Biochar Use in Annual and Perennial Crop Production: Practical insights and impacts

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Practical Biochar Implementation Webinar Series

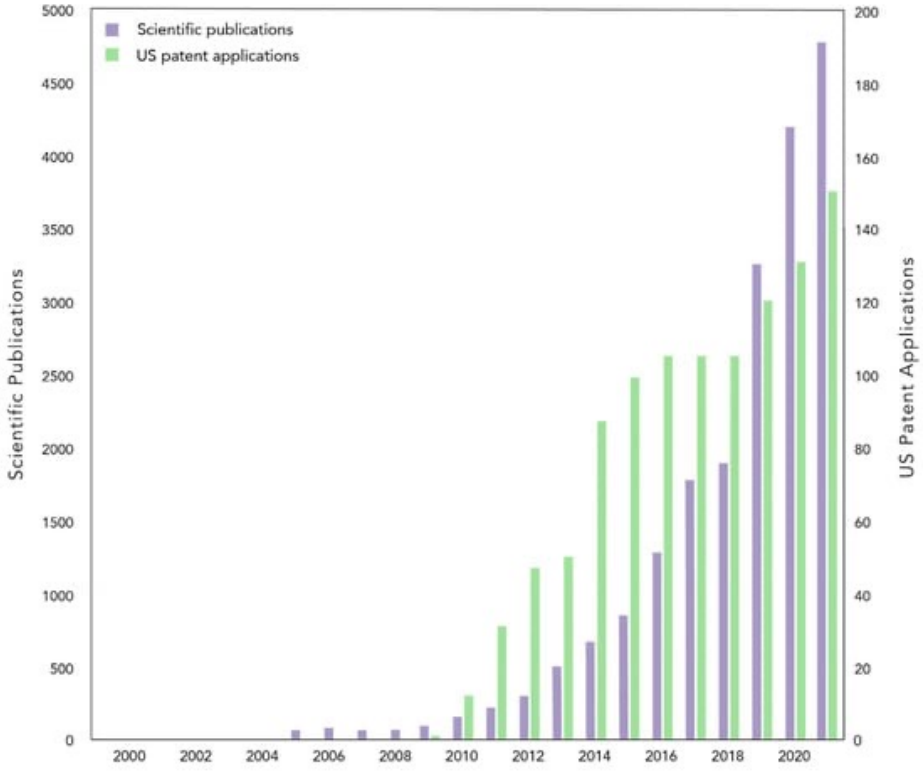
January 24th, 2024

Cornell CALS
College of Agriculture and Life Sciences

NEW YORK SOIL HEALTH

Our understanding of biochar continues to grow, widespread adoption still lags

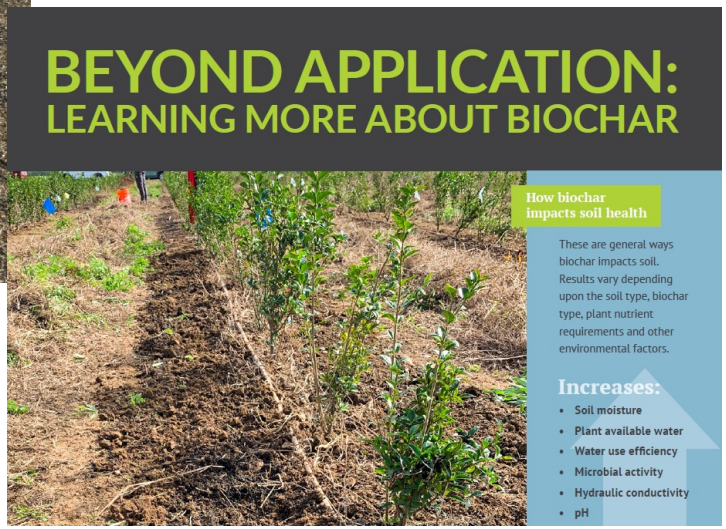
Close to 30,000 publications over the last 10 years



- The complexity and variability of biochar has limited widespread adoption particularly in agricultural systems
- **Continued need for practical information!**

Gelardi and Parikh, 2021. *Sustainability.*

Factsheets available online!



USBI Building the future from the ground up.™

the next 150

Nebraska Forest Service, University of Nebraska-Lincoln

General Biochar Systems

Instituto Latinoamericano del Biochar

New York Soil Health

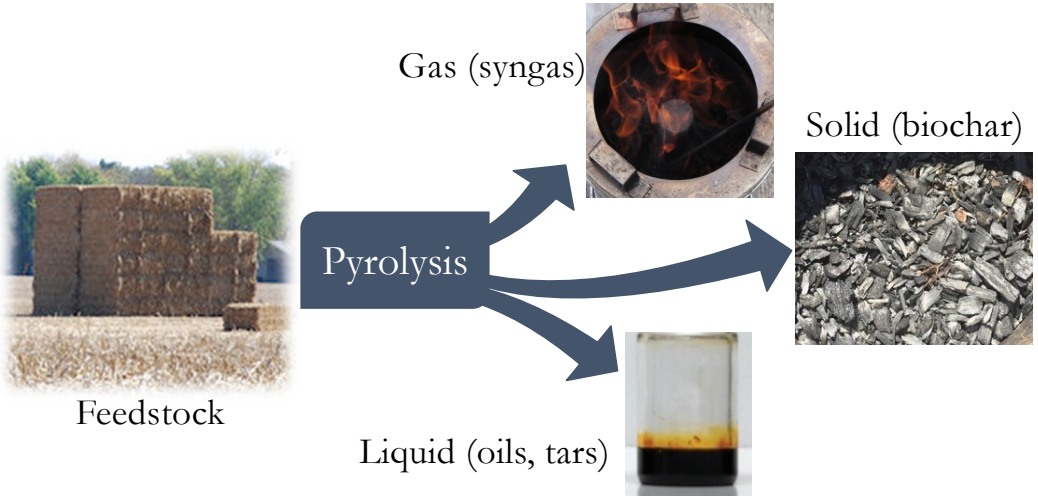
Cornell University, Founded A.D. 1865 — CornellCALS College of Agriculture and Life Sciences

USDA Agricultural Research Service

American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

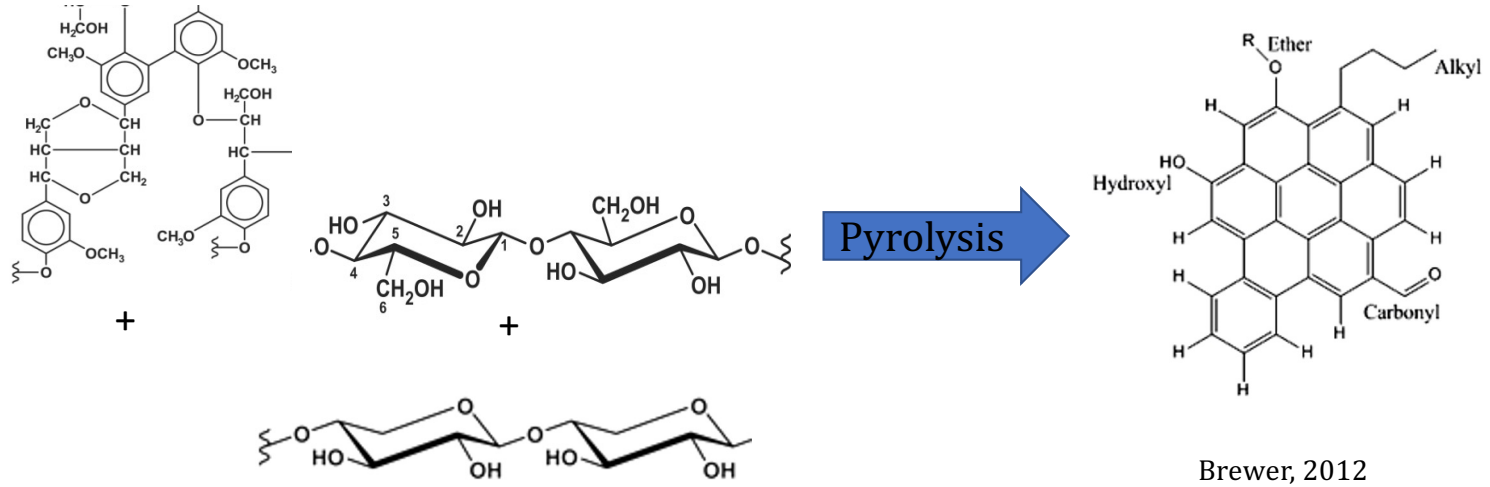
Biochar: a C-rich material made through pyrolysis

