Introduction to Biochar: Benefits for Climate, Soil Health, and Waste Conversion

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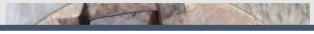
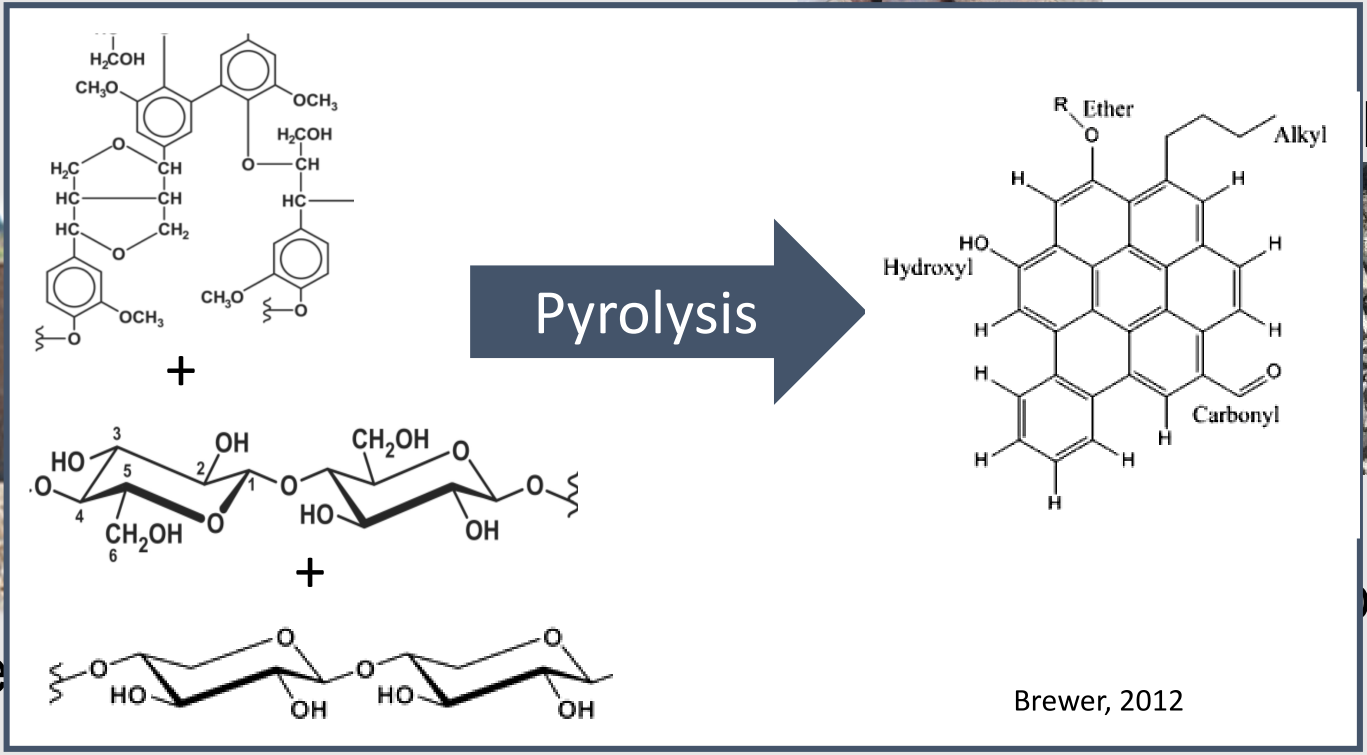
What is Biochar?

- Solid co-product of biomass pyrolysis
- *Pyrolysis* - the thermochemical decomposition of biomass at high temperatures in the absence of oxygen



Fee



Brewer, 2012

biochar)

ils, tars)

What is Biochar?

