Biochar Use In Stormwater Management

Report prepared by :

DOVETAIL PARTNERS

USBI

International Biochar Initiative

Biochar is the output of heating organic feedstocks[1] in a low oxygen environment, creating a stable, carbon-rich product. Biochar has been used commercially in stormwater management in the US for more than ten years to bring public and private storm water management systems into compliance with regulatory permits. Use has grown as more trials are being conducted and biochar's benefits and value proposition are better understood. Stormwater management applications include ponds, streams, erosion control and reduction of runoff from impervious surfaces (e.g., roads, parking lots, etc.)

One of the most publicized projects is from Stockholm, Sweden where biochar is used extensively since initially being piloted in 2009 to reduce runoff and revitalize tree plantings. In the US, Minnesota has published specifications for biochar use in stormwater management and the City of Minneapolis has begun instituting city wide programs after visiting Stockholm and learning from the project managers there. Other US municipalities are also exploring biochar in urban stormwater management projects.

Biochar can be a cost-effective filtration solution where organic and inorganic substances, as well as some microbial constituents, need to be removed. Research and experience have proven biochar to be useful in a variety of stormwater management applications as a filtration and water treatment media. It is also used in soil restoration and remediation, constructed wetlands, green roofs, and water treatment. Increasingly, biochar is used in applications where activated carbon (AC) has traditionally been used such as water or gaseous filtration. Where activated carbon is made from peat, coal, and organics including dense coconut shells or wood; biochar is made from organic (i.e., renewable) sources exclusively. And since biochar sequesters carbon it provides an opportunity to access carbon credits.

[1]Biochar feedstocks are largely woody or crop residues , but could include bones, manure, livestock litter, and other inputs to create specialized chars.va

The full Biochar Use In Stormwater Management can be found on Dovetail's website.

Biochar Use in Stormwater Management

- Kathleen Draper, Chair, *International Biochar Initiative*
- Harry Groot, *Dovetail Partners*
- Ashley McFarland, *Dovetail Partners*
- Tom Miles, Chair, *US Biochar Initiative*

The work upon which this presentation is based is funded through a grant awarded by the US Forest Service Wood Education Resource Center's Wood Innovation Grant 20-DG-11083150-011

Project Overview

- The project explored the potential for using biochar in three applications:
  - Viticulture, Livestock and Poultry, and Stormwater Management.
- The process used was to:
  - Interview experienced users
  - Review relevant published scientific research
  - Analyze needs of users and other market data
  - Provide educational outreach
    - Reports
    - Webinars

Stormwater Management Report Highlights

- There is a large body of research supporting biochar’s characteristics which are beneficial in Stormwater Management
  - Adsorption of heavy metals
  - Large surface area for housing microbiota
  - High carbon content which is stable for centuries to millennia

- Biochar has been successfully used in Stormwater Management projects for over a decade.

- There are many suppliers of biochar in US.
  - Biochar’s specific characteristics are important and analysis is critical.

Today's Speakers

- **Kathleen Draper**–Finger Lakes Biochar (NY), Co-Author of *Burn–Using Fire to Cool the Earth*, IBI Chair, USBI Board Member

- Chuck Hegberg– Ecotone LLC, an ecological restoration design/build B-Corp, USBI Board Member

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Photo Credit: Rain Dog Designs, Gig Harbor, WA

Biochar in Stormwater Management

International Biochar Initiative

DOVETAIL PARTNERS

February 9, 2022

Biochar in Stormwater Management

- Introduction
- What is Biochar?
- General Summary of Biochar Benefits
- Challenges of Stormwater Management
- Green Infrastructure & Biochar's Role
- Biochar Amended Engineered Media
- In-Situ Urban Soil Restoration
- Comments on Standards & Specifications
- Q&A and Technical Request

Photo Credit – sustainablilityactive.com

Photo Credit – NJFuture.org

What is Biochar?

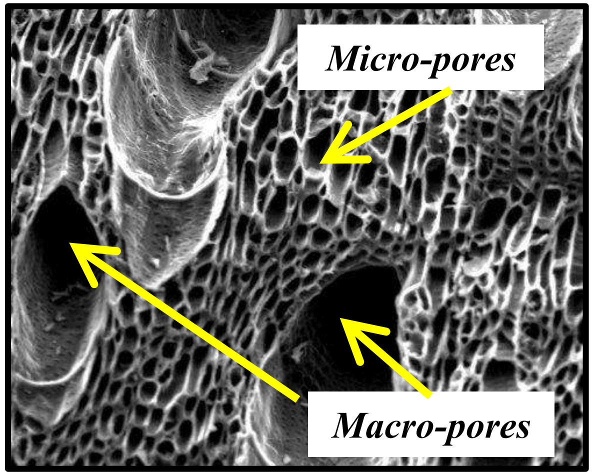
Produced from the carbonization of biomass using little or no oxygen