- Conversion of organic waste to a high value product
- *Pyrolysis* - the thermochemical decomposition of biomass at high temperatures in a no/low oxygen environment



- Charcoal like material produced from organic waste materials
- ~60-80% carbon (C-rich material!)
- Highly porous – like a sponge!
- Long-lasting soil amendment

Pyrolysis makes the structure more complex!



Brewer, 2012

As pyrolysis temperature increases:

- Biochar yield decreases
- Fixed carbon content, surface area, and ash content increase

Numerous potential benefits of biochar

- Long lasting agronomic, environmental, and social benefits
  - Crop – growth/yields
  - Soil – fertility/health
  - Water – quality/WUE
  - Nutrients – retention/NUE
  - Microbial activity
  - Bioremediation
  - Waste management
  - Human health
  - Climate mitigation & adaptation

- **Not a silver-bullet**, but another tool in the soil health management toolbox!

Photo: Debbie Aller

Biochar has long been used to improve soils

500-8000 years ago
Central Amazon

Anthropogenic
dark earths
(Glaser, 2007)

Terra Preta do Indio
(Oxisol + biochar)

Oxisol
(tropical soil)

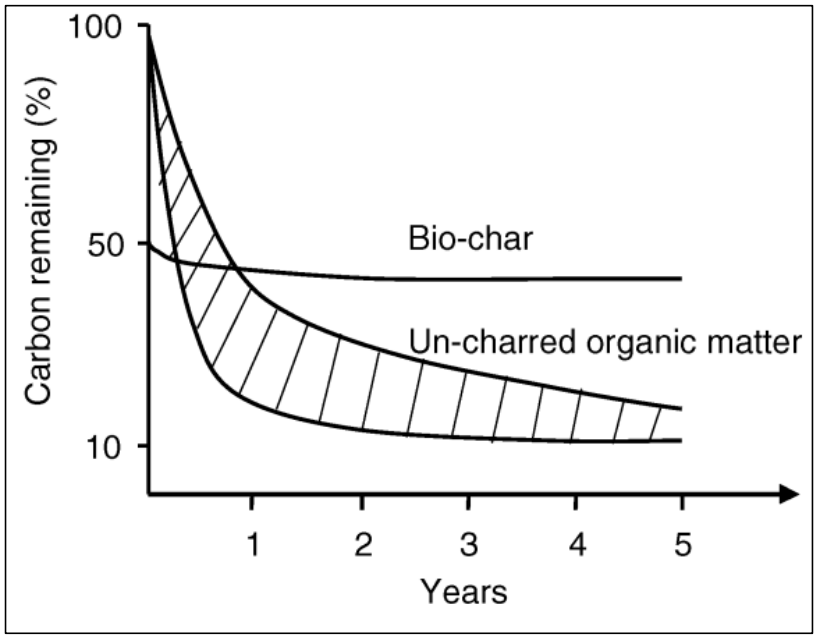
Similar soils found in Liberia, Germany, Australia, US Midwest.

Likely resulting from repeated applications of small amounts of charred organic waste materials

Photo: Glaser et al., 2001

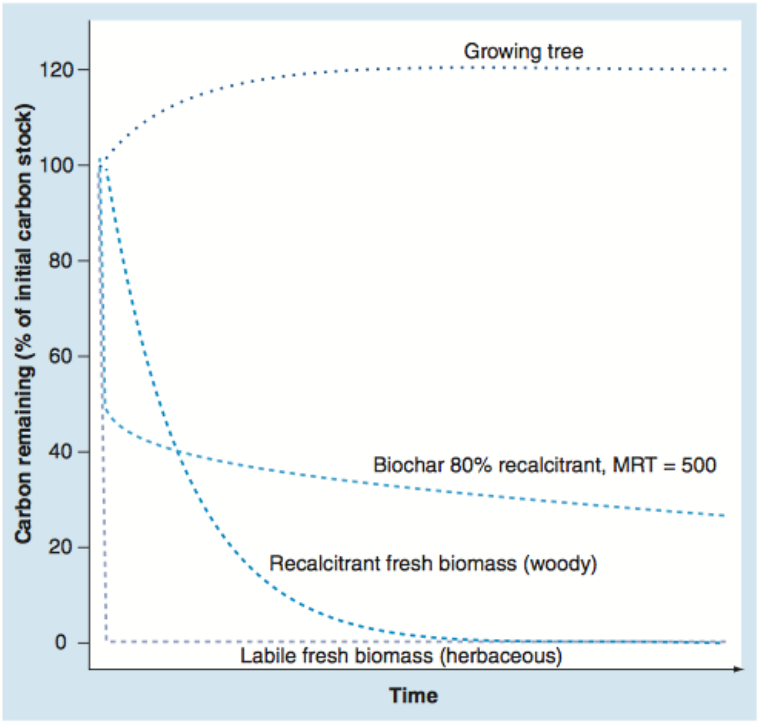
Biochar is stable, degrading on centennial time scales

Dead (passive, recalcitrant) pool of SOM



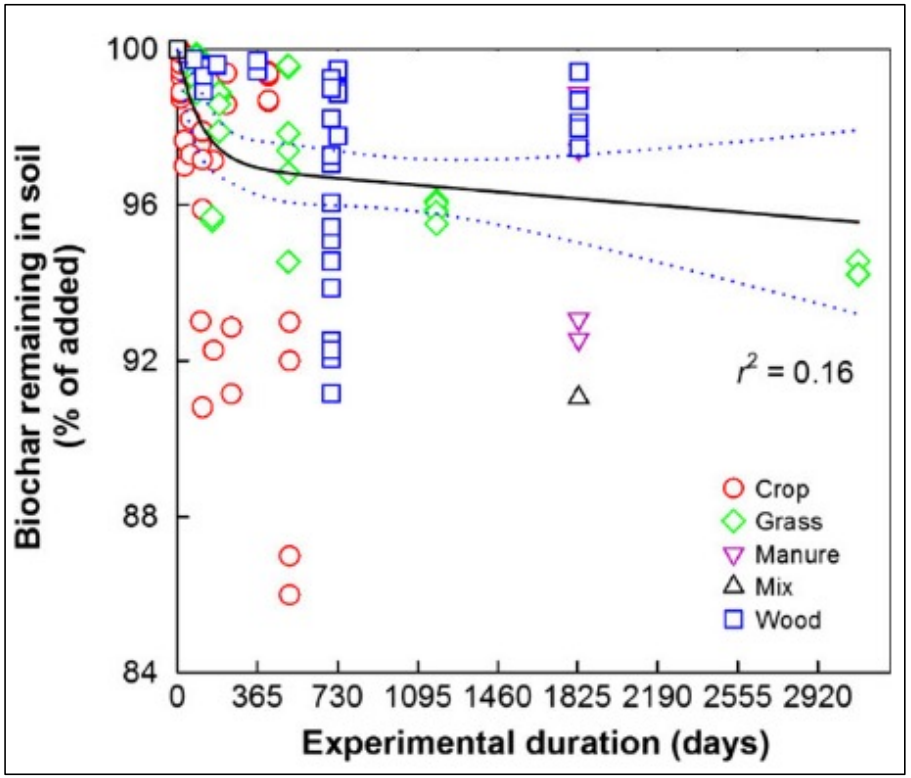
Essential stability of biochar. Crop residue