- Charcoal like material that is intended for application to soil for an environmental or agronomic benefit
- Carbon-rich
- Highly porous – like a sponge!
- Recalcitrant (resistant to degradation)

History of Biochar

Terra Preta
(Oxisol + biochar)

Oxisol
(tropical soil)

500-8000 years ago
Central Amazon

Similar soils found in Liberia and the US Midwest

Photo: Glaser et al., 2001

Char - Charcoal - Biochar

- Any carbonaceous residue from pyrolysis (including natural fires)

Definition: Robert Brown, ISU

Char - Charcoal - Biochar

- Char produced from pyrolysis of organic matter in kilns for use in cooking or heating (intended for use as fuel)

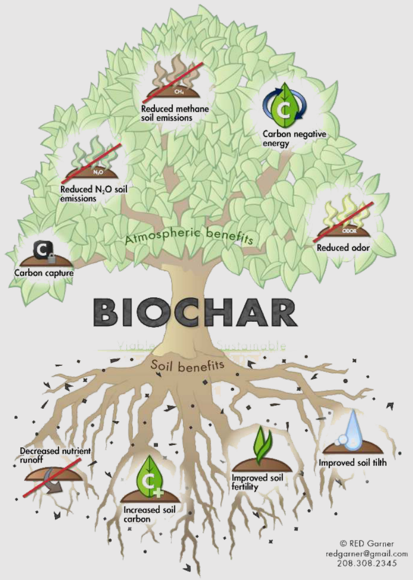
Definition: Robert Brown, ISU

Char - Charcoal - Biochar

- Char produced specifically for application to soil for agronomic or environmental management
- Designer biochars – for specific end uses

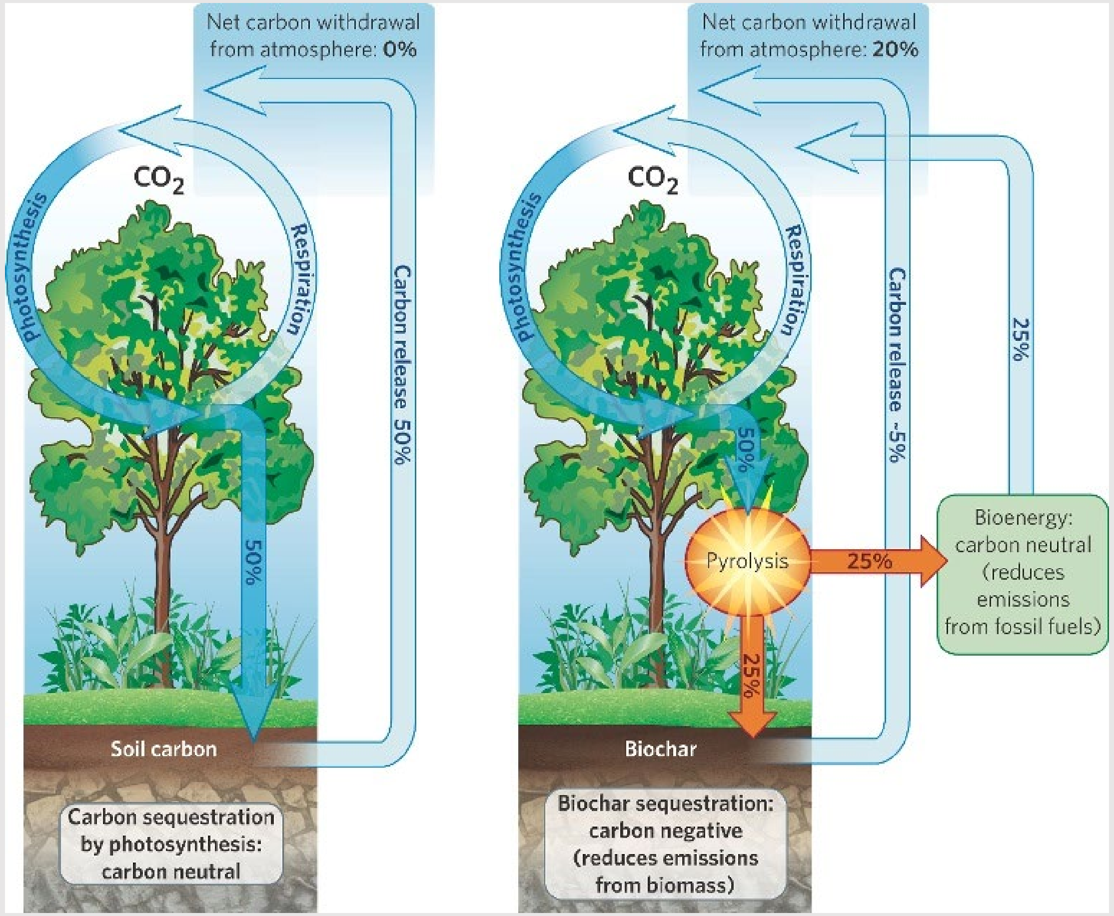
Definition: Robert Brown

Benefits of Biochar



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

- Not a silver-bullet!



