Using Carbon to Achieve Chesapeake Bay (and Watershed) Water Quality Goals and Climate Resiliency:

The Science, Gaps, Implementation Activities and Opportunities

STAC Workshop Report & Research Synthesis Briefing

Chuck Hegberg, RES, LLC, Committee Chair
Jenny Egan, PhD, UM EFC, Committee Co-Chair

March 5, 2024

Workshop Objective & Goals

To convene a workshop with leading national and local experts to *elevate the use of biochar in practice Bay-wide* by evaluating and *translating current research for integration into current Chesapeake Bay protocols*.

Workshop Goals

1. Evaluate and Synthesis Current Biochar Research
2. Translate Biochar Research & Empirical Evidence into Protocols, Standards & Specifications
3. To Promote Biochar Adoption & Use in the CBw
4. Advance Empirical Evidence for Biochar Protocols, Standards & Specifications
5. Foster Networking & Collaboration (Community of Practice)
6. Identify Actionable Recommendations

Biochar Workshop Attendees		
	DAY 1	**DAY 2**
ROMOTE	82	92
IN PERSON	54	45
TOTAL	136	137

Biochar Workshop Agenda

BIOCHAR TOPICS COVERED

- Facilitated 2-Day Workshop & Discussions
- Guest Speakers
- Biochar History, Research and Science
  - Climate Smart Agriculture & Forestry
  - Urban Landscapes (Stormwater)
  - Emerging Toxic Contaminants
- Existing CBw Protocols & Model
- Recommendations
- Mentimeter Participate Surveys

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Using Carbon to Achieve Chesapeake Bay (and Watershed) Water Quality Goals and Climate Resiliency: The Science, Gaps, Implementation Activities and Opportunities
May 25-26th, 2023
Workshop Webpage
Hotel Hershey (100 Hotel Rd, Hershey, PA 17033)
****Exact Times Are Subject to Change****

Workshop Desired Outcomes: Provide recommendations to Bay Science and Technical Assessment and Reporting as well as by Science and Technical Advisory Committees for
- Integration of biochar in Chesapeake Bay model for nutrients and climate and
- Biochar credit in existing BMPs and protocols

Thursday, May 25th 2023
Zoom Registration Link

8:30 am **Coffee & Light Breakfast (Provided)**

9:00 am **Introduction & Workshop Objectives - What Brought Us Here**
– Jason Hubbart, Ph.D. (Professor, Associate Dean of Research, West Virginia University, and Associate Director of the West Virginia Forestry and Agricultural Experiment Station), Jennifer (Jenny) Egan, Ph.D. (Program Manager, *University of Maryland Environmental Finance Center*)

9:15 am **Biochar Industry - Myths, Fake News & Facts**
– Tom Miles (Executive Director, *US Biochar Initiative*), Chuck Hegberg (Senior Project Manager, *Resource Environmental Solutions LLC*)

10:00 am **Questions, Answers & Comments**

10:15 am **Break**

10:30 am **Existing Protocol Review and Group Discussion**
- David Wood (Executive Director, *Chesapeake Stormwater Network*)
- Chris Brosch (Nutrient Management Program Administrator, *Del. Dept of Agriculture*)
- Carol Wong, P.E. (Water Resources Engineer, *Center for Watershed Protection*)
- Larry Trout Jr., P.E. (*Straughan Environmental*)

11:30 am **The TMDL for the Chesapeake Bay** – Gary Shenk (Hydrologist, *USGS*)
Gary Shenk will discuss the Total Maximum Daily Load for nitrogen, phosphorus, and sediment including recent additional reductions necessary to offset climate change effects.

12:00 pm **Lunch – Keynote Address**
"A Maryland State Change Agent's Journey to Produce and Utilize Biochar for Good"
– Charles Glass, Ph.D., P.E. (Executive Director, *Maryland Environmental Services*)

1:00 pm **Break**

State of the Science on Biochar

facilitated by Dominique Lueckenhoff (Senior Vice President, *Hugo Neu*)
- **State of the Science speaker:** Isabel Lima, Ph.D. (*USDA ARS*)
- **Expert Panel (Facilitated):**
  - Isabel Lima, Ph.D. (*USDA ARS*)
  - Charles Glass, Ph.D. (Executive Director, *Maryland Environmental Service*)
  - Mark Johnson, Ph.D. (*US EPA*)
  - Sean Sweeney, P.E. (Vice President, *Barton & Loguidice*)
  - Ken Pantuck (Senior Scientist, *US EPA Region III*)

5:15 pm **Day 1 Wrap-up and Objectives for Day 2**

5:30 pm **Recess**

6:00 pm **Optional Dinner at Smoked Bar and Grill**

Friday, May 26th 2023
Zoom Registration Link

8:00 am	**Coffee & Light Breakfast (Provided)**
9:00 am	**Focus of Day 2**
9:15 am	**City of Minneapolis Biochar Story: Bloomberg Climate Challenge** – Jim Doten, Carbon Sequestration Program Manager (*City of Minneapolis*)
10:00 am	**Facilitated Group Discussion on Biochar State of the Science** 30-minute Q&A session on the presentations from the first day.
10:30 am	**Break**
10:45 am	**Set up for Breakout Sessions**
11:00 am	**Technical Breakout Groups**
12:00 pm	**Working Lunch (Provided)**
1:00 pm	**Break**
1:15 pm	**Breakout Group: Report-out**
2:00 pm	**Synthesize Results and Recommendations**
2:30 pm	**Workshop Adjourns**

Workshop Attendee Notice

The STAC Biochar Committee and the technical experts that will be participating in this workshop are looking forward to this focused discussion on the scientific merit, policy and protocol aspects of biochar within the Chesapeake Bay watershed to accelerate its restoration. While there will be much conversation around the various topics identified in the agenda, the workshop will not provide any introductory information about biochar. The committee assumes that the attendees are knowledgeable about the topic of biochar and thus will spend the time we have delving into the specifics outlined in the agenda. It is not the intention of the committee to exclude anyone from the conversation, the time allowed is limited and our objectives are clearly related to the purpose of this workshop. For those not familiar with biochar and want to prepare in advance of the workshop, we have provided some information and key links to additional information for your use. Please go to https://tinyurl.com/2p9ezmp3 for more introductory information on biochar.