- Solid carbon material
- Produced from organic matter
- Resistant to decomposition
- Unlike charcoal, not used for energy

An Ancient Technology, Rediscovered

Carbon-Negative Process CO_2:C ratio = 3:1

Biochar's Are Not Created Equal



Summary of Biochar Benefits

Re-establish Soil Functions

- Increases Infiltration/Retention
- Increases CEC/AEC (up to 50%)
- Increases Microbial Activity
- Balances pH
- Decreases Bulk Density

Water Quality

- Intercept/Absorb/Assimilate
- Nutrients/Heavy Metals/Hydrocarbon
- Enormous Surface Area
- Activated Carbon Replacement

Biomass Upcycling

- Biomass Waste (Manures)
- Cropped Biomass
- Flexibility Application Methods

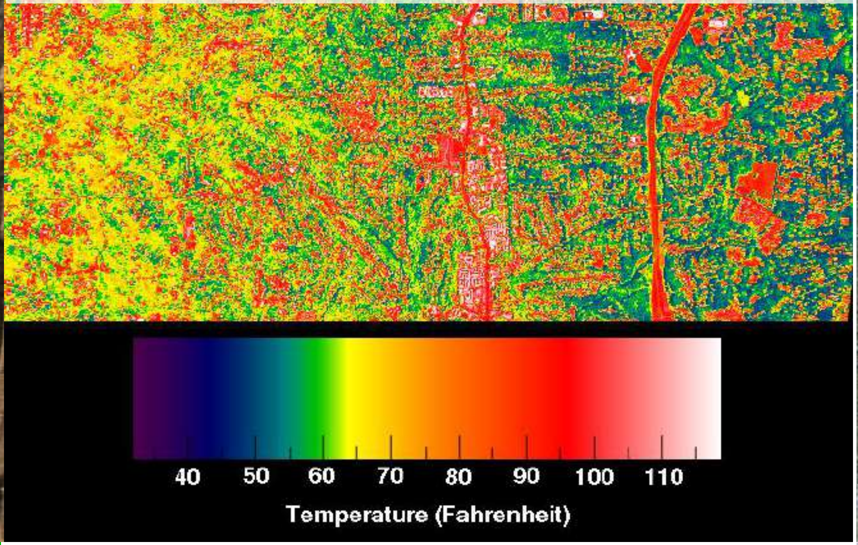
Longevity

- Short Term Soil Organic Carbon (1-5 years)
- Long Term Soil Organic Carbon (100's of Years)

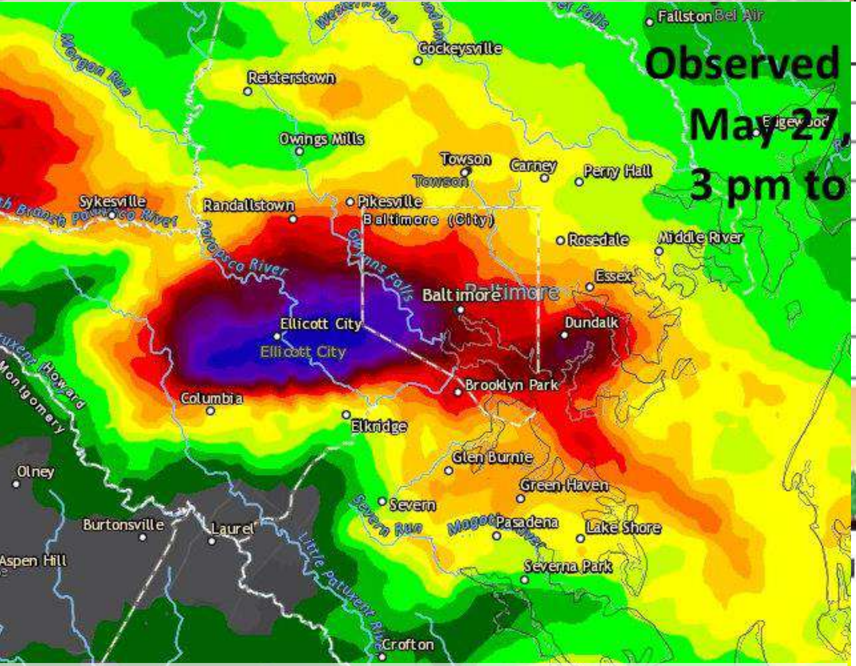
Challenges of Stormwater Management - Urbanization Effects