Lehmann et al., 2006. *Mitigation and Adaptation.*

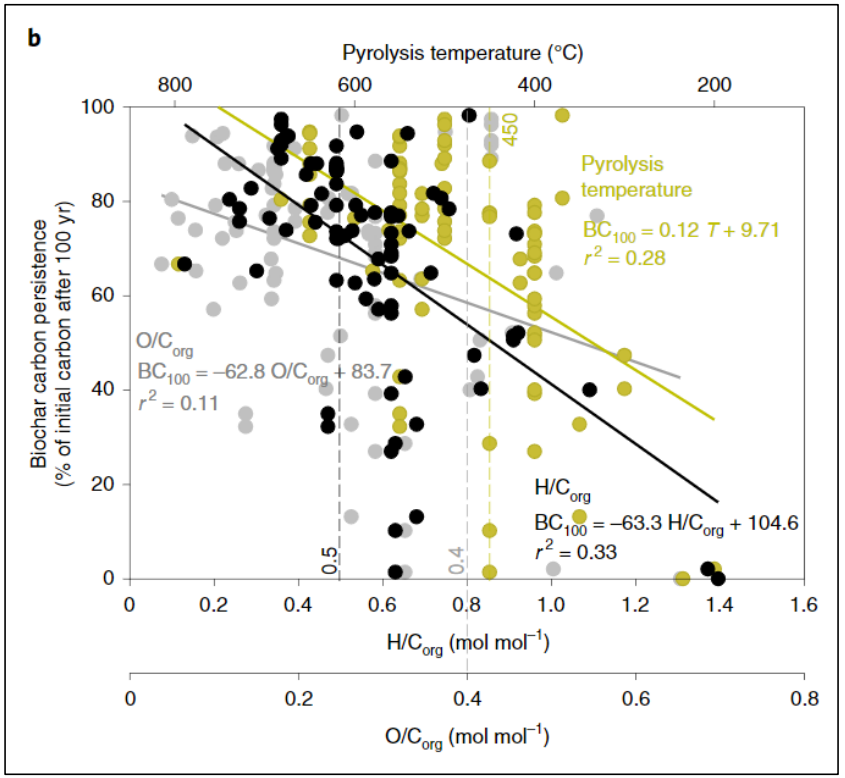


Whitman et al. 2010. *Carbon Management*

But its stability varies depending on feedstock and production conditions



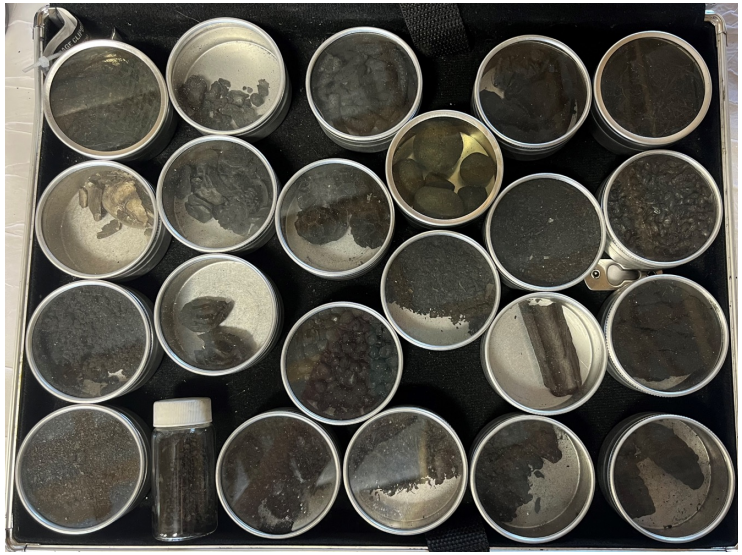
Wang et al. 2016. *GCB Bioenergy*

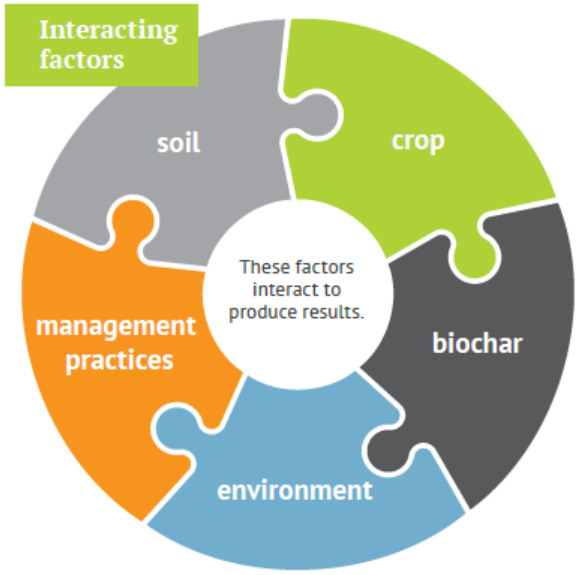


Lehmann et al. 2021. *Nature Geoscience*

Biochar diversity leads to different impacts

- Impacts are **soil x crop x biochar x environment x management** dependent
  - Properties and impacts change over time (fresh vs. 'aged') (Joseph et al., 2021)
    - Can produce designer biochars for specific end uses (Novak et al., 2009)