Workshop Steering Committee, Technical Experts & Practitioners

Workshop Steering Committee

- Jason Hubbart, Ph.D.*, West Virginia University (Workshop co-chair)
- Chris Brosch*, DE Department of Agriculture
- Charles Hegberg, USBI/RES, LLC (Workshop Chair)
- Jennifer Egan, UM Environmental Finance Center (Workshop co-chair)
- Tom Miles, USBI/TR Miles Consultants, Inc.
- Paul Imhoff, University of Delaware
- Wayne Teel, James Madison University
- David Wood, Chesapeake Stormwater Network
- Dominique Lueckenhoff, Hugo Neu, Inc.
- Kenneth Pantuck, USA EPA Region 3

Technical Subject Matter Experts

- Gary Shenk*, USGS
- Carol Wong, PE, Center for Watershed Protection
- Larry Trout, PE, Straughan Environmental Services
- Brandon Smith, Ph.D., Allied Soil Health Services
- Kristin Trippe, Ph.D., USDA
- Debbie Aller, Ph.D., Cornell University
- Sabina Dhungana, USDA Forest Service, (formerly VA Dept of Forestry)
- Carolyn Voter, Ph.D., University of Delaware
- Jim Doten, City of Minneapolis (Technical & Guest Speaker)
- Isabel Lima, Ph.D., USDA ARS
- Charles Glass, Ph.D., PE, Maryland Environmental Services (Guest Speaker)
- Mark Johnson, Ph.D., US EPA
- Sean Sweeney, PR, Barton & Loguidice

Acknowledgements

- Meg Cole, STAC Coordinator, Chesapeake Research Consortium
- Tou Matthews, STAC Projects Manager, Chesapeake Research Consortium
- Rachel Tardiff, Rachel Tardiff, LLC
- UM CCC Student Support
- US Biochar Initiative – Travel & Lodging Accommodations for many of the biochar subject matter experts.

Biochar – Legislation, Policy & Guidelines

Federal Activities

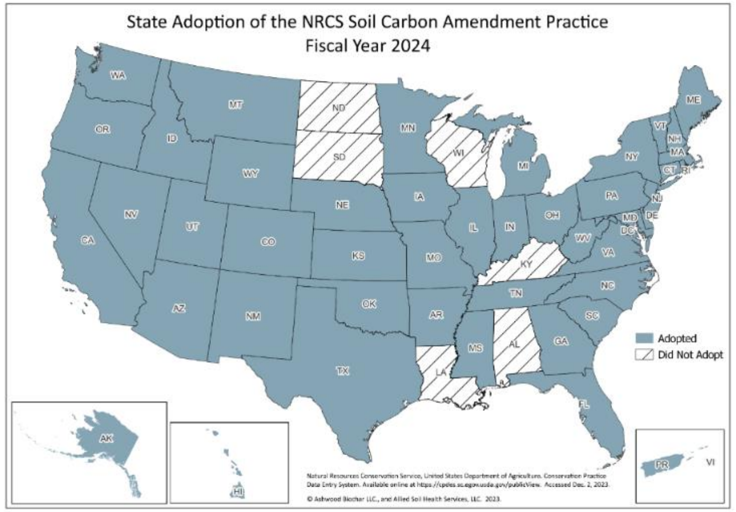
- Biochar Act of 2021 (H.R 2581 – 117th Congress)
- National Biochar Research Network Act of 2022 (S. 4895),
- Biochar in the Infrastructure Investment and Jobs Act, (H.R. 3684)
- 2023 US Farm Bill – Working to get biochar and carbon credits into next bill,
- NRCS CP-808/336 – Soil Carbon Amendments (all but 6 states), USDA Climate-Smart Commodities, USFS Wood Innovations Program.
- USDA ARS National Biochar Atlas & Online Tools – Currently being Expanded

State Activities

- Washington State – SB/HR 5961 incentives state & local governments to use biochar in government contracts (Passed),
- Colorado State HBN23-1069– Biochar in abandoned gas/oil well as part of capping (Passed).
- Maine, New York, Vermont, Nebraska – Developing biochar legislation

Local Activities

- State and local governments adding biochar to stormwater projects, updates to specifications and in stormwater manuals.
- Biochar production for forest residuals/urban wood/green waste and biosolids in VA, MD



USDA National Biochar Atlas & Carbon Tools

- Develop Biochar Database
- Develop GHG & Carbon Model
- Expand Map & Crop Function
- Farmer & Conservation Planner Outreach

Biochar in CBw – Condensed Timeline

Pre - 1990
- Biochar name rebranding (1987)
- 1st Biochar Paper Published (1989)
- Frye Energy, LLC – 1st Poultry Litter to Char

2009
- US Biochar Initiative Established
- S. River/S. Fork Shenandoah Mercury Remediation Demo, VA

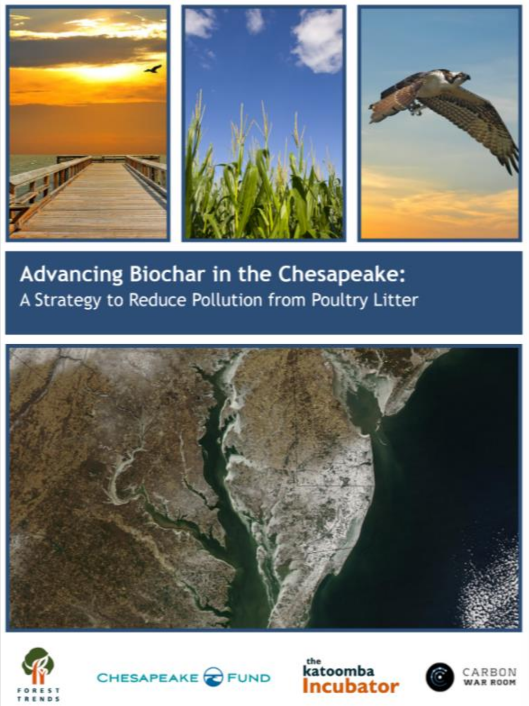
2010
- Advancing Biochar in the Chesapeake Report (**207 Published Papers**)
- University of Delaware begins biochar research