Lehmann, 2007.

Climate benefits

- Biochar and its long-term storage in soil can contribute to a reduction of ~12% of current anthropogenic CO_2 emissions (Woolf et al., 2010)
- ‘The maximum sustainable C-drawdown potential of biochar technology is ~ 3.3 Gt CO_2 /yr and, over the course of a century, could account for a third of the 1,000 Gt CO_2 that needs to be removed from the atmosphere.’ (Amonette 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)

https://www.youtube.com/watch?v=hQc4P5ujWxs&list=PLI6mLg_xLNIYI7fxaM_d5d5-9S6p-xBXm&index=3

Biochar production is scalable

Integrated Bioenergy-Biochar System

- Slow/Fast Pyrolysis or Gasification
- Oil + Gas + (less)Biochar produced
- Temp. 350-1200 °C

Small kiln + cooking stove

- Slow Pyrolysis
- (more)Biochar produced
- Temp. 350-600 °C

<u>Biochars are not all the same!</u>

Biochar diversity

- Bioch… n conditions

Photo Robert Brown – Iowa State University

Photo courtesy UC Davis Biochar Database

Example – manure derived biochars

Research on-going into beef, dairy, poultry, swine, etc. derived biochars

- Good source of P and other micronutrients
- Can be used to replace expensive potting media mixes for horticultural industry
- Turns a ‘waste product’ into a ‘value added product’
- Reduces odor and concentrates nutrients
- Persists for longer in the environment (>100yrs)
    - Pyrolysis stabilizes the OM

Example 1 – dairy manure biochar

- Overall: ‘DMB is an odor- and pathogen-free, nutrient-rich fertilizer with 2x the nutrient content by mass of the original manure and >3x by volume’
- DMB valued between $0.91 – $0.96/lb
- Replacing commercial media with DMB reduced wholesale product costs up to 2.26%
- DMB biochar is cost competitive with organic P fertilizer sources
- Challenge: moisture content

(Enders et al., 2018. Feasibility Assessment of Dairy Biochar as a Value-Added Potting Mix in Horticulture and Ornamental Gardening. Available in the Cornell Field Crops Newsletter.)

Example 2 – dairy manure biochar

- Study evaluated manure biochar and manure biochar pre-treated with CO_2 and NH_3
- Found that the pre-treated biochar increased growth of radishes and tomatoes by up to 35% and overall N uptake
- Support that separated dairy manure treated with CO_2 + NH_3 can offset 23–82% of N fertilizer needs in NYS
- Pyrolysis stabilizes both the solid and liquid fraction of manure, reducing environmental pollution

(Krounbi et al., 2021. Plant uptake of nitrogen adsorbed to biochars made from dairy manure. Sci Rep 11, 15001. https://doi.org/10.1038/s41598-021-94337-8)

Biochar and Soil Health

- Decreased nutrient leaching (Laird et al., 2010a)
- Increased available soil water (Rogovska et al., 2014) and soil microbial activity (Steiner et al., 2008; Lehmann et al., 2011), soil pH, CEC, AEC, and total soil C and N (Rondon et al., 2006; Lawrinenko and Laird, 2015; Mukherjee and Lal, 2016)
- Indirect effects on soil physical properties –aggregation, bulk density, hydraulic conductivity, and soil micro- and macro-porosity (Bot and Benites, 2005; Gaskin et al., 2007; Thies and Rilling, 2009; Hardie et al., 2014).
- Aged biochars impact soil-water relations differently than the equivalent fresh biochars (Aller et al., 2017)

What is the problem you are trying to solve?

Organic Matter

Nutrients

Water retention

Soil pH

Microbial Activity

Structure

Infiltration

Compaction

Aeration

Erosion

Fertility

Disease

C sequestration

Biochar Classification Tool

USING THE CLASSIFICATION TOOL: AN EXAMPLE

In the example below, the user enters data for a biochar[1] produced from poultry litter feedstock at 550°C as follows (note that the particle size data are hypothetical):

Carbon Storage Class

H/C_{org}	0.26		
C_{org}	%	14.1	total mass, dry basis

Fertilizer Class

Total N	%	3.77	mass basis	Avail. N	%	0.19	mass basis
Total P	%	3.32	mass basis	Avail. P	%	2.69	mass basis
Total K	%	3.35	mass basis	Avail. K	%	3.35	mass basis
Total S	%	0.48	mass basis	Avail. S	%	0.36	mass basis
Total Mg	%	0.9	mass basis	Avail. Mg	%	0.86	mass basis
Total Ca	%	6.36	mass basis	Avail. Ca	%	6.3	mass basis

