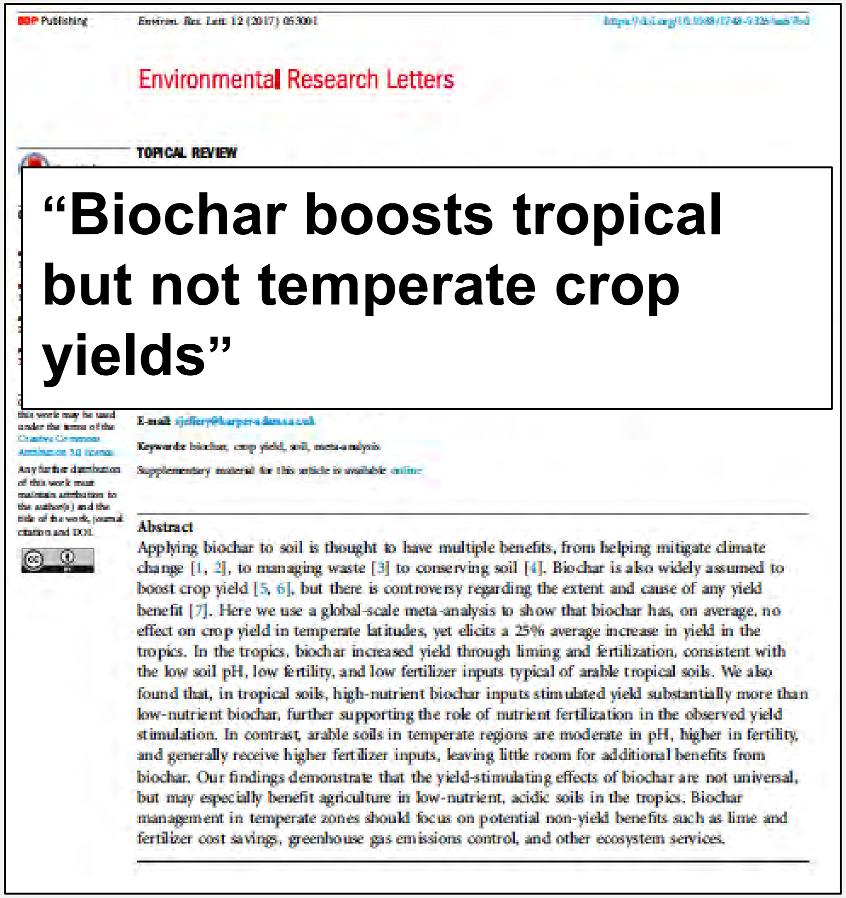
"Is current biochar research addressing global soil constraints for sustainable agriculture?"



IOP Publishing Environ. Res. Lett. 12 (2017) 053001 https://doi.org/10.1088/1748-9326/aa67bd

Environmental Research Letters

TOPICAL REVIEW

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Keywords: biochar, crop yield, soil, meta-analysis

Supplementary material for this article is available online

Abstract

Applying biochar to soil is thought to have multiple benefits, from helping mitigate climate change [1, 2], to managing waste [3] to conserving soil [4]. Biochar is also widely assumed to boost crop yield [5, 6], but there is controversy regarding the extent and cause of any yield benefit [7]. Here we use a global-scale meta-analysis to show that biochar has, on average, no effect on crop yield in temperate latitudes, yet elicits a 25% average increase in yield in the tropics. In the tropics, biochar increased yield through liming and fertilization, consistent with the low soil pH, low fertility, and low fertilizer inputs typical of arable tropical soils. We also found that, in tropical soils, high-nutrient biochar inputs stimulated yield substantially more than low-nutrient biochar, further supporting the role of nutrient fertilization in the observed yield stimulation. In contrast, arable soils in temperate regions are moderate in pH, higher in fertility, and generally receive higher fertilizer inputs, leaving little room for additional benefits from biochar. Our findings demonstrate that the yield-stimulating effects of biochar are not universal, but may especially benefit agriculture in low-nutrient, acidic soils in the tropics. Biochar management in temperate zones should focus on potential non-yield benefits such as lime and fertilizer cost savings, greenhouse gas emissions control, and other ecosystem services.