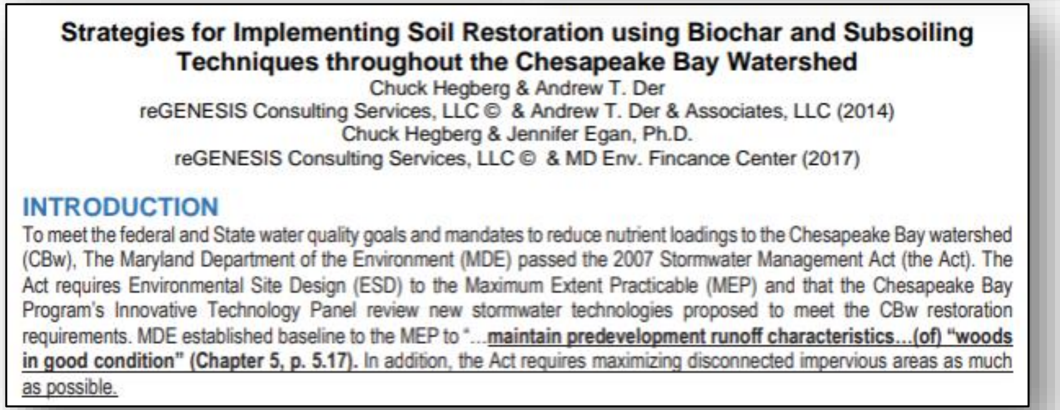
2014
- CBP STAC Biochar Review (1st Biochar Consideration) (**2,005 Published Papers**)
- Strategies for Implementing Soil Restoration using Biochar and Subsoiling Techniques throughout the CBw Strategy White Paper

2014-2023
- CBw Biochar Research & Installations Expanded.
- Leaders – UD, DelDOT, MDTA, several non-profits and consulting firms

2022-2024
- CBP STAC Workshop, Report & Presentation (2nd Biochar Consideration) (**34,288 Published Papers – 2023**)
- Scaling Up Biochar Applications for Accelerated Stormwater Runoff Reduction in the CBw" grant NFWF (#0602.22.074143).

10-year Gap



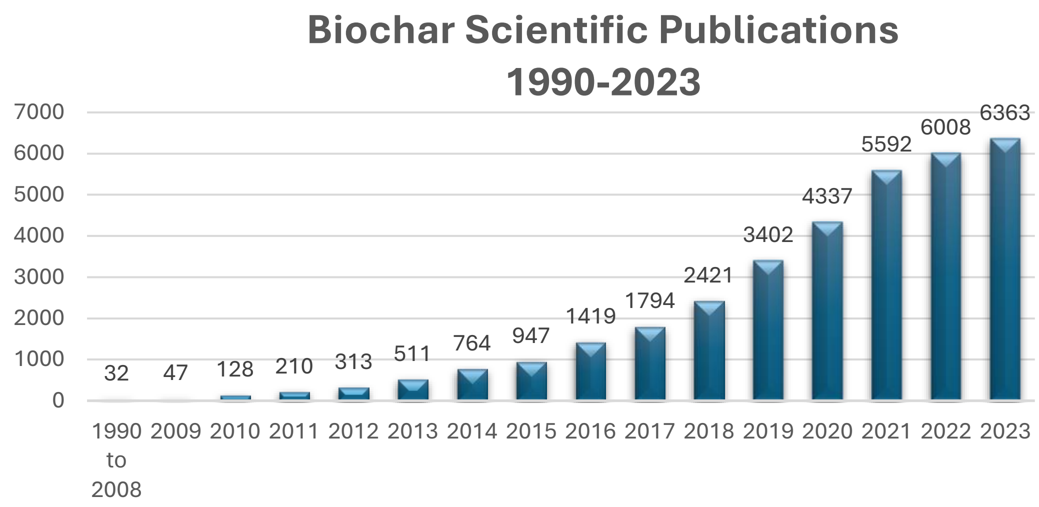

Strategies for Implementing Soil Restoration using Biochar and Subsoiling Techniques throughout the Chesapeake Bay Watershed

Chuck Hegberg & Andrew T. Der
reGENESIS Consulting Services, LLC © & Andrew T. Der & Associates, LLC (2014)
Chuck Hegberg & Jennifer Egan, Ph.D.
reGENESIS Consulting Services, LLC © & MD Env. Fincance Center (2017)

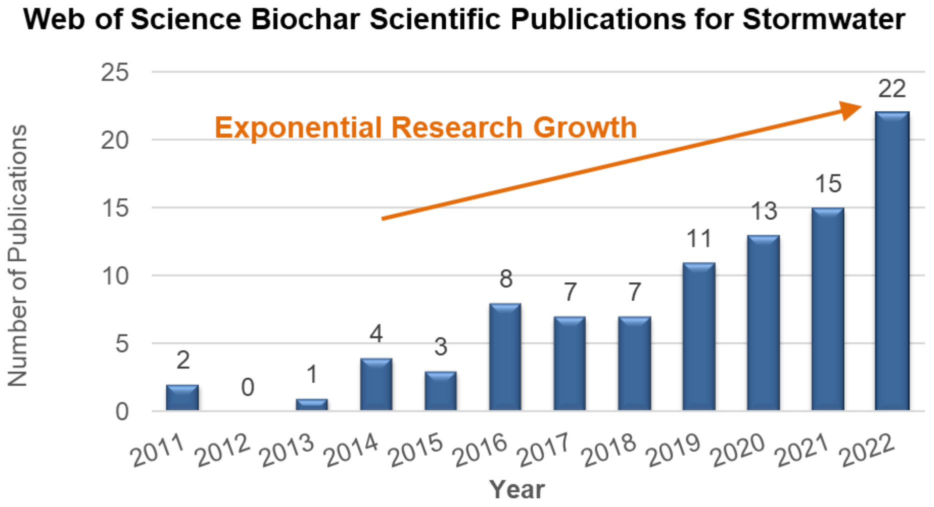
INTRODUCTION

To meet the federal and State water quality goals and mandates to reduce nutrient loadings to the Chesapeake Bay watershed (CBw), The Maryland Department of the Environment (MDE) passed the 2007 Stormwater Management Act (the Act). The Act requires Environmental Site Design (ESD) to the Maximum Extent Practicable (MEP) and that the Chesapeake Bay Program's Innovative Technology Panel review new stormwater technologies proposed to meet the CBw restoration requirements. MDE established baseline to the MEP to "...**maintain predevelopment runoff characteristics...(of) "woods in good condition" (Chapter 5, p. 5.17).** In addition, the Act requires maximizing disconnected impervious areas as much as possible.