Liming Class

$CaCO_3$	%	13.0	equivalent

Particle Size Class

<0.5mm	%	42	2 - <4mm	%	6	16 - <25mm	%	0
0.5 - <1mm	%	30	4 - <8mm	%	1	25 - <50mm	%	0
1 - <2mm	%	21	8 - <16mm	%	0	≥50mm	%	0

Show Classification

The user clicks on ***Show Classification*** and the tool returns the following classification output:

Class		
Carbon Storage Class	1	$sBC_{+100} = 98.7 g\ kg^{-1}$
Fertilizer Class	4	$P_{2t}\ K_{2t}\ S_{5t}\ Mg_{3t}$
Liming Class	2	$CaCO_3$ - eq = 13.0%
Particle Size Class	Pd	Blended Powder

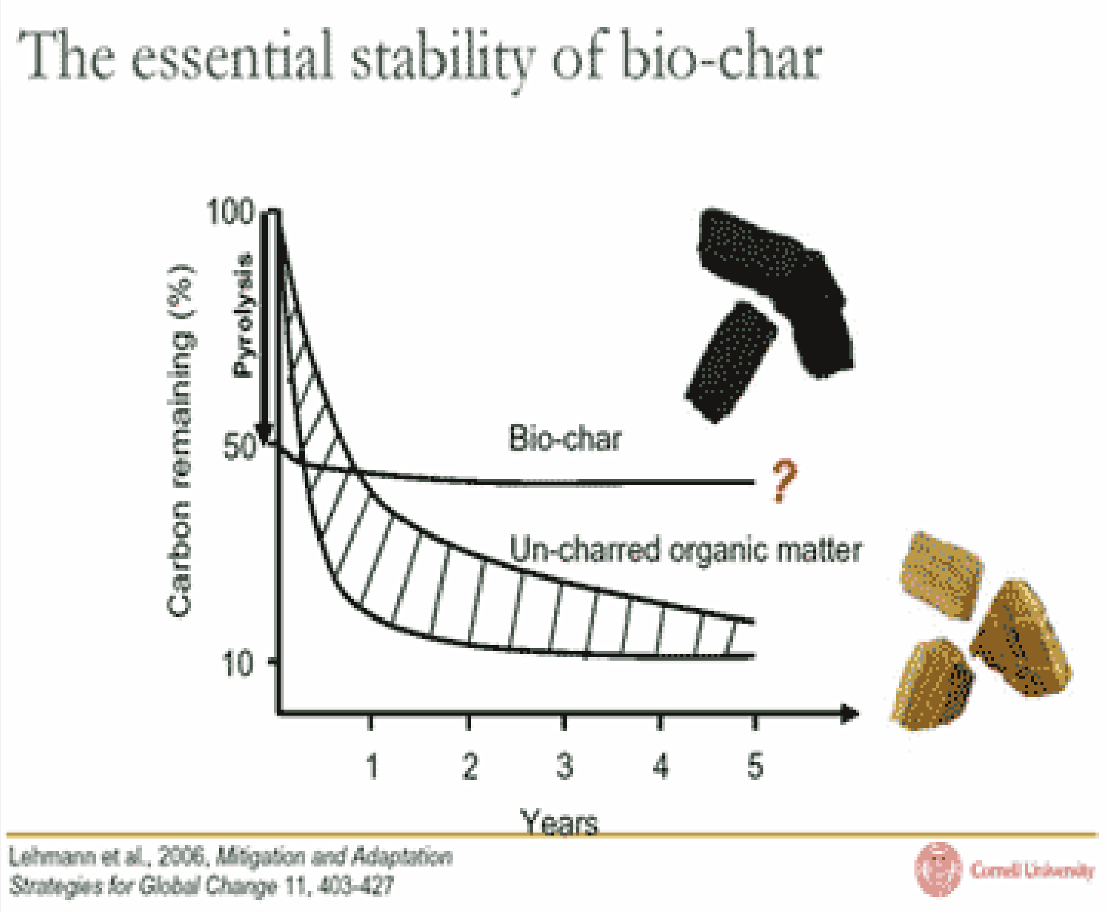
Fertilizer Grade

Total N = 3.77%	Avail N / Total N = 0.05
Total P_2O_5 = 7.61%	Avail P / Total P = 0.81
Total K_2O = 4.04%	Avail K / Total K = 1.00
Total S = 0.48%	Avail S / Total S = 0.75
Total MgO = 1.49%	Avail Mg / Total Mg = 0.96
Total CaO = 8.90%	Avail Ca / Total Ca = 0.99