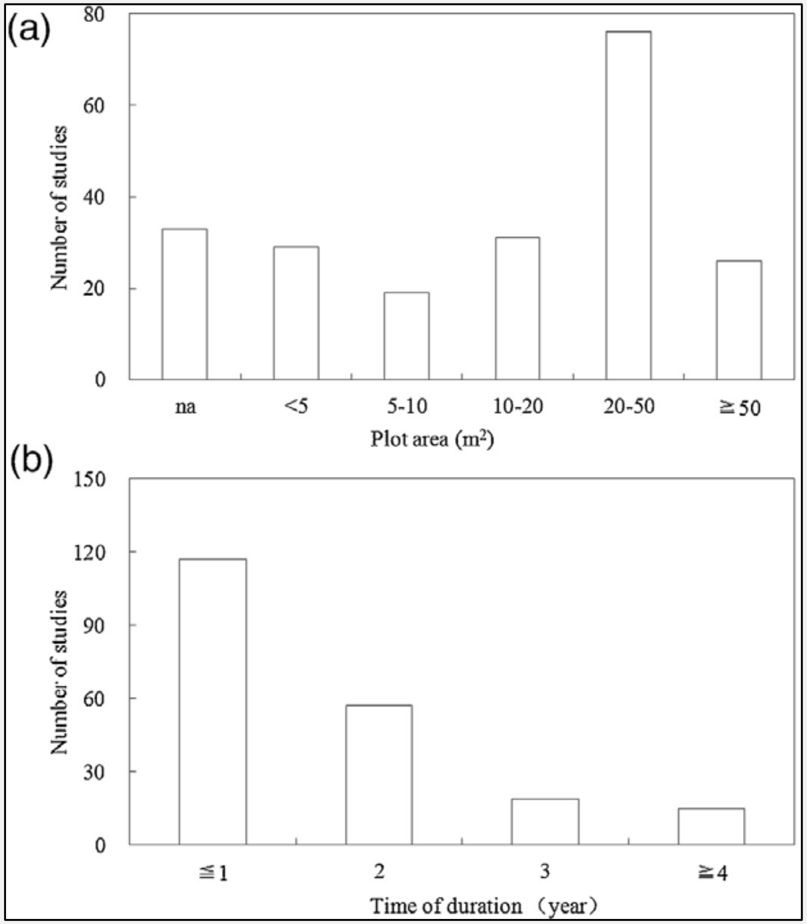
"Biochar boosts tropical but not temperate crop yields"

Zhang 2016, Jeffrey 2017

Gaps in literature

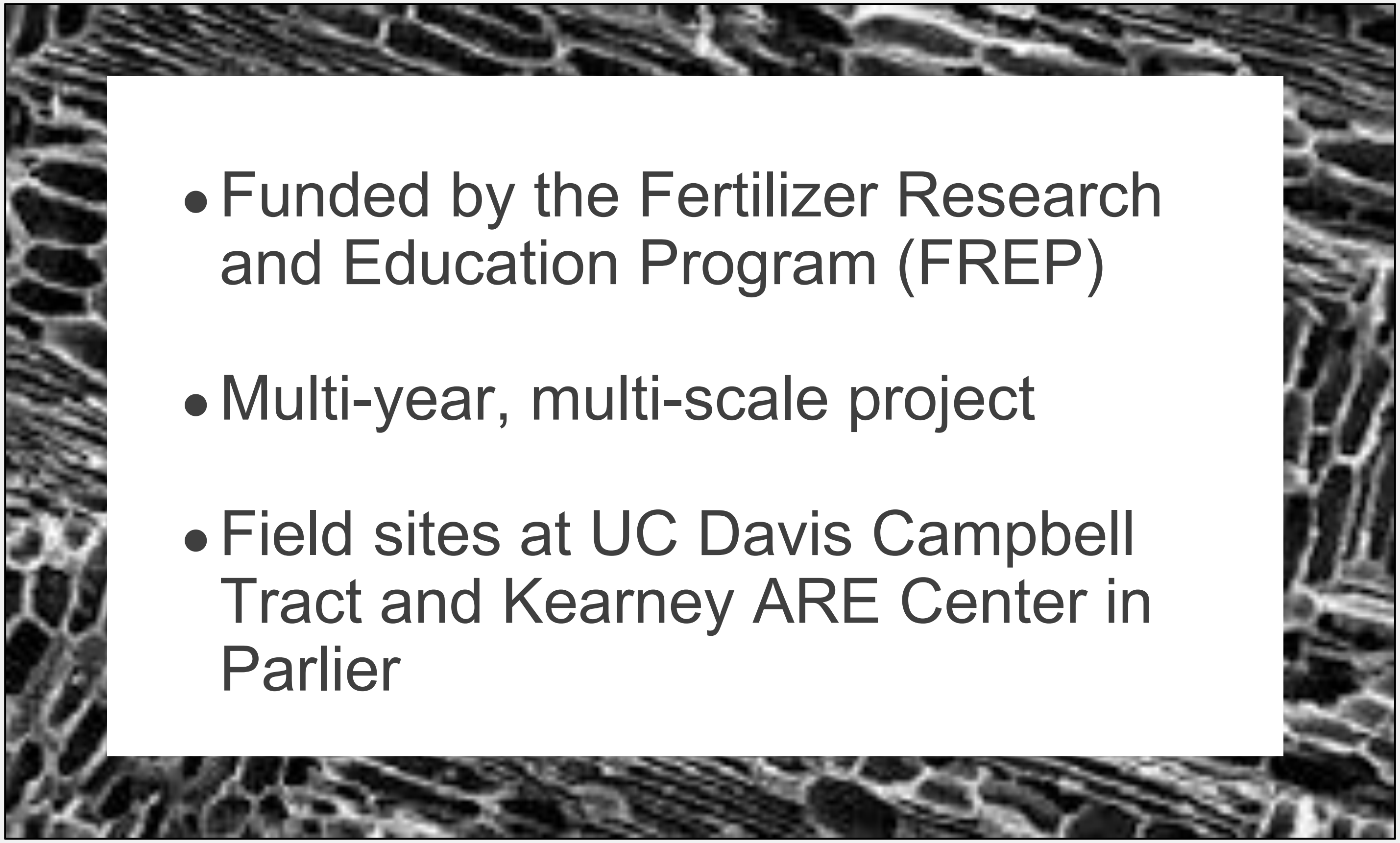
Of the 798 published studies as of August 2015:

- Only 25% conducted in field
- 56% of field studies for < 1 year. Only 16% 2+ years
- Over 50% field plots < 20 m^2



Zhang 2016

Project Overview



- Funded by the Fertilizer Research and Education Program (FREP)
- Multi-year, multi-scale project
- Field sites at UC Davis Campbell Tract and Kearney ARE Center in Parlier

Objectives

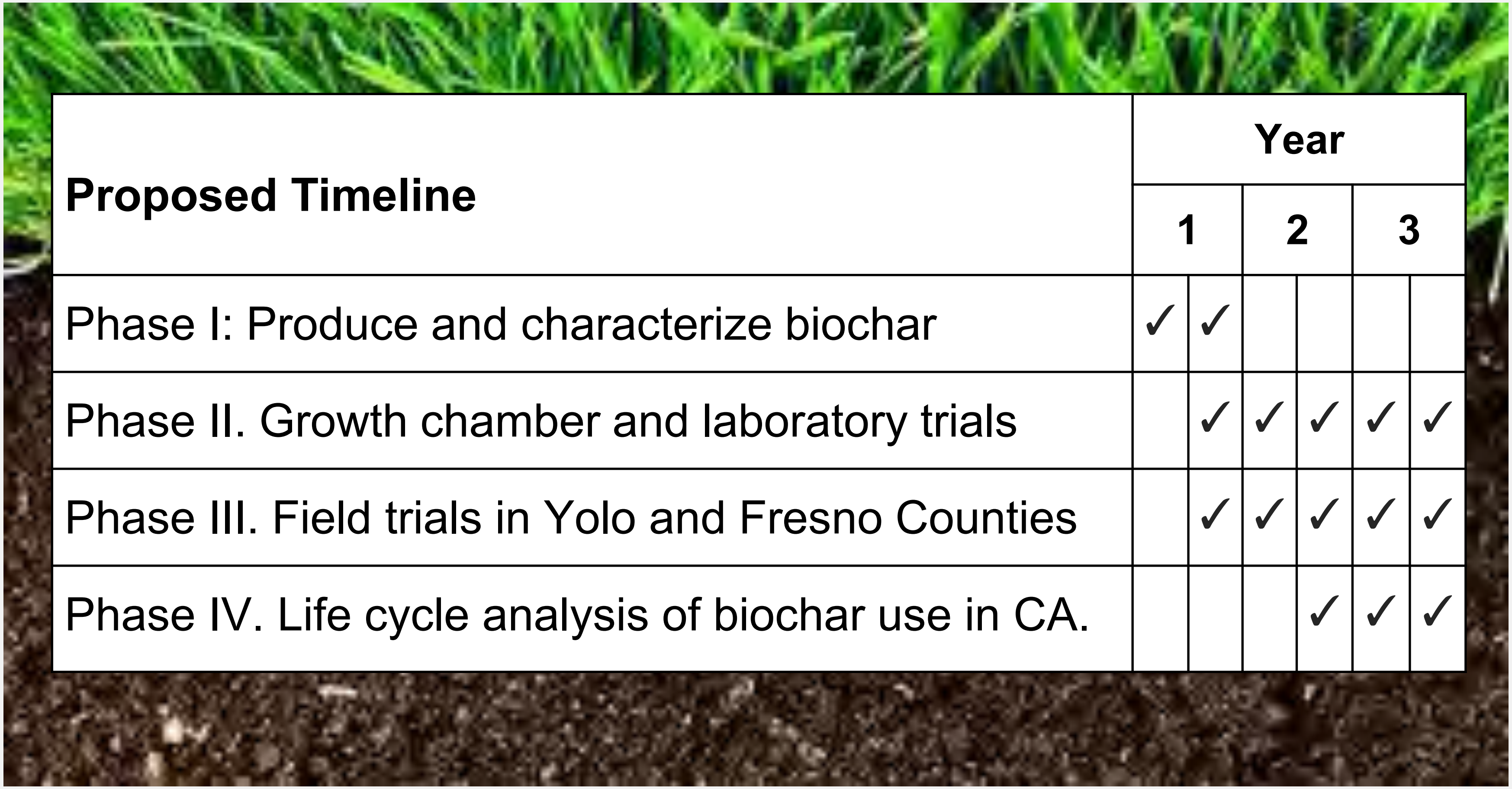
1. Produce and characterize biochars

2. Evaluate biochar impact on plant and soil properties

3. Evaluate application rates most likely to lead to beneficial outcomes

4. Conduct a life cycle analysis

Timeline



Proposed Timeline	**Year**					
	1		**2**		**3**	
Phase I: Produce and characterize biochar	✓	✓				
Phase II. Growth chamber and laboratory trials		✓	✓	✓	✓	✓
Phase III. Field trials in Yolo and Fresno Counties		✓	✓	✓	✓	✓