Biochars can be modified for specific applications

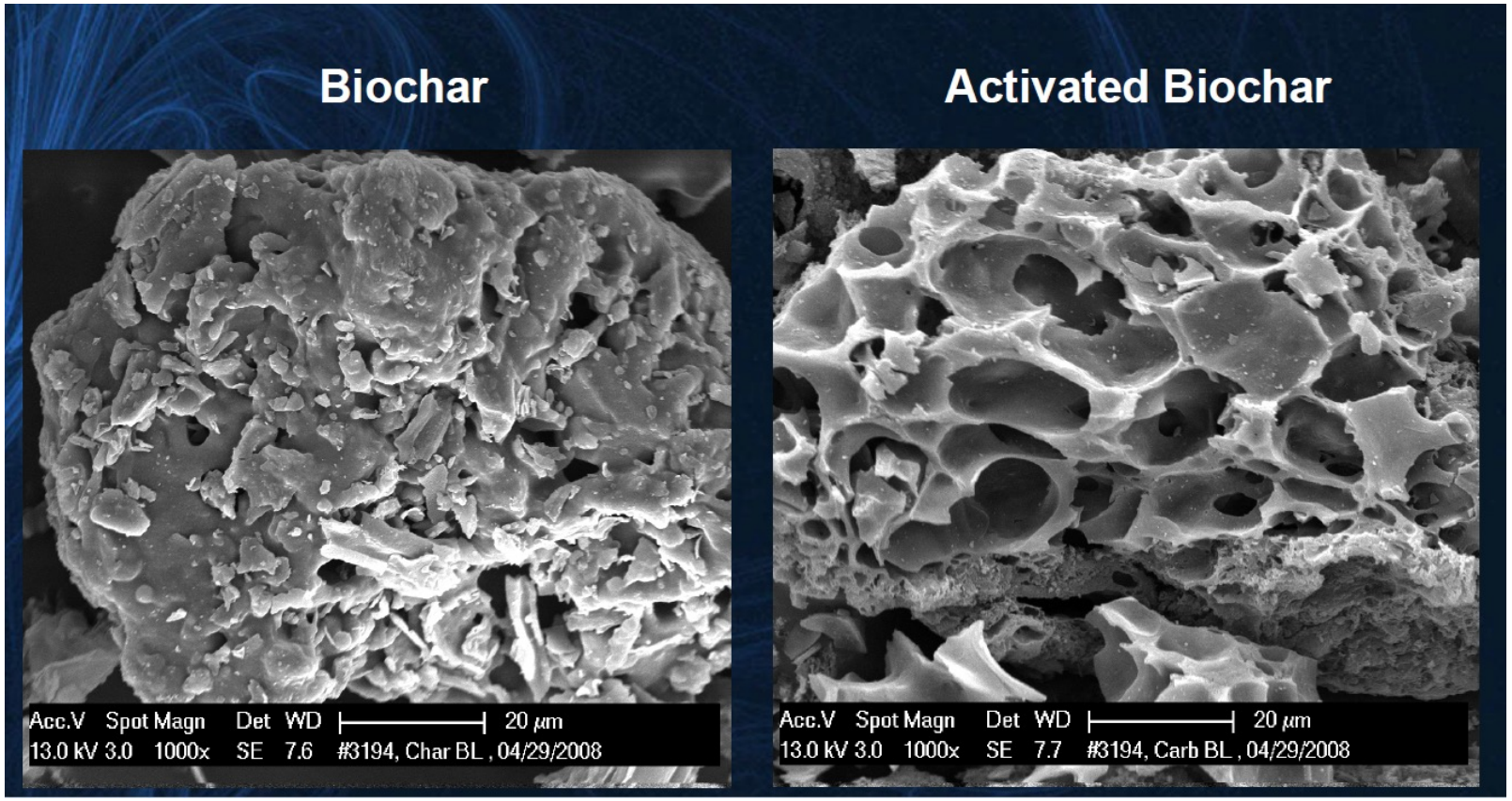
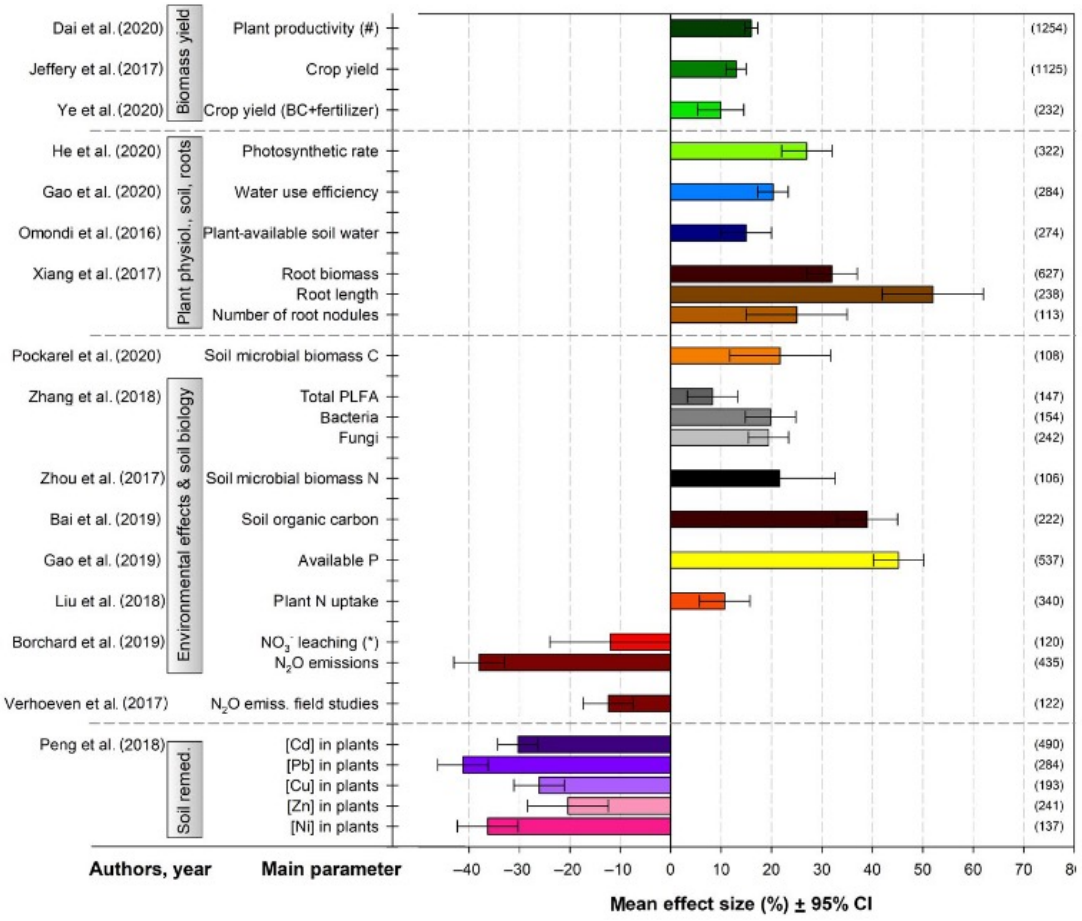


Photo: Isabel Lima

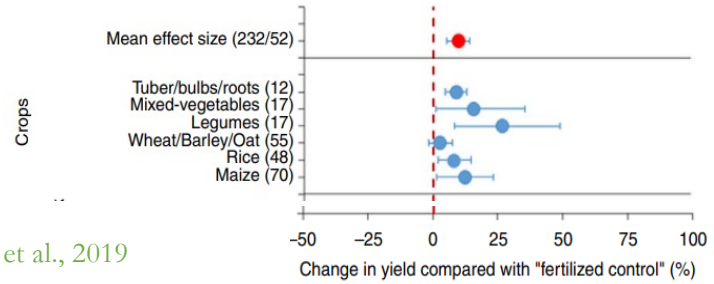
Across thousands of studies biochar positively impacts numerous agronomic parameters



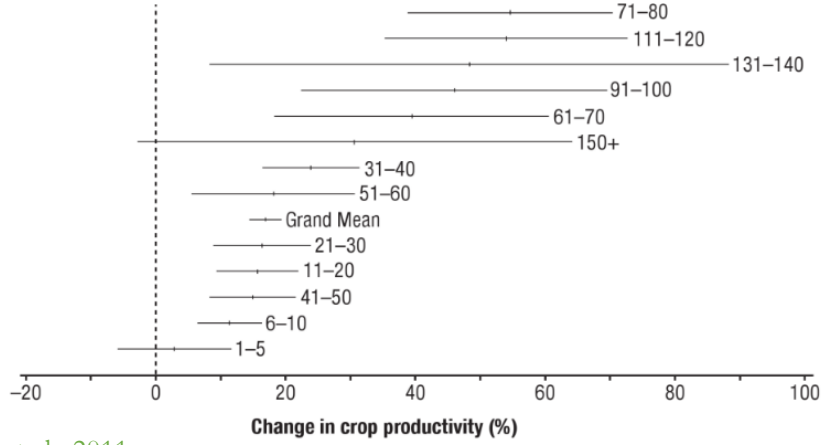
Systematic review of 26 meta-analyses published between 2016-2020