Show

Camps Arbestain M, et al., 2015. *A Biochar Classification System and Associated Test Methods.*

Importance of time – biochar aging



Half-life of ~1,400 years

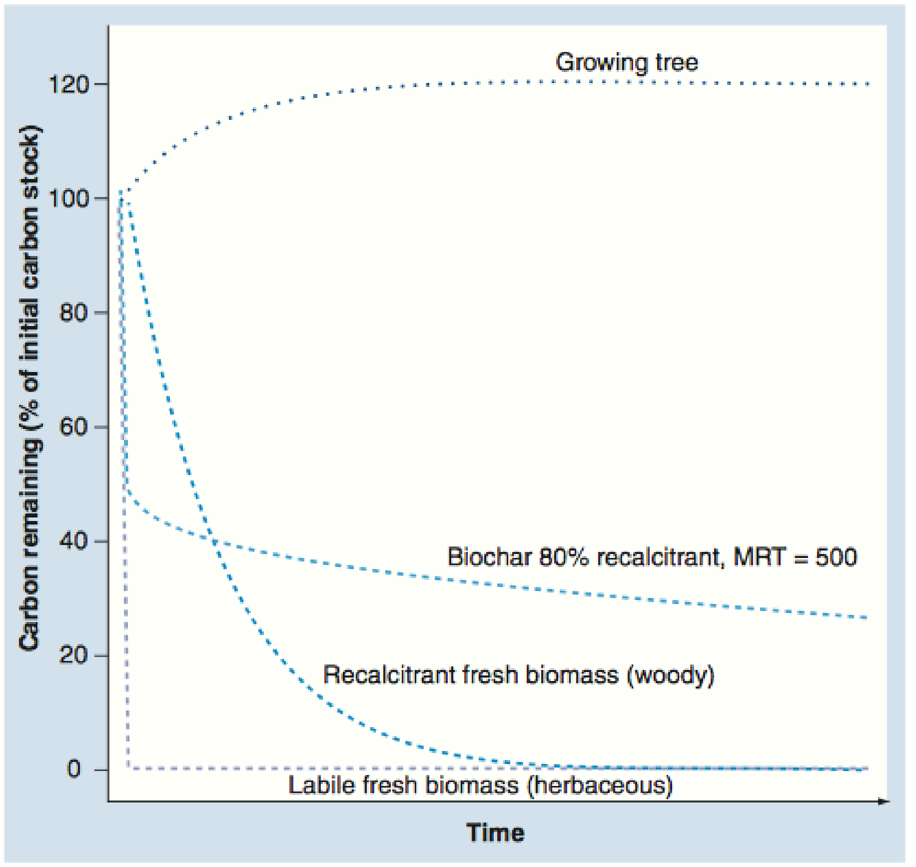


Figure 2. Alternative scenarios for biomass carbon dynamics. Each curve represents the fate of an equivalent mass of organic matter.
MRT: Mean residence time.

Lehmann et al., 2006

Whitman et al. 2010. *Carbon Management*

Availability and Cost

- Availab
- High co
  - $40
- Produc
- Can se
- Shippi
- As mar
  - Fut

NRCS CPS code 808 – cost share for biochar and other soil carbon amendments

United States Department of Agriculture

808-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SOIL CARBON AMENDMENT

CODE 808

(ac)

DEFINITION

Using amendments derived from plant or animal residues to improve the physical, chemical, and biological properties of the soil.

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Maintain, increase, or improve soil organic matter quantity and quality
- Maintain or improve soil aggregate stability
- Maintain or improve habitat for soil organisms
- Improve plant productivity and health
- Improve moisture management and enhance the efficient use of irrigation water
- Improve air quality by reducing emissions of particulate matter (PM) and PM precursors, GHGs, ozone precursors and airborne reactive nitrogen

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all land where carbon amendment applications will improve soil conditions.