Phase IV. Life cycle analysis of biochar use in CA.				✓	✓	✓

Phase 1:
Char Production Complete

<u>Final products:</u>

Seven biochars of diverse pyrolysis temperatures, production methods, and (mostly) CA feedstocks

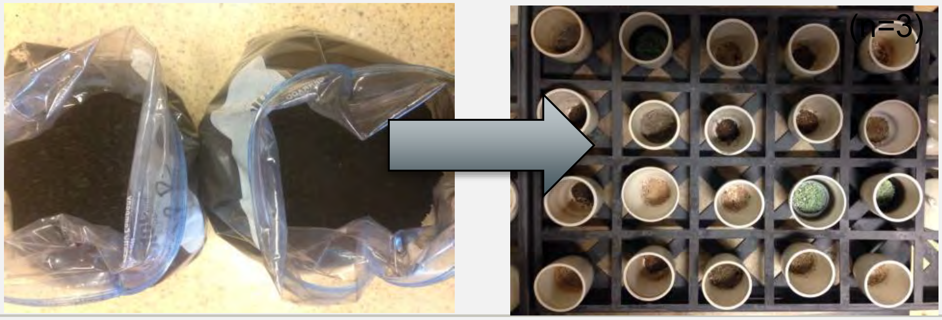
Biochar Characterization Data

Treatment ID	Production temp (°C)	Feedstock	Production method
NO (control)	NA	NA	NA
AS	Unpyrolyzed	Almond shell	NA
AS500	400-500	75% Almond shell, 25% Sawdust (Assorted softwood)	Fractional Hydro Pyrolysis
AS800	700-800	Almond shell	Gasification
SW500	400-500	Sawdust (Assorted softwood)	Fractional Hydro Pyrolysis
SW500- I	400-500	Sawdust (Assorted softwood) w/ inoculant	Fractional Hydro Pyrolysis
SW650- M	550-650	Pine (modified)	Slow pyrolysis
SW800	800	Softwood forestry thinning	Mixed
CS650	550-650	Coconut shell (modified)	Slow pyrolysis