Schmidt et al., 2021
https://doi.org/10.1111/gcbb.12889

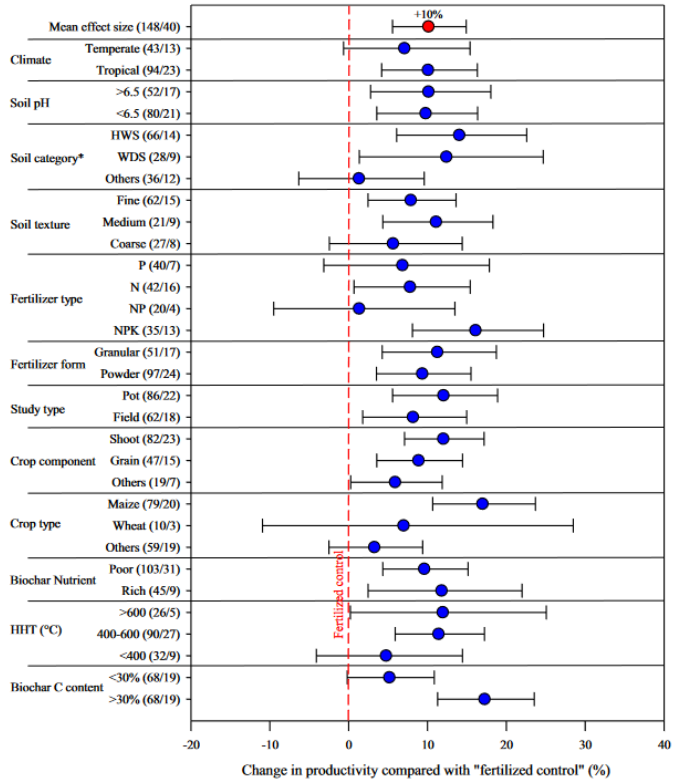
Global crop yields increase with biochar application: 11-28% above average



Ye et al., 2019

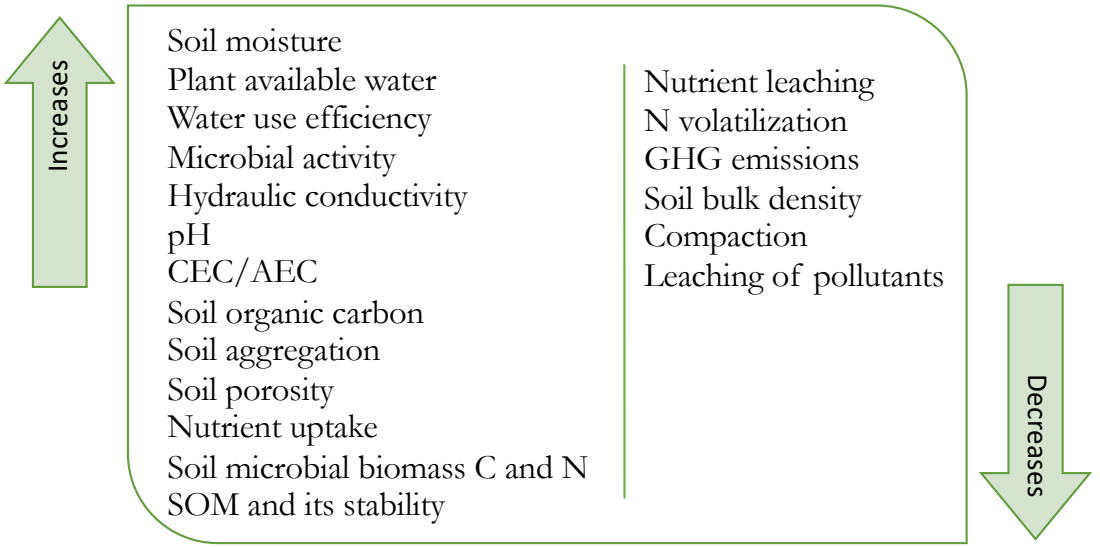


Jeffery et al., 2011



Melo et al., 2022

Biochar improves soil health and can be part of the soil health management toolbox



- Contributes to negative priming over the long-term (Wang et al., 2016; Blanco-canqui et al., 2019; Joseph et al., 2021)
- 33% of the global soils have been degraded, but soil degradation can be reversed by increasing SOC stocks, and the most effective way to accumulate SOC is to increase C inputs (FAO, 2019; Lal et al., 2018; Fujisaki et al., 2018)

What is the resource concern you are trying to solve? biochar is not one size fits all