Biochar Momentum in Research



Web of Science Biochar Research (1990-2023)



Growth in number of scientific publications of biochar applications for stormwater management (WoS)

Web of Science Biochar Research versus Approved BMPs (1990-2022)

WoS BMP Global Search	
STREAM PRACTICES	28,670
BIOCHAR	**27,925**
FOREST PRACTICES	27,800
INFILTRATION PRACTICES	15,837
ALTERNATIVE PRACTICES	8,449

STREAMS PRACTICES	
Channel Restoration	9,062
Stream Restoration	7,871
Channel Stabilization	7,350
Stream Stabilization	1,844
Urban Stream Restoration	1,212
Urban Channel Restoration	496
Streambank Erosion	434
Stream Daylighting	225
Streambank Stabilization	100
Urban Stream Stabilization	76

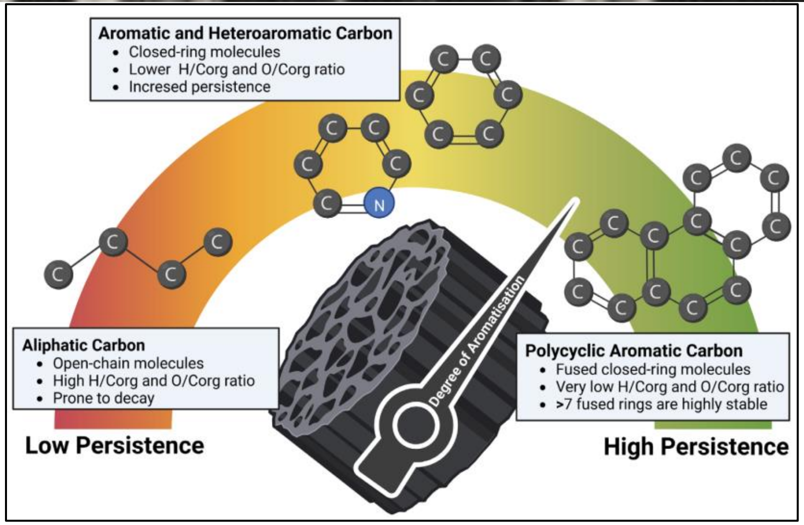
ALTERNATIVE PRACTICES	
Street Sweeping	5,018
Urban Soil	1,633
Living Shorelines	933
Floating Treatment Wetlands	652
Woodchip Bioreactors	169
Impervious Disconnection	29
Regenerative Stormwater Conveyance	15

INFILTRATION PRACTICES	
Infiltration Basin	5,021
Rain Garden	2,506
Infiltration Bed	2,038
Grass Buffer	1,696
Grass Channels	1,364
Bioretention	1,324
Vegetative Filter Strip	528
Infiltration Trench	483
Seepage Pit	387
Dry Well	274
Dry Swale	122
Bioswales	94

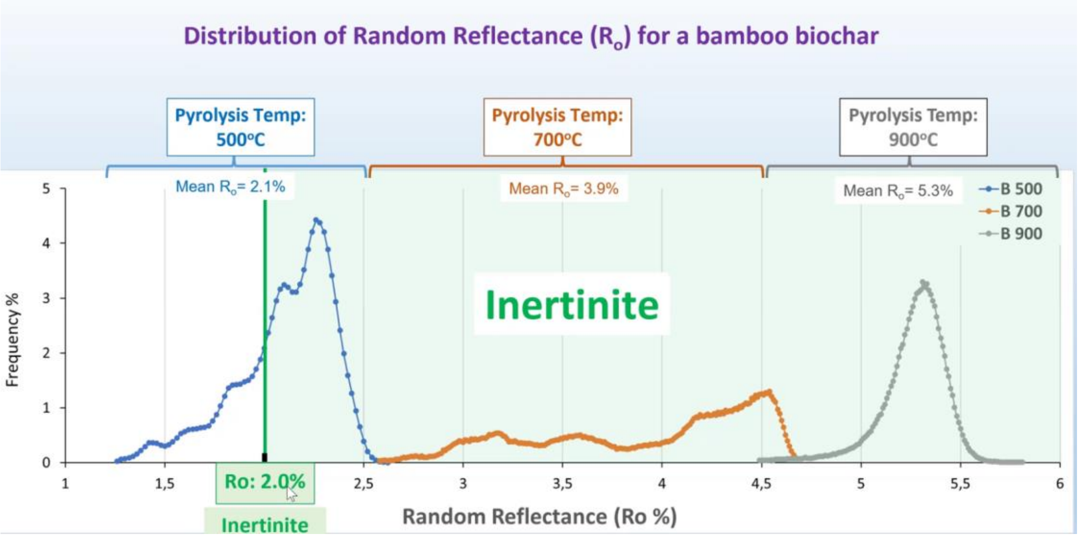
FORESTS PRACTICES	
Reforestation	8,320
Forest Buffer	7,829
Urban Tree Planting	6,238
Riparian Buffer	2,850
Tree Pits	2,533
Expanded Tree Pits	30

Biochar History & Permanence

- **Ancient Technology, Rediscovered:** Biochar use for soil enhancement, known as "Terra Preta," has origins dating back over 7,000 years in the Amazon (Valev et al., 2022).
- **Assessing Commercial Biochar:** Research shows 76% of commercial biochar matches the stability of pure inertinite, indicating significant longevity (Sanei et al., 2024).
- **Longevity and Analysis of Biochar:** Inertinite biochar is estimated to have a degradation period of around 100 million years, with its stability and organic composition analyzable through advanced geochemical and petrological techniques (Sanei et al., 2024).