Biochar Characterization Data

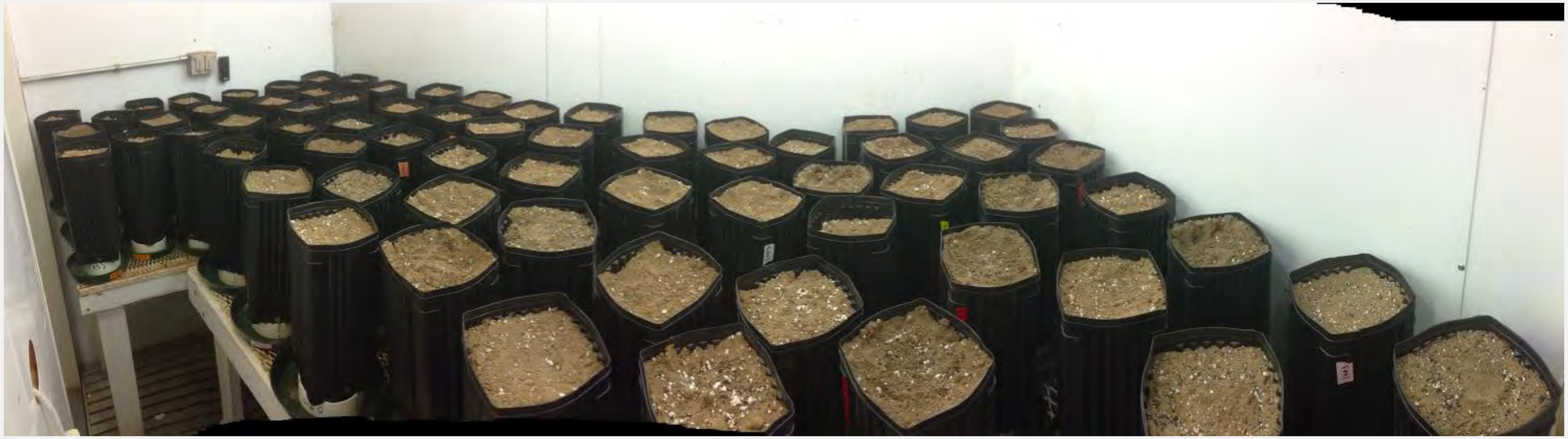
Treatment ID	Moisture Content (%)	Volatile Content (%)	Ash Content (%)	pH	EC (mS/cm)
NO	-	-	-	-	-
AS	-	-	-	-	-
AS500	4.0 ± .05	30.7 ± 2.18	19.0 ± .81	9.3 ± .02	3.2 ± .01
AS800	11.5 ± .23	28.2 ± .50	55.4 ± .76	10.1 ± .01	27.2 ± .10
SW500	4.1 ± .10	38.0 ± .86	4.5 ± .06	7.8 ± .02	2.5 ± .02
SW500-I	4.1 ± .08	38.8 ± 1.21	9.2 ± .53	10.4 ± .01	2.1 ± .02
SW650-M	4.1 ± .02	26.9 ± .29	4.5 ± .29	8.0 ± .03	.124 ± .002
SW800	5.5 ± .07	21.7 ± .17	31.5 ± 1.2	10.3 ± .01	2.7 ± .05
CS650	.7 ± .02	31.8 ± .36	5.3 ± .15	7.8 ± .01	.278 ± .004

All values reported as mean ± SE (n=3)



Phase 2:
Growth Chamber Trials

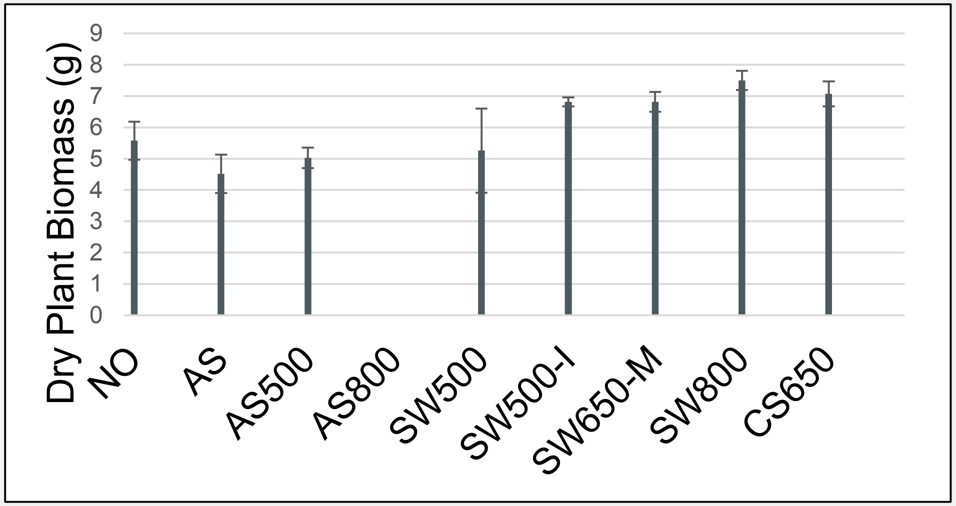
- Biochars and controls amended to soil at 2% (w/w) in 4 reps
- Romaine lettuce in Hanford sandy loam
- Pots fertilized with synthetic NPK and irrigated to 50% of water holding capacity until harvest



Growth Chamber Trial Results

Results:

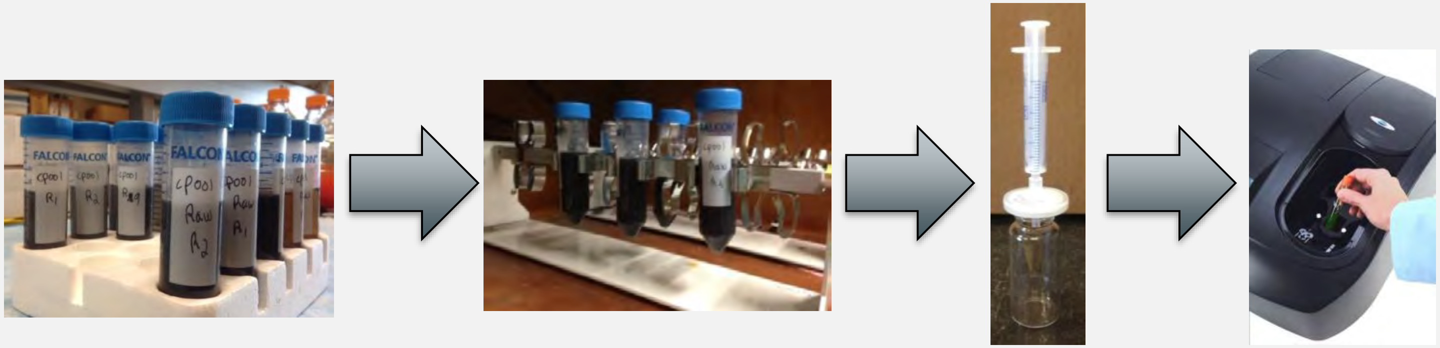
- Softwood- and coconut- derived biochars supported significantly greater crop yield, N uptake, and lower C:N ratios than controls
- AS800 prevented seed germination and transplant growth , likely due to high EC/ pH



All values reported as mean ± SE (n=4)

Phase 2: Sorption Trials

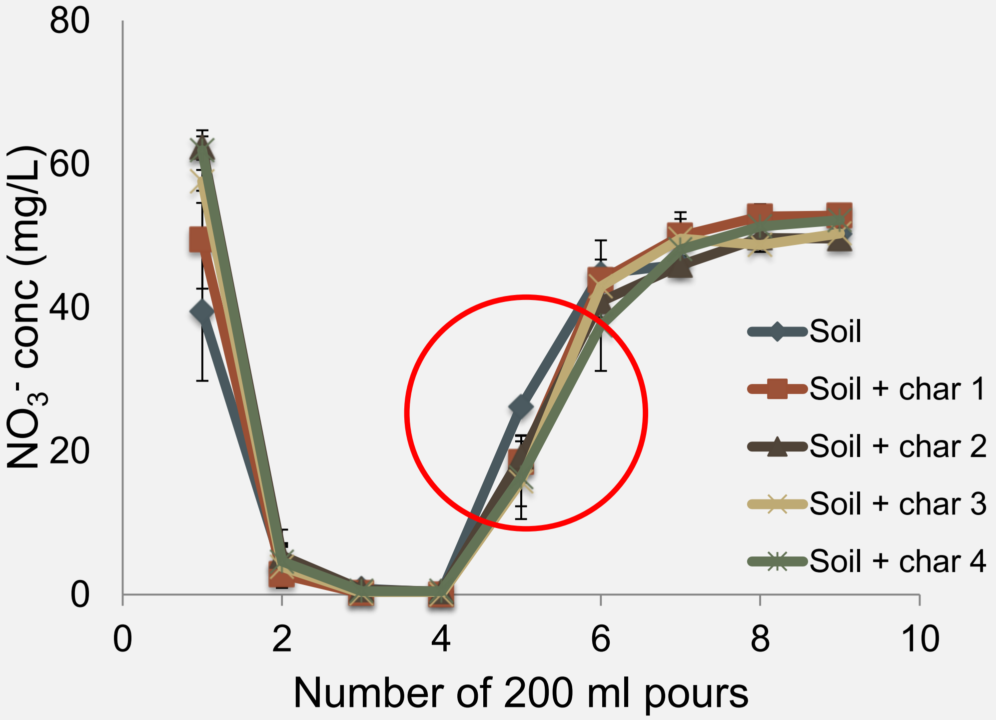
- Preliminary sorption experiments indicate no electrostatic affinity between nitrate and biochars
- Ammonium-biochar sorption has been observed at low rates and is pH-depedent