Nutrient use efficiency

Organic Matter

Water retention

Soil pH

Microbial Activity

Structure

Infiltration

Compaction

Aeration

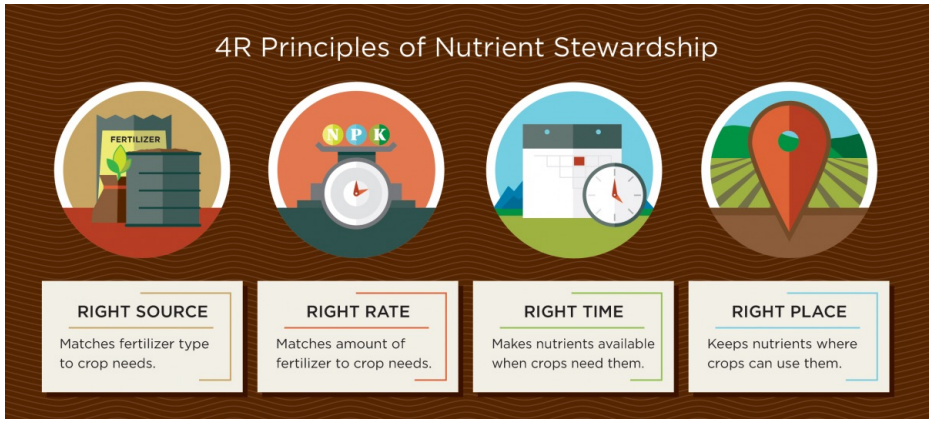
Erosion

Fertility

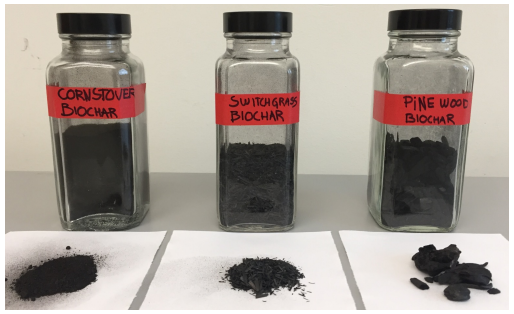
Disease

C sequestration

Take a similar approach as the 4Rs



Right Source



Right Rate

Right Time

Right Place

Photo: Doug Beck

Right Source: local, available, sustainable

Photo: David Laird

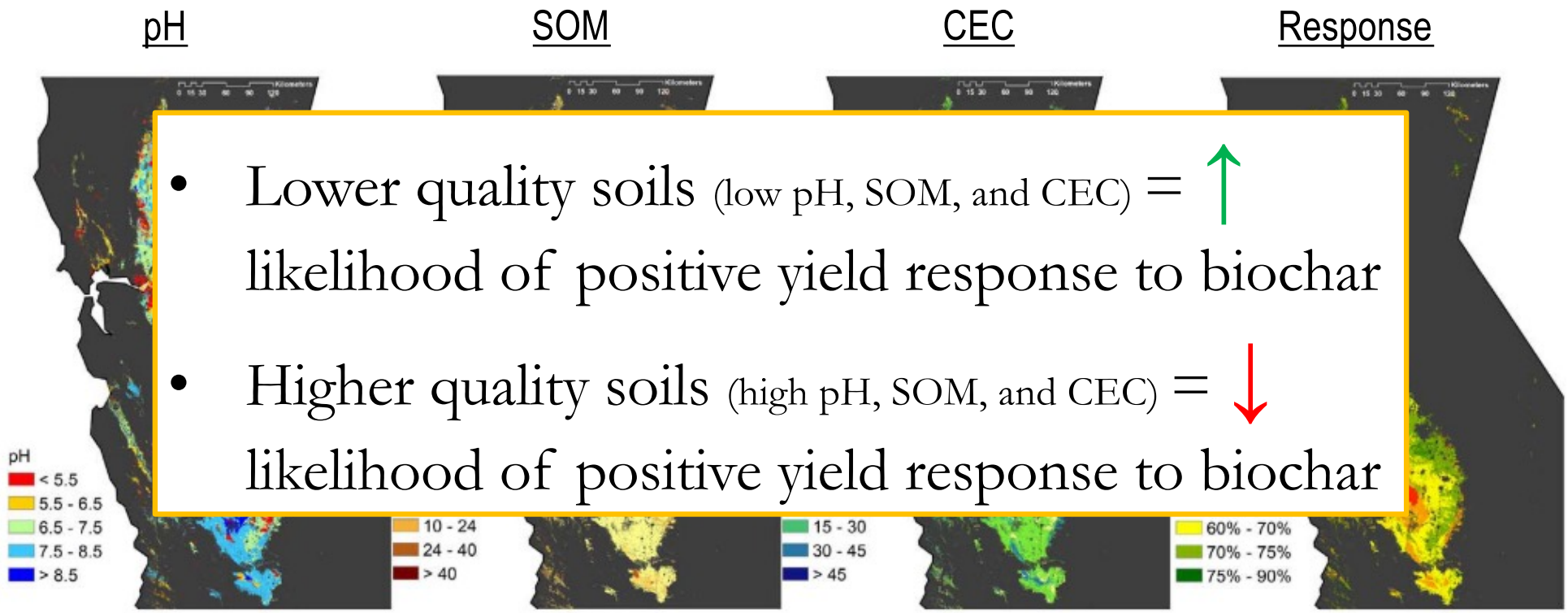
Photo: Debbie Aller

Photo: Isabel Lima

Photo: Debbie Aller

Right Place: where do I apply biochar?

Example: Central Valley, California

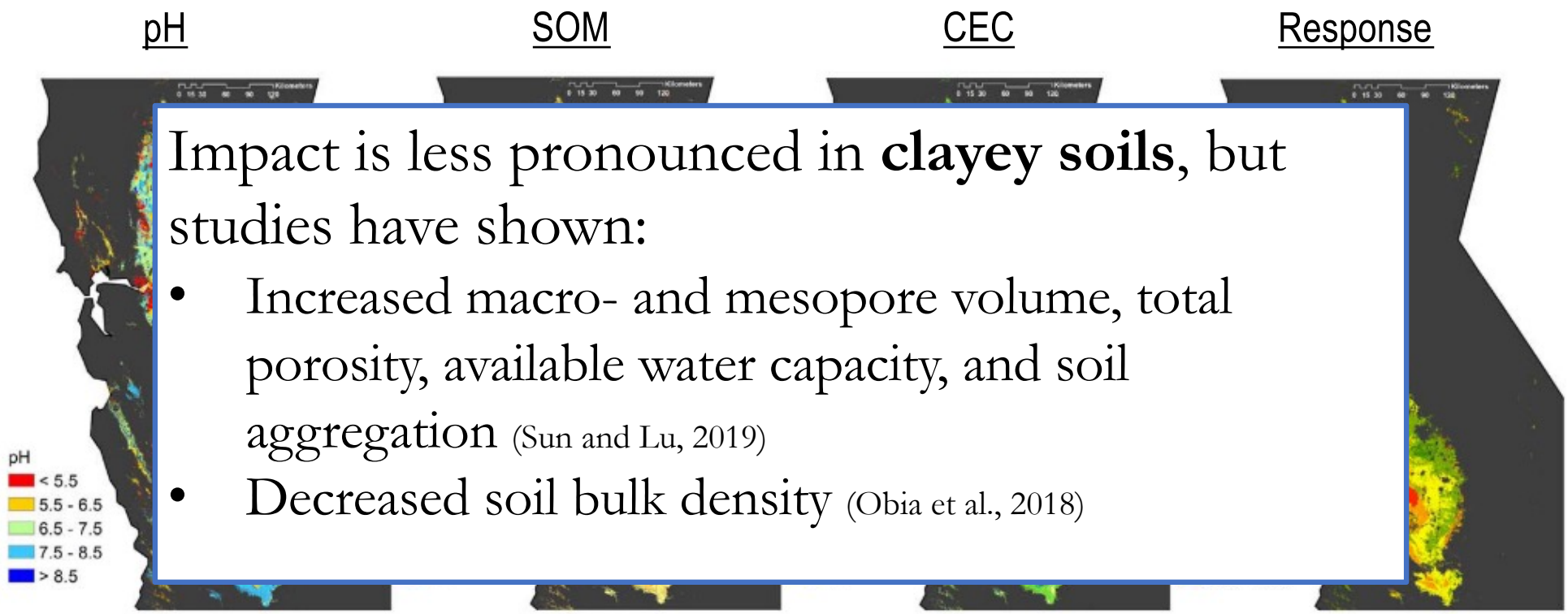


- Lower quality soils (low pH, SOM, and CEC) = ↑ likelihood of positive yield response to biochar
- Higher quality soils (high pH, SOM, and CEC) = ↓ likelihood of positive yield response to biochar

Figure 3 - Dokoohaki, et al 2019.

Right Place: where do I apply biochar?

Example: Central Valley, California



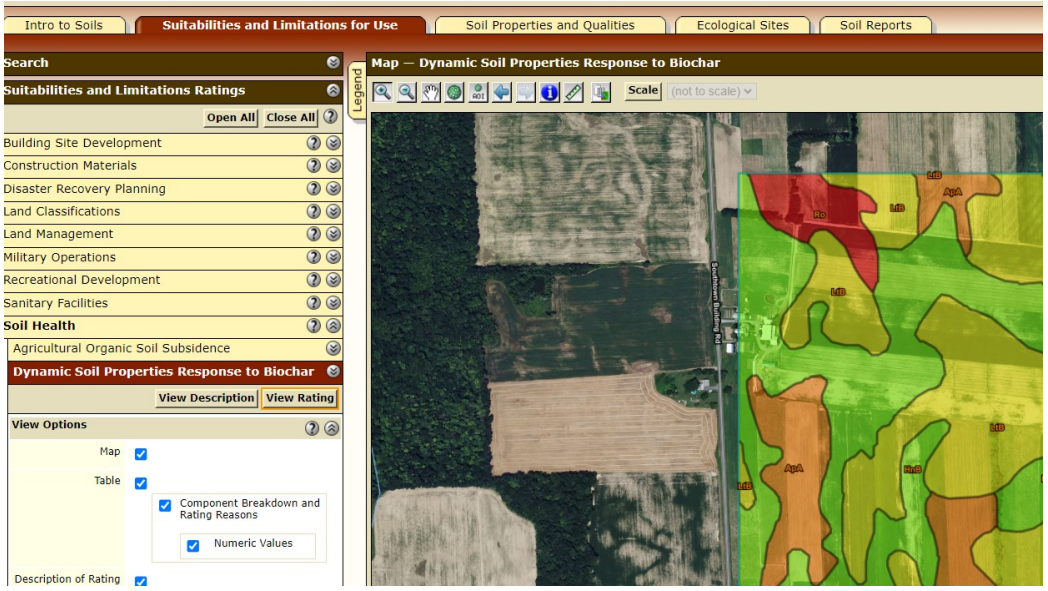
Impact is less pronounced in **clayey soils**, but studies have shown:

- Increased macro- and mesopore volume, total porosity, available water capacity, and soil aggregation (Sun and Lu, 2019)
- Decreased soil bulk density (Obia et al., 2018)

Figure 3 - Dokoohaki, et al 2019.