Applying biochar

- Recommended application rates are soil – crop – biochar – environment dependent
- Safety standards for soil application (guidelines - IBI)
- How much should I apply?
  - Consistent benefits observed up to 10% (v/v)
  - Can make small more frequent applications
  - Field rates: 1-7 t/ac (17 t/ha, 15 Mg/ha)
- Evidence that too much may be detrimental to yield
- Charging/inoculating/co-composting is best before application
- Protective equipment (recommended)
  - Particle mask, safety glasses, and gloves

Application Methods - Field

- Broadcast or manually spread + incorporate

Photos: Mina Vescera

Photos: David Laird

Application Methods

- Radial trenching
- Vertical mulching
- Top-dressing
- Banding
- Sidedressing


Photo: Michael Schafer


Photo: Debbie Aller

- Liquid injection
- Subsurface application



Photos: Mina Vescera

Where to apply biochar

Degraded soils, low fertility, sandy soils

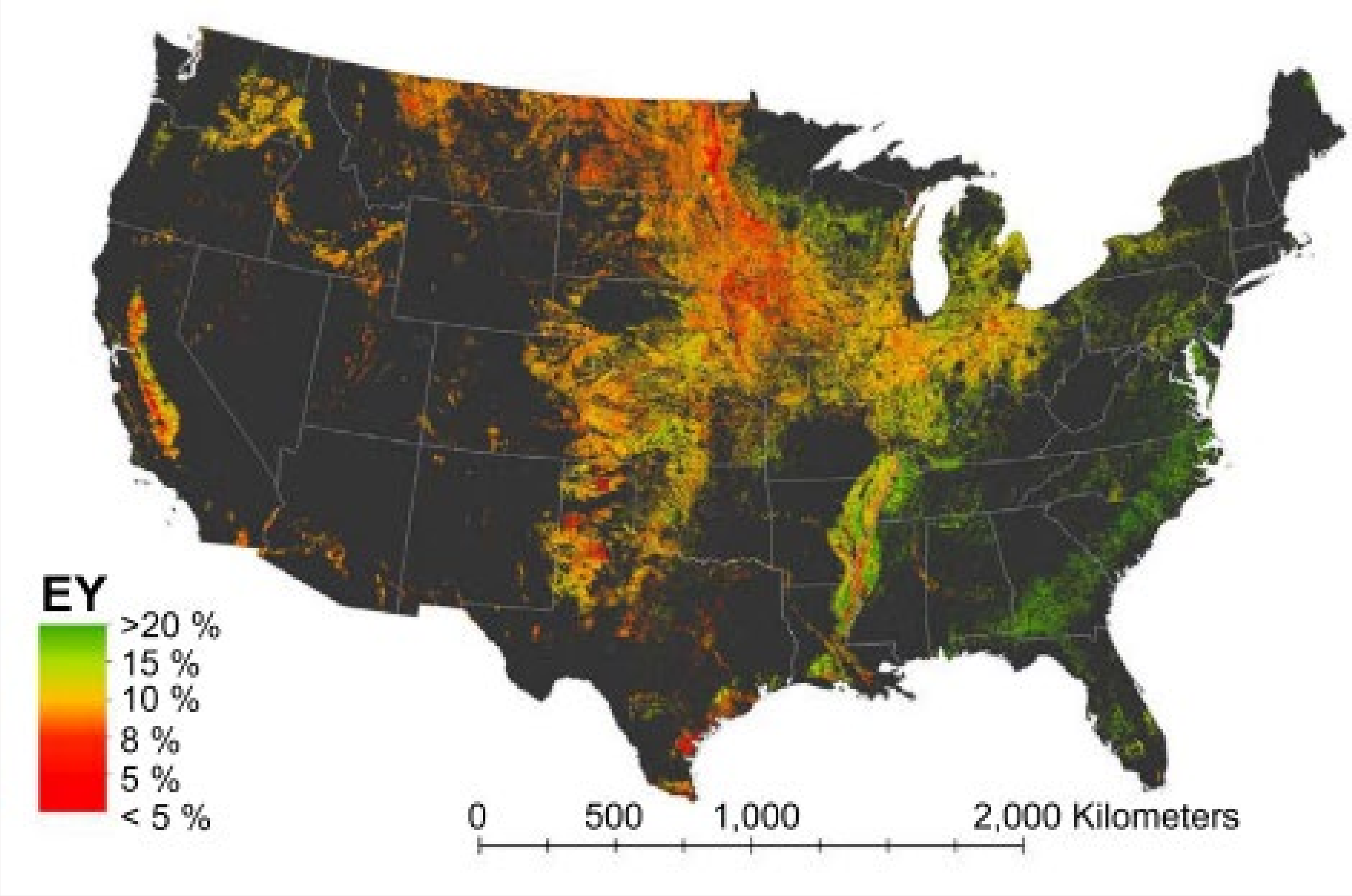


Figure 2 - Dokoohaki, et al 2019.