Flooding/Flash Floods – Ellicott City, MD

Thermal Imagery – Urban Heat Island

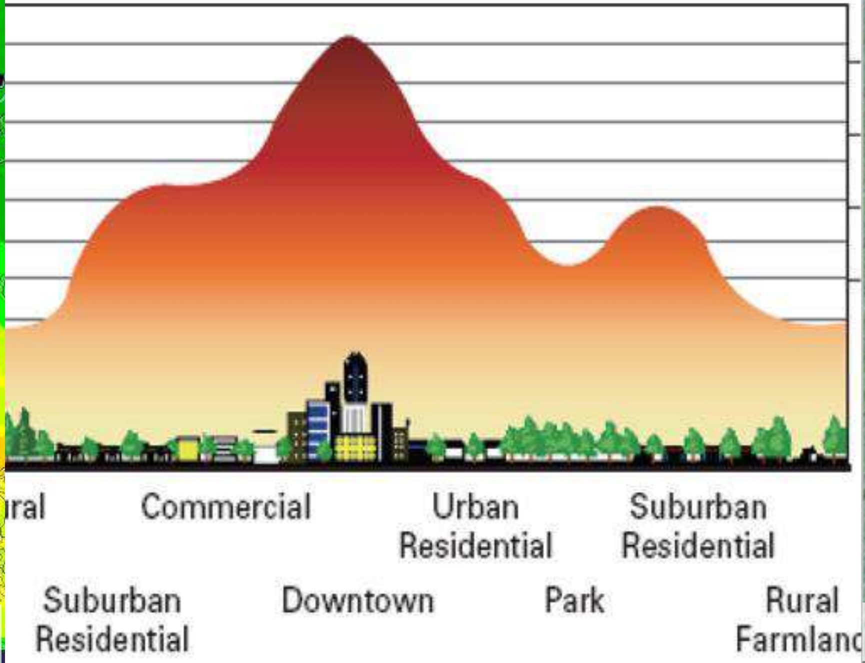


Urban Runoff – Water Quality Impacts

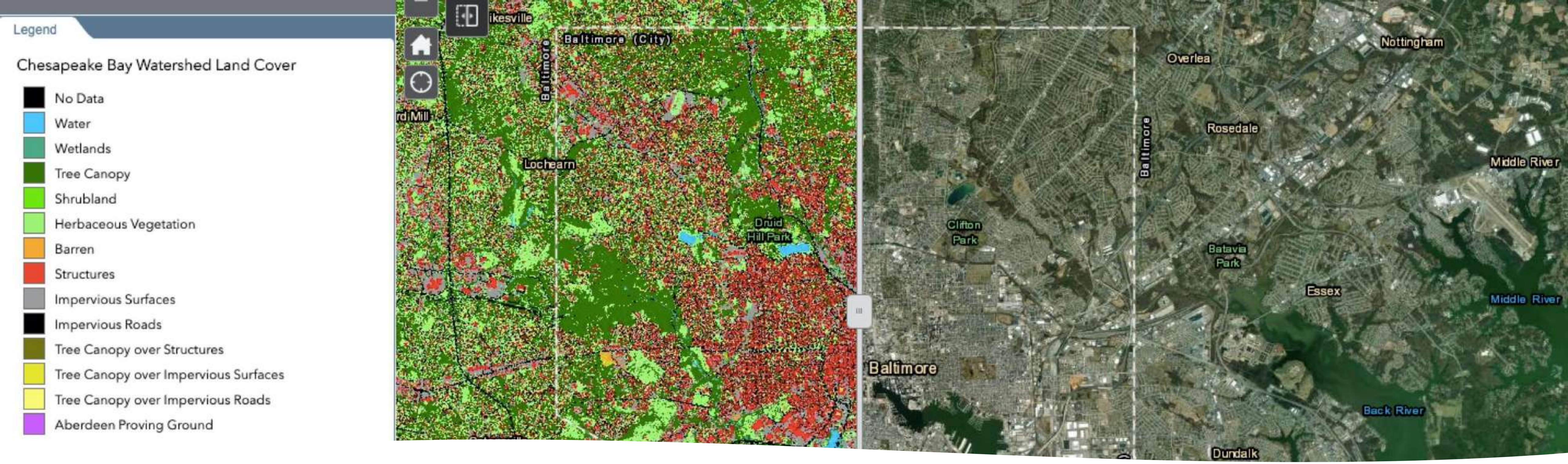


Intensity, Duration & Frequency Changes – Ellicott City, MD

Thermal Imagery – Urban Heat Island



Urban Runoff – Nutrient Overload/Toxic Algae Blooms



Challenges of Stormwater – Impervious Impacts to Our Environment

- Currently 100 million acres of developed land in USA
- Most has occurred prior to stormwater regulations
- Today 27.5 million acres of impervious cover in USA
- In USA Turf accounts for 40 million acres
- Retrofitting urban areas costs average $250,000 + per impervious acre
- Less than 5% of Clean Water State Revolving Funds have been invested in addressing stormwater needs