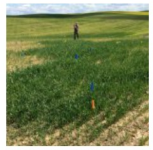
Decision support tools are available to help farmers (and advisors) make more informed decisions!

Web Soil Survey



https://websoilsurvey.sc.egov.usda.gov/app/

Biochar Atlas



Soils Data Explorer

Explore soils data from the Natural Resources Conservation Service to

Biochar Property Explorer

This tool shows the agricultural properties of different biochars made Northwest. Explore the data to see how feedstock and production cor

Biochar Selection Tool

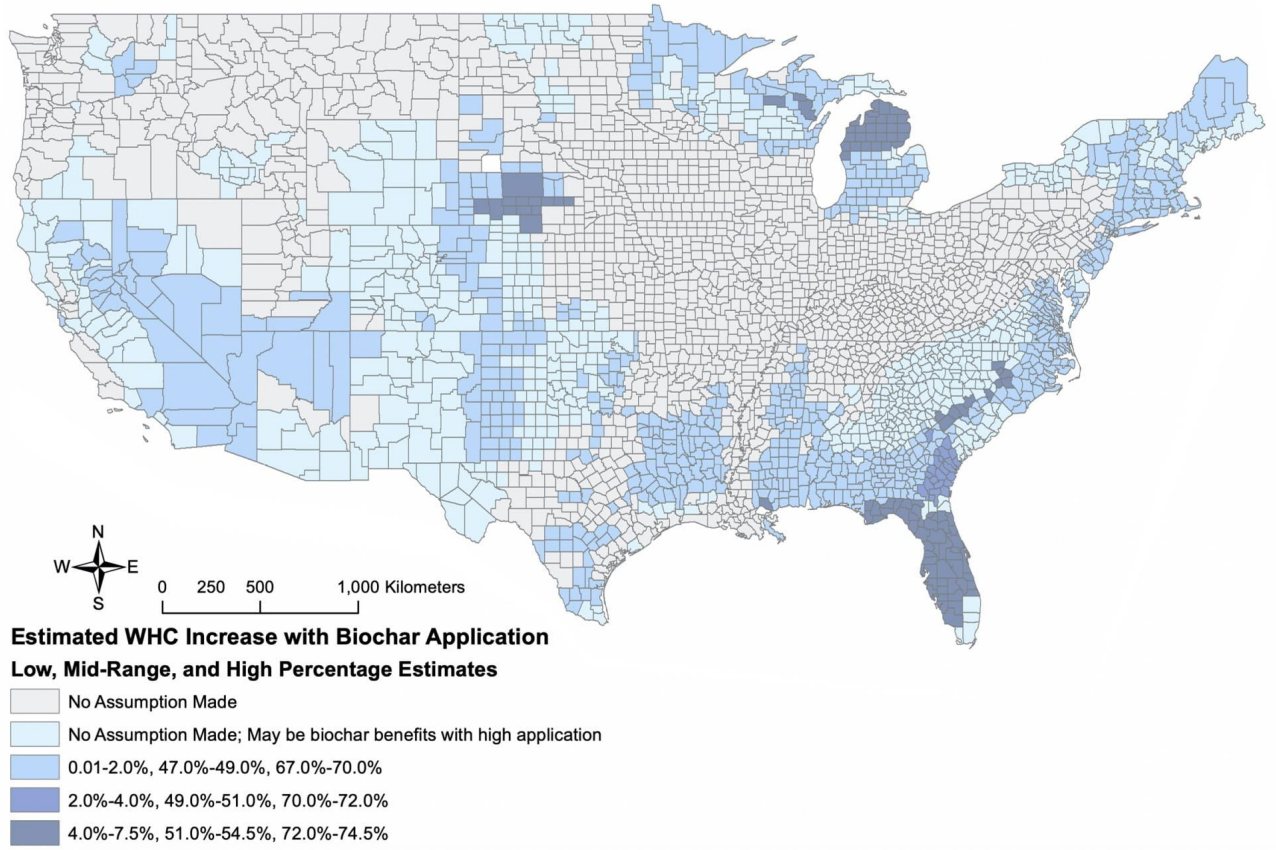
This tool guides users to assess their soil needs, select the most appro appropriate amendment rate.

Cost Benefit Analysis Tool

This tool guides users through a cost-benefit analysis to assess wheth

http://www.pnwbiochar.org/

Sandy soils will benefit the most from improved soil water holding capacity with biochar applications



Kroeger et al. 2020. *GCB Bioenergy*

Right Rate: More is not always better

- Application rates differ: S x C x B x E x M
- Field rates: 1-10 t/ac
  - 1 t/ac (4 cu yd/ac) – lowest effective rate to improve soil organism habitat
  - 3 t/ac (12 cu yd/ac) – for improved SOM levels
- Container rates and tree plantings: 5-25% (v/v)

Photo: Sam Rathke

Photos: Debbie Aller

Right Time: single & repeated applications can work

- **Single applications**
  - Biochar resists decomposition so does not need to be applied annually
  - Ideal for perennial cropping systems where the biochar can be incorporated directly into the root zone (closer to the main roots)
- **Repeated applications**
  - More economically feasible
  - May align better with current management practices (no-till, equipment, logistics, etc.)

Photo: Kristin Trippe, USDA-ARS

Equipment and methods of Application

There are many ways to apply biochar

Photo: Debbie Aller

Photos: David Laird

Photos: Roy Smith

Examples: spreaders, injection, and drills

Photo: Kaitlin Shahinian

Photo: Mayall Ullstein Bild

Photo: Dan Pratt

Photo: Andrew Borner

Photo: Les Everett

Other application considerations

Pelletized biochar

- Moisten biochar before application to minimize dust and reduce risk of loss
- Incorporate biochar into soil
- Use appropriate PPE (particle mask, glasses, gloves)
- Pelletized biochar
  - produced by compacting residual biochar into small pellets with or without a binder
  - Easier to transport and apply using existing equipment and makes biochar denser, reducing potential loss
- Prilled biochar
  - Similar product to prilled urea plus biochar
  - Aids in slow release of N and improved fertilizer use efficiency

Biochar is the carrier – inoculation is key!

- **Biochar must be inoculated/charged/blended before application**
- When combined with inorganic fertilizer, biochar increased crop productivity by 15% compared to inorganic fertilizer only (n=56) (Ye et al., 2020)
- Co-application of biochar with both inorganic and organic fertilizers increased crop yield by 179.6% ± 18.7 (Bai et al., 2022)
- Prevents nutrient immobilization
- Prevents yield drag or loss
- More economical

Photo: Suzanne Hunt

Many different sources of inoculant can be used

- Sources: compost, manure, compost tea, fertilizer, urine, and microbial inoculants.
- Which inoculant you select depends on availability, scale and farmers' fertility practices.
- No length of time established to activate, but 1-3 weeks is minimum
- **Biochar-based fertilizers** (BBFs)
  - Produce tailor-made biochar for specific needs
  - Utilize pre- or post-pyrolysis methods to load biochar with nutrients
  - Significantly increased crop productivity by 10%, lower in temperate compared to tropical environments (Melo et al., 2021)