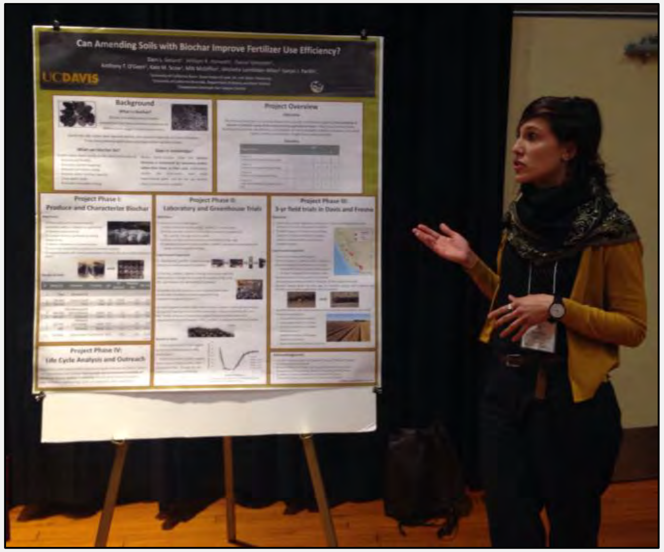
Phase 2: Column Studies

Results:

- Supports no apparent chemical affinity between nitrate and biochar
- Perhaps a physical delay in nitrate movement?
- More studies to follow!



Phase 3: Field Trials Experimental Questions



Does biochar use in CA soils:

1. Reduce N leaching?
2. Increase uptake of N or other crop nutrients?
3. Have an impact on yield?
4. Alter nutrient dynamics in plant and/or soil?
5. Alter C dynamics?
6. Impact microbial biomass?
7. Migrate great distances through the soil due to tillage?
8. Impact soil aggregation?
9. Impact soil-water dynamics?

Field Trial Overview

- Biochar installed in Parlier and Davis in Winter 2017

- Treatments banded directly above the drip tape at low and high rates, to be combined with low and high N fertilizer rates

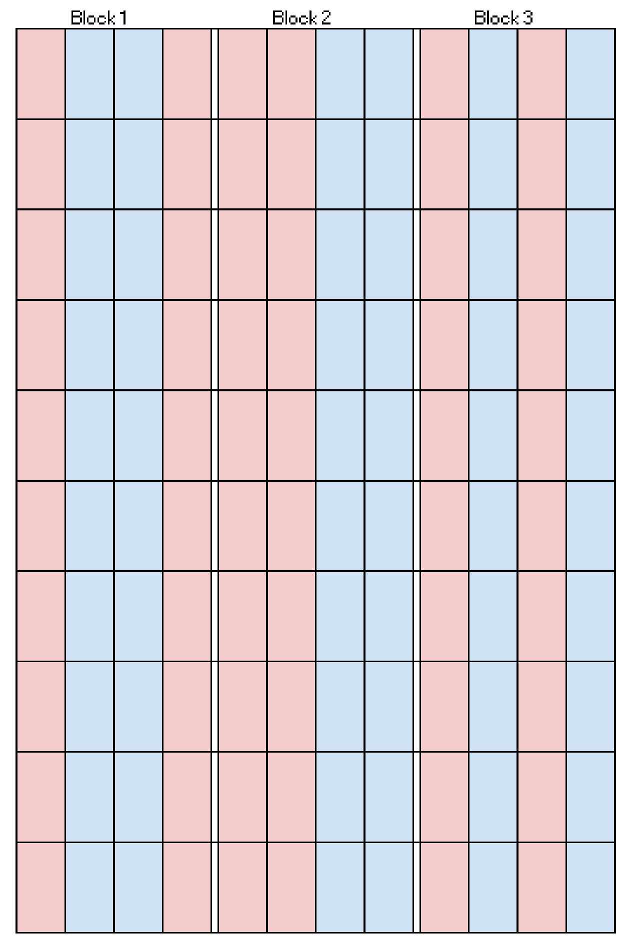
- Fields planted with tomatoes in early May