Where to apply biochar

Example: Central Valley, California

pH SOM CEC Response

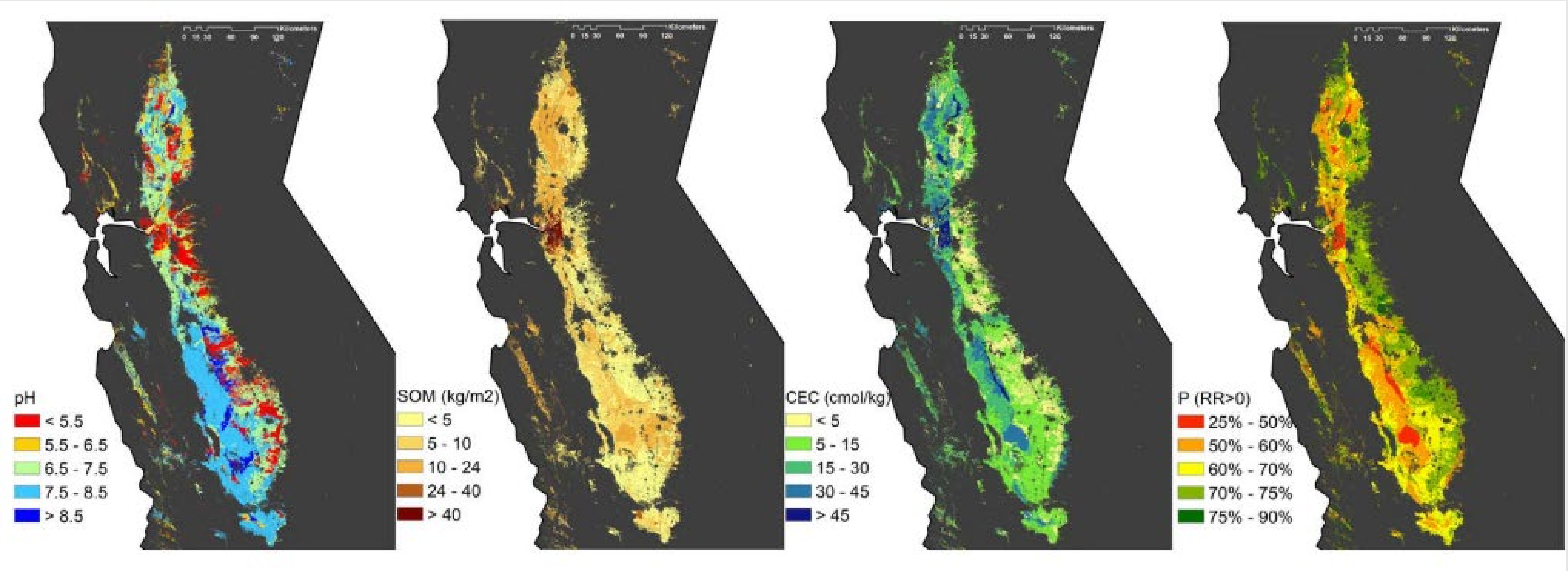


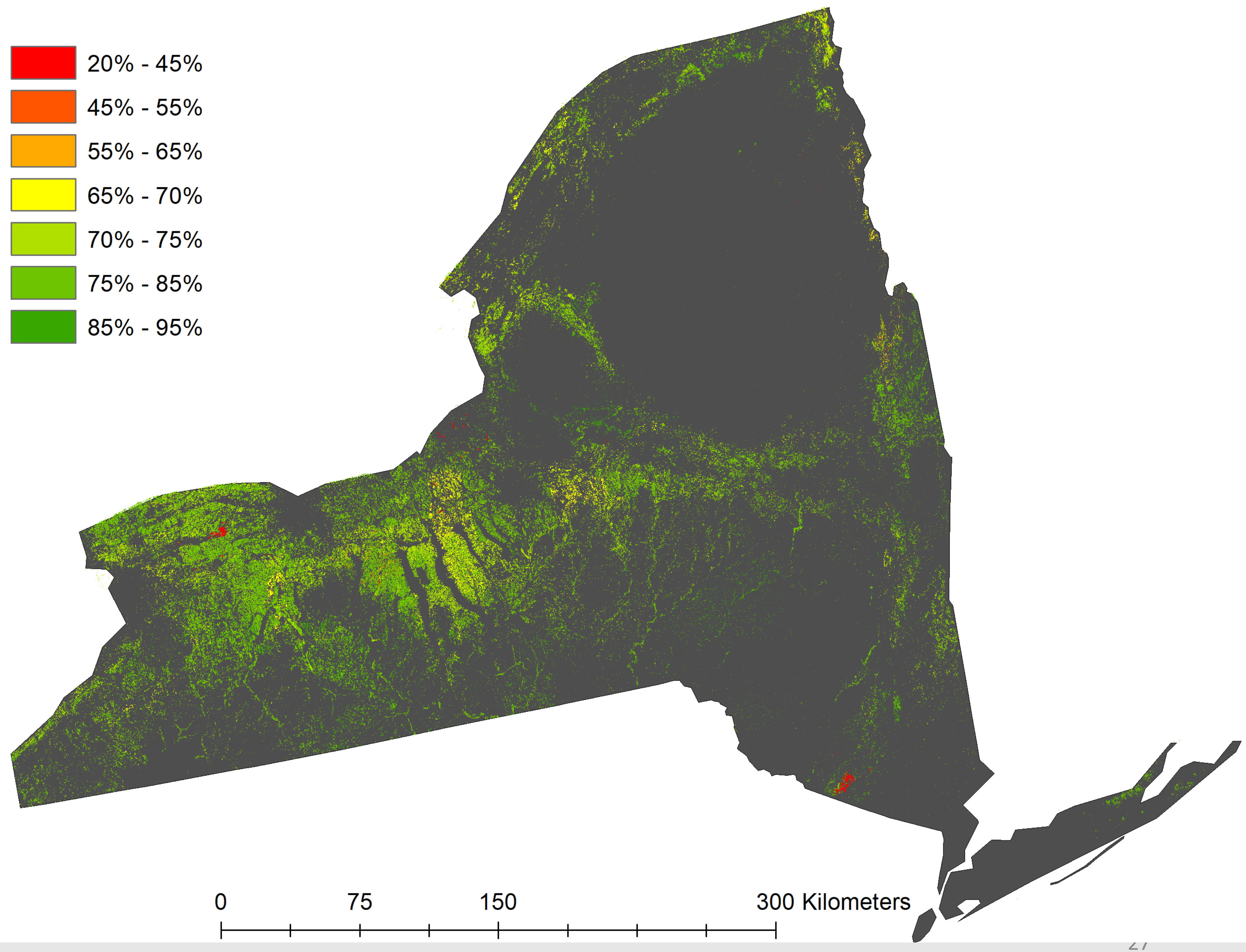
Figure 3 - Dokoohaki, et al 2019.

Where to apply biochar

Example: Central Valley, California

- Low pH, SOM, and CEC = ↑ likelihood of positive yield response to biochar
- High pH, SOM, and CEC = ↓ likelihood of positive yield response to biochar

Biochars potential in NYS



Long Island Biochar Research

NORTHEAST SARE
Sustainable Agriculture Research & Education

Biochar container and field trials

Will biochar reduce N loss and increase water retention in field and container grown nursery production?

Photos: Mina Vescera

Container trials

- 2 different incorporation methods and 3 rates of biochar
- Evaluating above and below ground growth

Field trials - Douglas Fir Christmas Trees

Field trials – California privet

Field trials – lysimeters and sensors

Final thoughts - what biochar can do…

- Increase plant growth/health, crop yields, and water/nutrient retention
- Improve numerous soil properties (SOM, CEC, pH, bulk density, compaction, aeration, etc.) and overall soil fertility and structure
- Decrease pathogen and disease severity
- Reduce input costs (fertilizer, pesticides, etc.)
- Be part of your management 'toolbox'
- Substitute common potting mixes (peat, perlite) in container nurseries
- Reduce on-farm organic wastes
- Reduce fertilizer and pesticide use
- Sequester carbon

Remember biochar is not a silver bullet solution, it is another tool in the toolbox for producers.

Thank you and Questions?

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