Schematic representation of different molecular forms of carbon in biochar (Schmidt et. al., 2022)



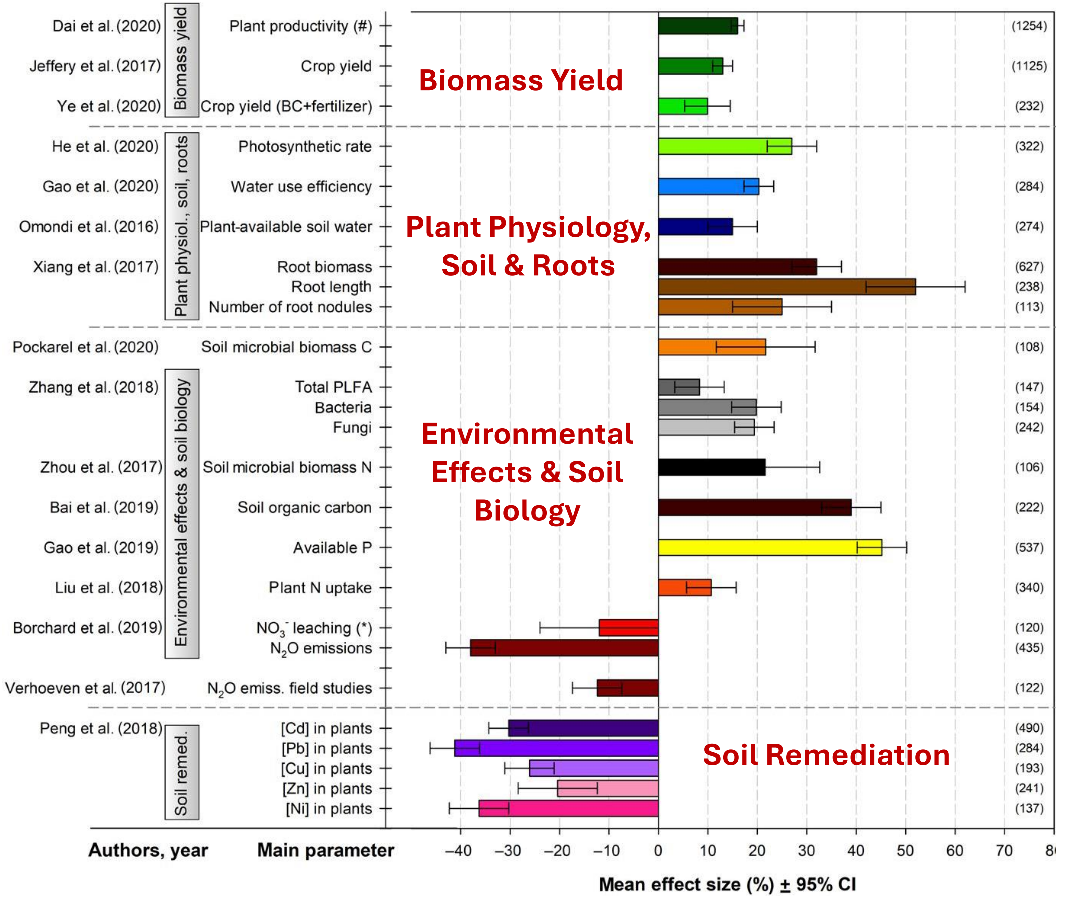
Distribution of Random Reflectance (R_O) for a Bamboo Biochar (Sanei, H. et al., 2024)

Climate Smart Agriculture & Forestry High Points

- **NO^3- Leaching Mitigation**: Biochar reduces nitrate (NO^3-) leaching an average of 26% to 32%. (Borchard et al., 2019; Liu et al., 2019).
- **Soil Structure Enhancement**: Reduces soil bulk density by 8%, improves water-holding capacity by 15% and hydraulic conductivity by 25% (Omondi et al., 2016). Depends on biochar porosity.
- **Water Efficiency by Texture**: Increases water availability by 47% in sandy soils, 9% in medium-textured soils, negligible impact on clayey soils (Razzaghi et al., 2020).
- **Biochar's Agricultural Impact:** Boosts SOC by 39%, surpassing other climate-smart soil health and carbon sequestration practices (Bai et al., 2019).

Biochar Agronomic and Environmental Benefits from 26 Reviewed Meta-Analyses

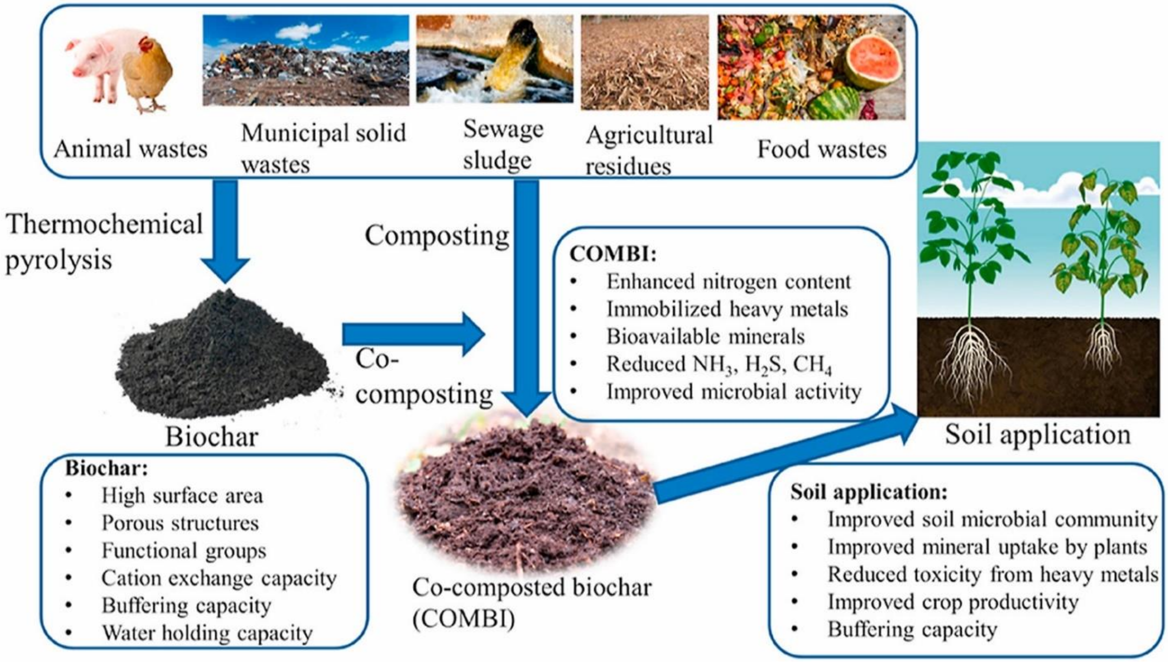
(Schmidt et. al. 2021)