- Sampling taken at 3 depths

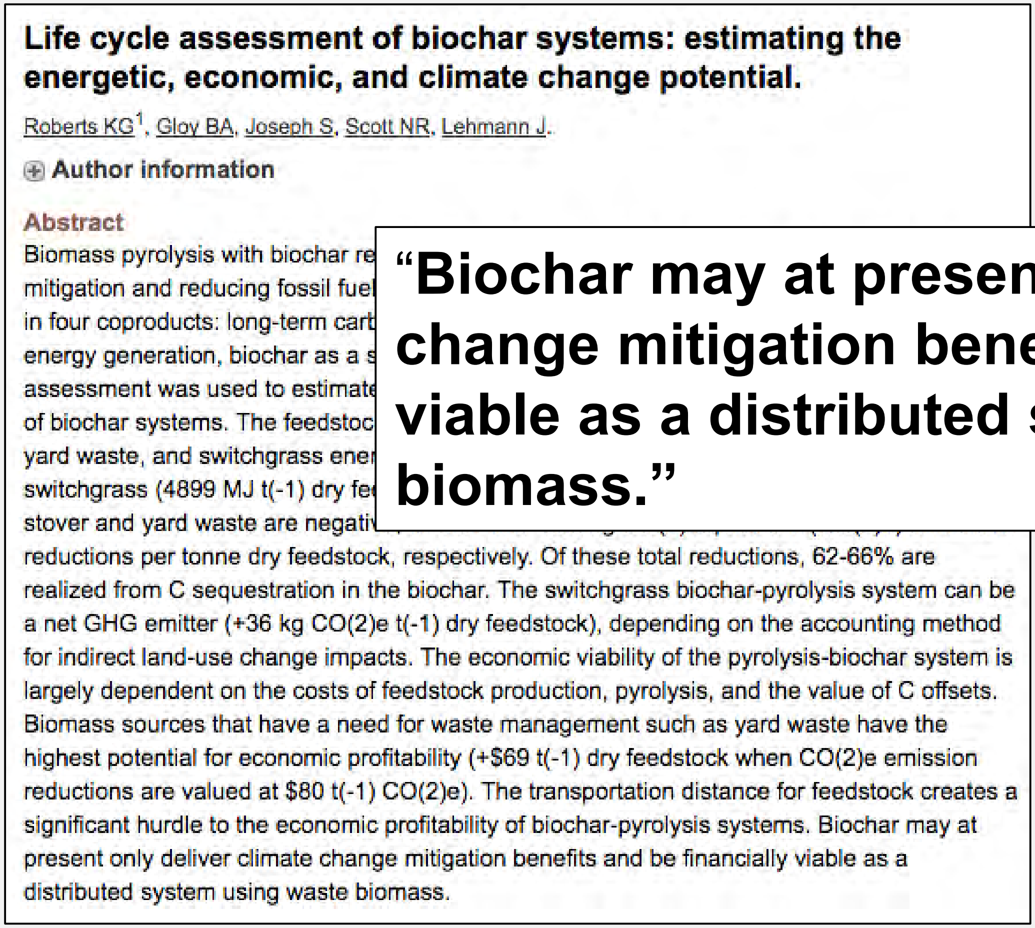
Field Trials:
Experimental Design

RCBD with three replicates per treatment

Biochar application rate	Low (~.25 lbs per linear foot)
	High (~.5 lbs per linear foot)
	Tiny* (.01 lbs per linear foot) *SW650-M and CS650 only
Fertilizer rate	Low- 150 lbs N/ acre
	High- 225 lbs N/ acre



Phase 4:
Life cycle analysis



Life cycle assessment of biochar systems: estimating the energetic, economic, and climate change potential.

Roberts KG[1], Gloy BA, Joseph S, Scott NR, Lehmann J.

⊕ **Author information**

Abstract

Biomass pyrolysis with biochar re
mitigation and reducing fossil fuel
in four coproducts: long-term carb
energy generation, biochar as a s
assessment was used to estimate
of biochar systems. The feedstoc
yard waste, and switchgrass ener
switchgrass (4899 MJ t(-1) dry fe
stover and yard waste are negati
reductions per tonne dry feedstock, respectively. Of these total reductions, 62-66% are realized from C sequestration in the biochar. The switchgrass biochar-pyrolysis system can be a net GHG emitter (+36 kg CO(2)e t(-1) dry feedstock), depending on the accounting method for indirect land-use change impacts. The economic viability of the pyrolysis-biochar system is largely dependent on the costs of feedstock production, pyrolysis, and the value of C offsets. Biomass sources that have a need for waste management such as yard waste have the highest potential for economic profitability (+$69 t(-1) dry feedstock when CO(2)e emission reductions are valued at $80 t(-1) CO(2)e). The transportation distance for feedstock creates a significant hurdle to the economic profitability of biochar-pyrolysis systems. Biochar may at present only deliver climate change mitigation benefits and be financially viable as a distributed system using waste biomass.

“Biochar may at present only deliver climate change mitigation benefits and be financially viable as a distributed system using waste biomass.”

Future Directions for Year 2

- Analyze all samples from field trials
- Complete physical and chemical biochar characterization
- Repeat growth chamber trials with 50% sand to analyze nitrate leaching
- Process micro-CT images to analyze physical properties of biochar-amended soils