Example – vineyards

Applications Preplant in Vineyards

Photo: Doug Beck; Monterey Pacific Inc

Oasis Biochar Study – King City, CA

- 8-acre field trial
- ½ acre plots (4 rows of 121 vines), replicated 4x
- 4 treatments:
  - control (no compost, no biochar)
  - compost (15 T compost, no biochar)
  - biochar (no compost, 10 T biochar)
  - biochar & compost (15 T compost, 10 T biochar).
- Results:
  - Biochar treatment resulted in more than 40% increase over the control after 3 years
  - Biochar investment was paid off with increased yields at 1st harvest (additional revenue of $2,600/acre in the first 2 producing years)

Applications to Established Vineyards

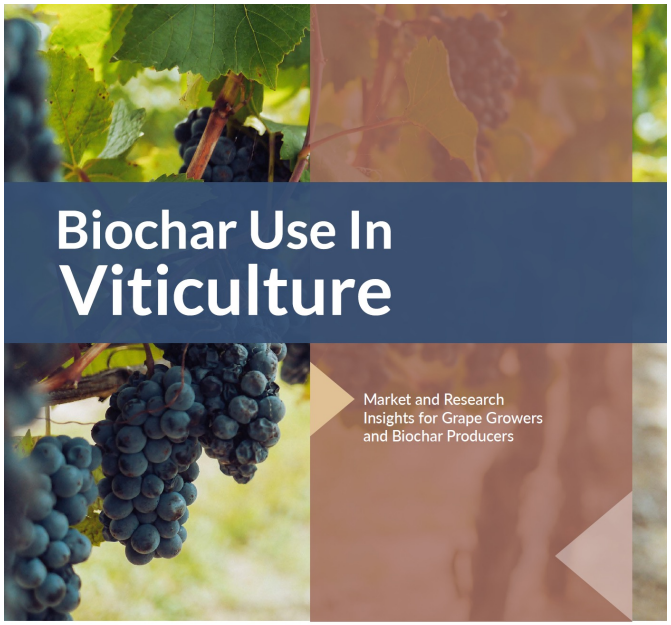
Photo: Doug Beck; Monterey Pacific Inc

Photo: Josiah Hunt; Pacific Biochar

Applications to Established Vineyards

Photos: Doug Beck; Monterey Pacific Inc

Biochar Use in Viticulture Resources



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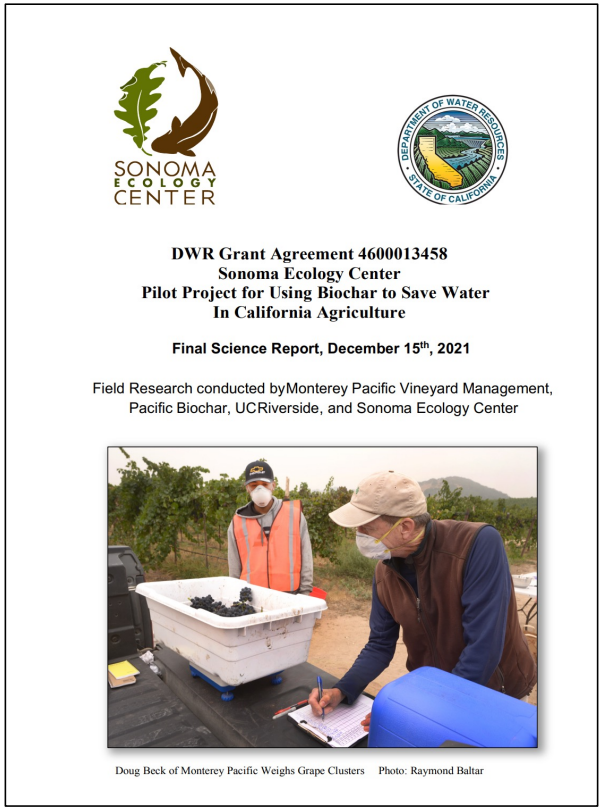
Report prepared by :
DOVETAIL PARTNERS



Webinar - https://www.youtube.com/watch?v=g00l8B9sfSw

Impacts to Vineyards- vine yield, grape quality, soil health

- 66.67% ↑ in SOM, 27% ↑ in yield increase, 33% ↓ in water usage, 15% ↑ in cluster counts and a 5% ↑ in cluster weight over 3-years after the application of a biochar/compost (Oasis Vineyard Trial, Monterey County, CA – Beck et al., 2021)
- Biochar effects on soil functions and fertility are maintained in the long term (10 years) after a one-time application. Biochar amended soils had increased pH, TOC, $NO3^-$-N, total P, available soil water content, and leaf water potential (Tuscany, Central Italy – Baronti et al., 2014; Giagnoni et al., 2019; Baronti et al., 2022).
- The topsoil application of biochar and biochar + compost led to only small, economically irrelevant and mostly non-significant effects over 3 years. Concluded no immediate economic value for vineyards in poor fertility, alkaline, temperate soil (Valais, Switzerland – Schmidt et al., 2014).

Impact on Soil Health in a NY Vineyard

2022

Measured Soil Textural Class: **loam**

Sand: **36%** - Silt: **43%** - Clay: **19%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.22	81	
physical	Surface Hardness	257	13	Rooting, Water Transmission
physical	Subsurface Hardness	360	29	
physical	Aggregate Stability	20.5	27	
biological	Organic Matter Soil Organic Carbon: 1.71 / Total Carbon: 1.73 / Total Nitrogen: 0.16	2.9	46	
biological	Predicted Soil Protein	5.10	33	
biological	Soil Respiration	0.4	29	
biological	Active Carbon	389	27	
chemical	Soil pH	6.2	95	
chemical	Extractable Phosphorus	6.4	100	
chemical	Extractable Potassium	382.6	100	
chemical	Additional Nutrients Ca: 1370.0 / Mg: 105.4 / S: 8.8 Al: 33.2 / B: 0.30 / Cu: 0.30 Fe: 3.2 / Mn: 8.1 / Zn: 1.2		100	

Overall Quality Score: **57** / Medium

2 tons/acre biochar blended w/ compost. Topdressed in vine rows

Seyval blanc variety

2023

Measured Soil Textural Class: **loam**

Sand: **36%** - Silt: **44%** - Clay: **18%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.22	82	
physical	Surface Hardness			Not rated: No Field Penetrometer Readings Submitted
physical	Subsurface Hardness			Not rated: No Field Penetrometer Readings Submitted
physical	Aggregate Stability	52.5	88	
biological	Organic Matter Soil Organic Carbon: 2.85 / Total Carbon: 2.87 / Total Nitrogen: 0.26	4.7	96	
biological	Predicted Soil Protein	7.60	62	
biological	Soil Respiration	0.8	74	
biological	Active Carbon	685	84	
chemical	Soil pH	7.3	100	
chemical	Extractable Phosphorus	8.6	100	
chemical	Extractable Potassium	248.4	100	
chemical	Additional Nutrients Ca: 2286.7 / Mg: 186.3 / S: 5.8 Al: 5.6 / B: 0.62 / Cu: 0.20 Fe: 0.8 / Mn: 6.5 / Zn: 0.7		100	

Overall Quality Score: **89** / Very High

Summary Points

- Biochar is a long-lasting C-rich soil amendment that has potential benefits for improving crop yields and soil health, and sequestering C in soils
- Biochar can provide benefits to both annual and perennial crop production systems
- Biochar applications should be made strategically to degraded or poor performing areas of fields
- Inoculate biochar before application to crops to eliminate nutrient immobilization
- Incorporate biochar into existing management strategies
- Cost of biochar continues to decrease, availability continues to increase
- Decision support tools and financial assistance to qualifying farmers will help encourage greater adoption in the agriculture industry

Thank you!
Questions?

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NEW YORK SOIL HEALTH

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