Climate Smart Agriculture & Forestry High Points

Co-Composting with Biochar

- **Biochar as a Compost Additive:** 10% biochar amendment to compost enhances nutrient cycling and reduces nitrogen loss by up to 50%, while also reducing odor emissions and improves soil carbon sequestration, boosting compost quality and yielding (Lehmann et al., 2006; Nguyen et al., 2023; Steiner et al., 2014).
- **Improving Compost Quality:** Biochar amendments improve compost's nutrient profile, decrease organic matter loss by 35%, and boost microbial activity, contributing to long-term carbon storage (Waqas et al., 2018).
- **Revolutionizing Waste Management:** Biochar's role in composting extends to climate change mitigation, showcasing its value in sustainable agricultural practices and waste management strategies.

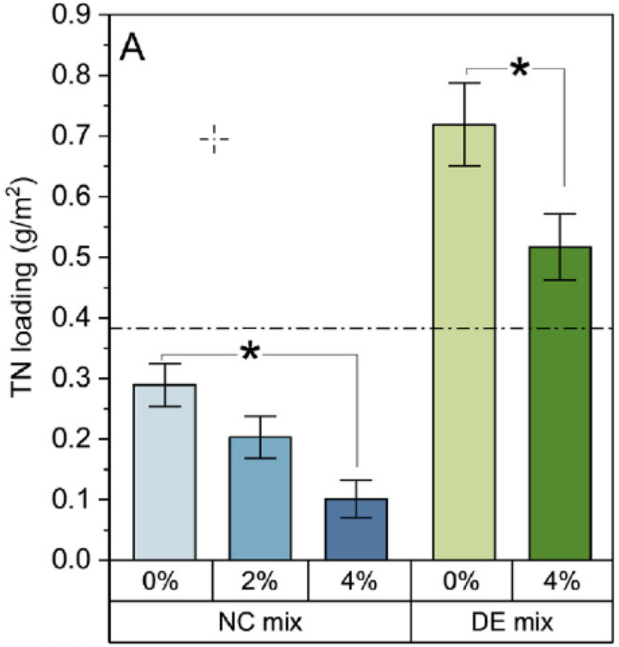


The Benefits of Biochar & Co-Composting Different Compost Wastes (Antonangelo, J.A. et al, 2021)

Urban Landscapes (Stormwater) High Points

Bioretention Engineered Media

- **Biochar Effectively Reduces Nutrients:** Proven to decrease nitrogen in more than 90% of bioretention lab studies, indicating a need for field studies to validate lab results (Biswal et al., 2022).
- **Biochar Boosts Hydraulic Conductivity and Nutrient Removal:** Enhanced bioretention media improved hydraulic conductivity by 50%, nitrate removal by 500%, and infiltration rates by fourfold (Imhoff, P.T., 2017; Tian, J., et al., 2018).
- **Biochar vs. Compost:** Offers long-term stormwater management benefits by improving soil structure, compaction issues and reducing nutrient leaching, outperforming compost (Imhoff, P.T., et al., 2018; Owen et al., 2023; Akpinar et al., 2023a; 2023b).
- **Wood Biochar's Prominence in Research:** 84% of bioretention studies focused on wood biochar, reducing or replacing compost, with efficiency in total nitrogen removal ranging from 32-64% (Biswal et al., 2022; Akpinar et al., 2023a; 2023b).



Effect of biochar amendment (0, 2, and 4% by mass) on total nitrogen (TN) loading from two bioretention media – NC mix (without compost) and DE mix (with compost). Influent TN loading is horizontal dashed line. Biochar amendment decreased TN loading from both media, although TN in DE mix exceeded influent when compost present. Taken with permission from Akpinar et al. (2023b).

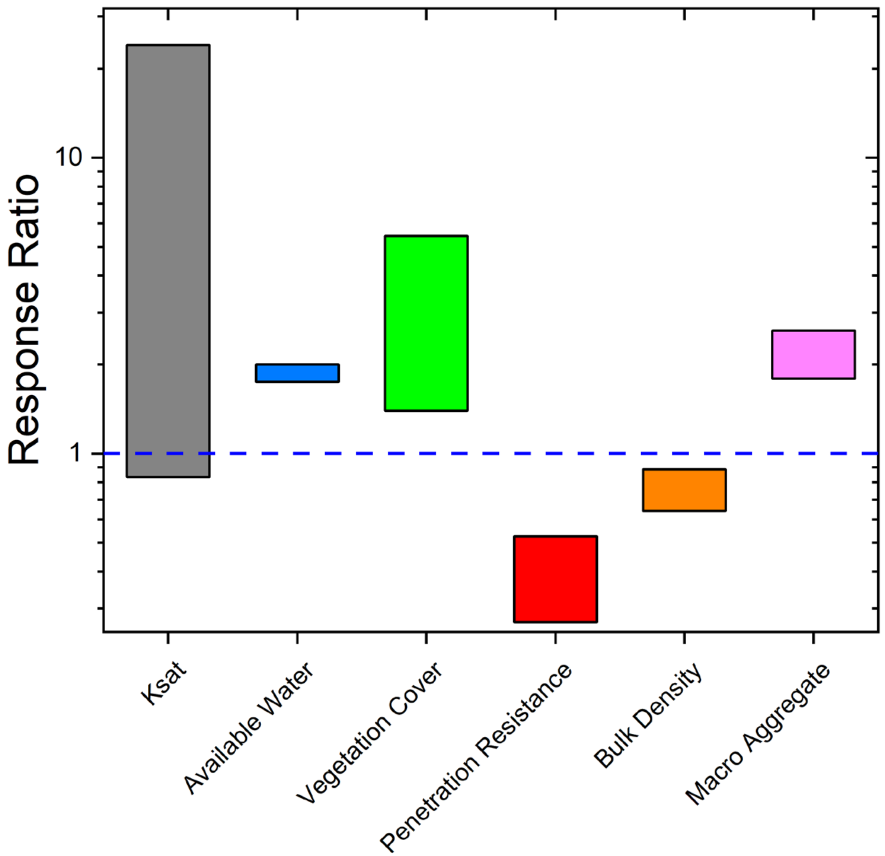
Pollutant	Reduction Range with Biochar
Heavy Metals	27 – 100%
Total Nitrogen	32 – 64%
Total Phosphorus	45 – 94%
Microorganisms	Log10 = 0.78 – 4.23
Organics (PAHs, etc.)	54 – 100%

Percent reduction of pollutants in bioretention when amended with biochar (Biswal et al., 2022)

Urban Landscapes (Stormwater) High Points

Biochar Amendment Soils (Coarse Grained Soils)

- **Runoff Reduction with Biochar:** Applications in Delaware and Maryland show biochar reduces stormwater runoff by 80% on average, influenced by the ratio of impervious to pervious surfaces. Effective in compacted soils and boosting natural soil aggregation (Imhoff, P.T., et al., 2017; 2018; 2019; 2020).
- **Soil and Water Benefits of Biochar:** Biochar amendments have shown to elevate soil infiltration and water-holding capacity by 25-27% depending on biochar porosity.
- **Biochar Amendment Ratios for Impervious Surfaces:** Amending a 30 cm layer of soil with a 2% biochar mixture at an impervious to pervious (IP:P) ratio between 8:1 and 12:1 is effective for treating stormwater from 1-acre of impervious roadway (Akpinar et al., 2023, Imhoff, P.T., et al., 2017).

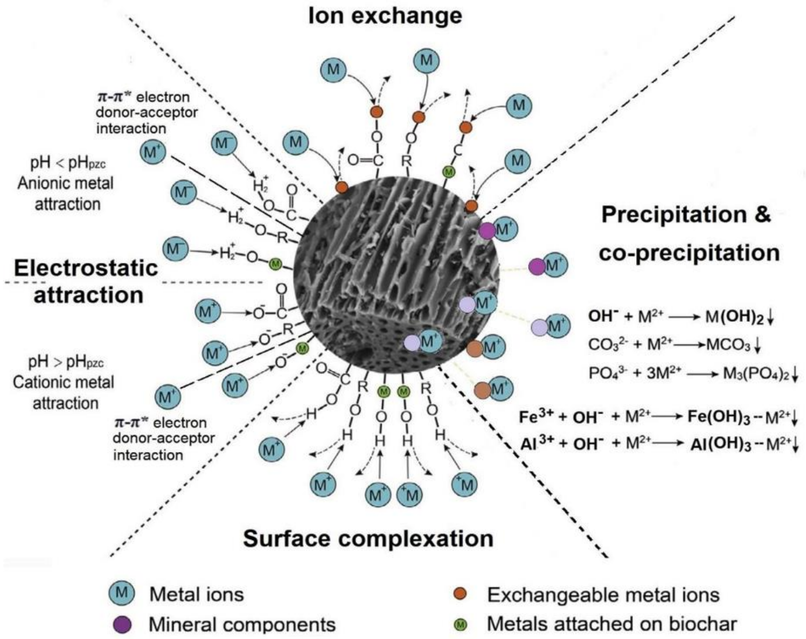


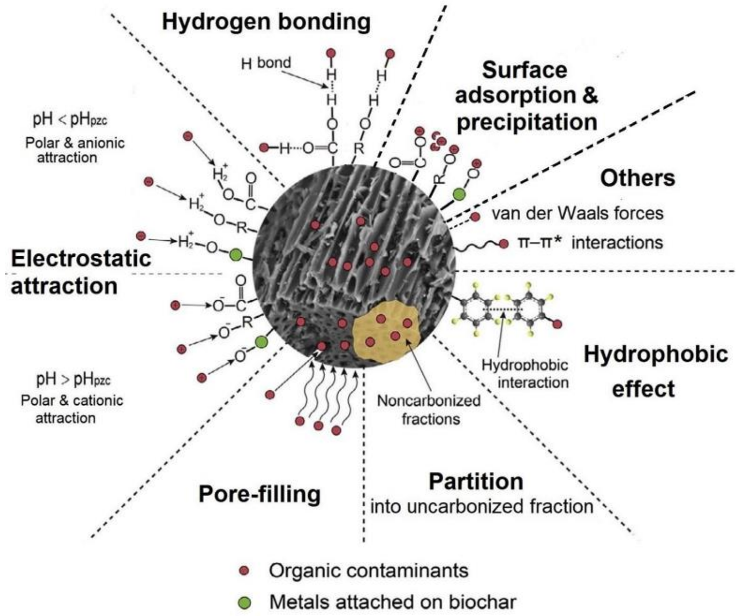
The range of response ratios for K_{sat} and related soil parameters for all sites except MDTA US-279. Data are based on measurements more than 1 year after 4% biochar incorporation. K_{sat} response ratio <1.0 indicates that biochar amendment decreased infiltration, observed at only one site where gravel was in the native soil but not in the biochar amended region. (Akpinar et al., 2023)

Emerging Toxic Contaminants (ETC) High Points

- **Biochar's Role in Contaminant Reduction:** Serves as a cost-effective and environmentally friendly solution for remediating soil and water contaminated with heavy metals, dyes, organic compounds and PFAS (Qiu et al., 2022).
- **Biochar in Heavy Metal Stabilization:** Amendments can stabilize heavy metals in soils, transforming them into less bio-accessible forms and reducing ecotoxicity, thus promoting safer crop cultivation and public land use (Guo et al., 2020).
- **Biochar for Organic Contaminant Remediation:** Effective in adsorbing and decomposing soil contaminants, biochar improves microbial activity and soil health, aiding the breakdown of organic pollutants (Guo, 2020).
- **“Green” Fit-to-Purpose Carbon:** Biochars made from different materials are able to serve specific remediation purposes,
    - wood/plant residues preferred for organic pollutants,
    - higher mineral content from manures and sludge are better for heavy metals (Ji et al., 2022).

Major mechanisms through which biochar stabilizes heavy metals in contaminated soils. Guo, et. Al., 2020. Graph modified from Tian et al., 2015





Major mechanisms through which biochar stabilizes organic contaminants in soil. Guo et al., 2020, Graph modified from Tian et al. 2015)

Biochar Workshop Recommendations

- **Support pursuing biochar enhancement credit for approved BMP Protocols:**
  - **Integrate Biochar in Nutrient Models** - Include biochar impacts in Chesapeake Bay nutrient management tools.
  - **Inform Policy with Biochar Data** - Use biochar data to guide policymakers and stakeholders on water quality strategies.
  - **Understand Biochar's Role** - Clarify biochar's contributions to water quality and climate resilience.
  - **Follow CBP Urban Stormwater Guidelines** - Adopt CBP's process for incorporating biochar into urban BMPs.

- **Recommend and expand applied research and knowledge filling:**
  - **Prioritize Biochar Research** - Focus on practical and field-scale studies to advance biochar knowledge.
  - **Commit to Science-Backed Solutions** - Investment in scientific research to address biochar application gaps.
  - **Support Data Collection** - Collect field data to validate biochar's benefits and best practices.
  - **Understand Contextual Effectiveness** - Assess biochar's effects in diverse Chesapeake Bay watershed scenarios.
  - **Refine Biochar Protocols** - Use research insights to improve biochar usage guidelines.

Biochar Workshop Recommendations

- **Support scaling up scientifically effective application of biochar use:**
  - **Expand Biochar Use Across Sectors** - Implement biochar in agriculture, forestry, and urban areas within the watershed.
  - **Address Contaminants** - Apply biochar to mitigate emerging and toxic substances.
  - **Develop Biochar Guidelines** - Establish clear guidelines for biochar application across various contexts.
  - **Set Biochar Standards** - Create standards to ensure biochar's effectiveness and safety.
  - **Accredit Biochar Practices** - Introduce accreditation programs to certify biochar application methods.

- **Provide letters of support to expand collaborative partnerships**
  - **Strengthen Multi-Sector Collaboration** - Unite government, academia, NGOs, and businesses around biochar adoption.
  - **Streamline Biochar Research** - Coordinate research activities to optimize biochar use.
  - **Share Best Practices** - Disseminate successful biochar applications and case studies.
  - **Accelerate Biochar Projects** - Fast-track biochar initiatives through joint funding and resources.
  - **Build a Biochar Community of Practice** - Create networks to support and promote biochar integration.

Presentation Discussion

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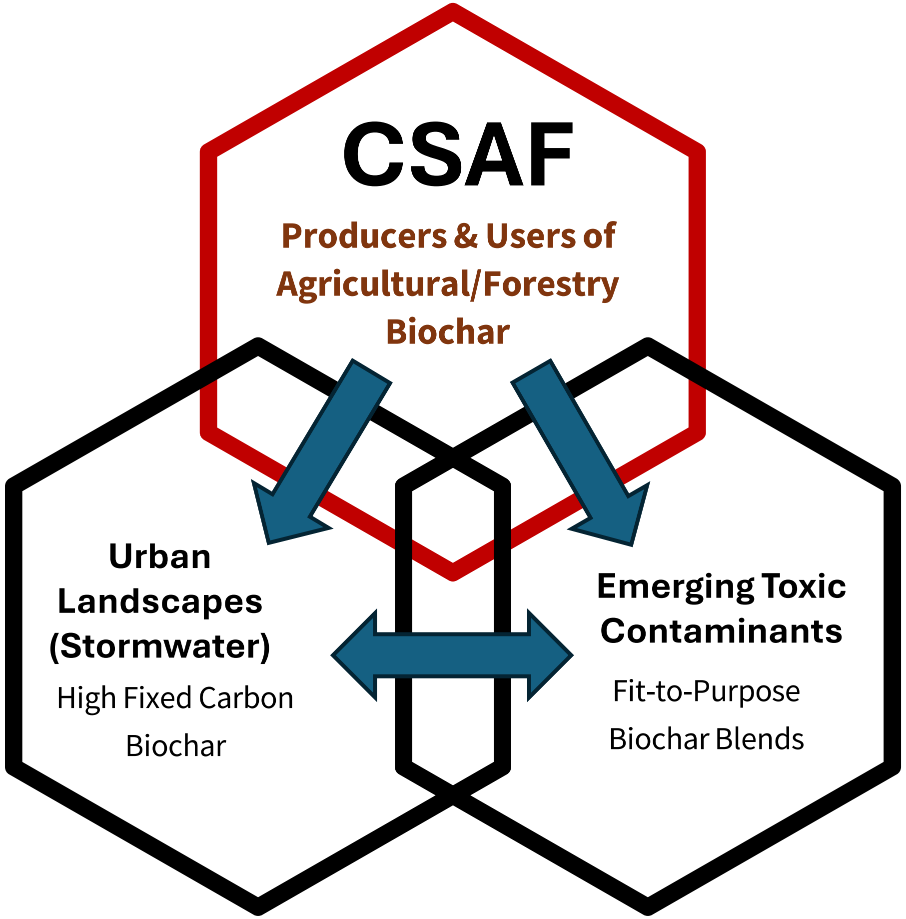
Senior Project Consultant
Biochar SME
chegberg@res.us



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