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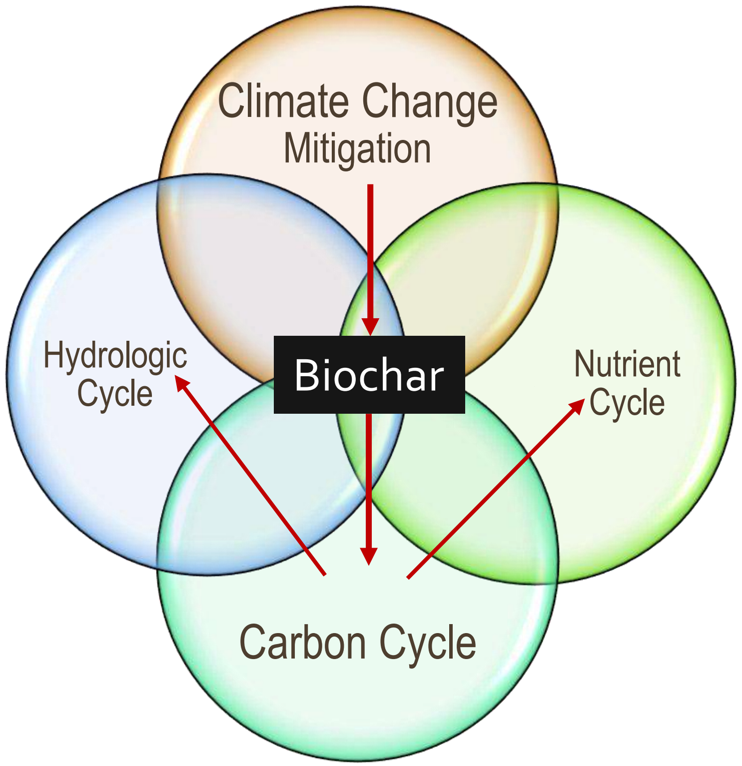
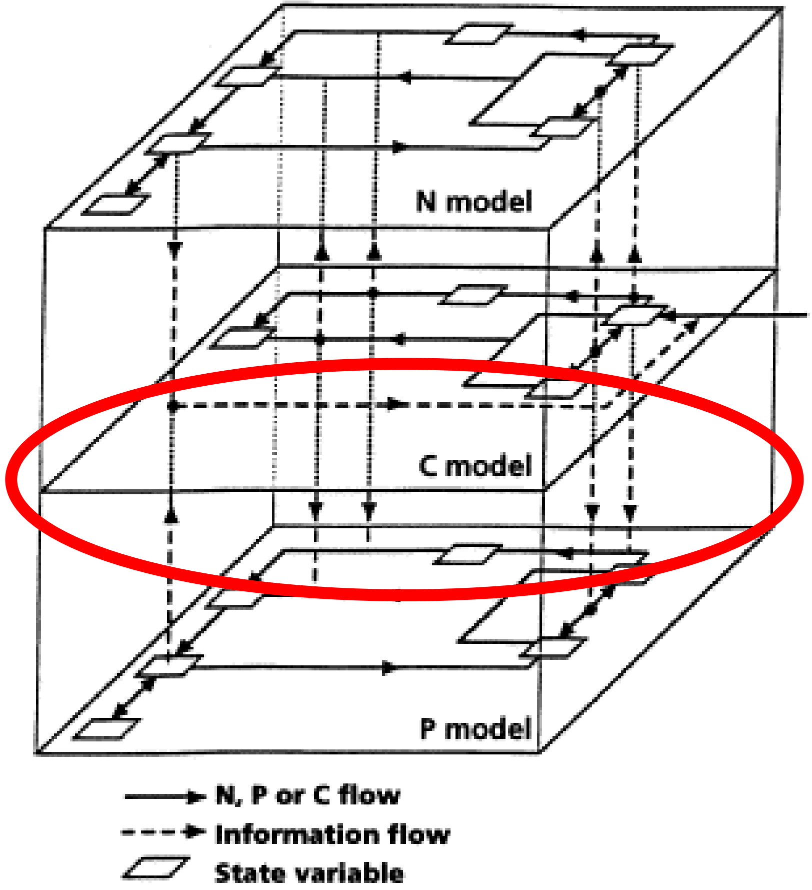


1 Ton Biochar = ~3 Ton CO^2e

…it is highly likely that as human stress on the natural environment increases, effects on individual biogeochemical cycles <u>will reverberate throughout the system and affect all of the other interlinked cycles</u>.
G.E. Likens et al, 1981



Challenges of Stormwater Management

The Carbon Link – Biogeochemical Cycles

Green Infrastructure (GI)

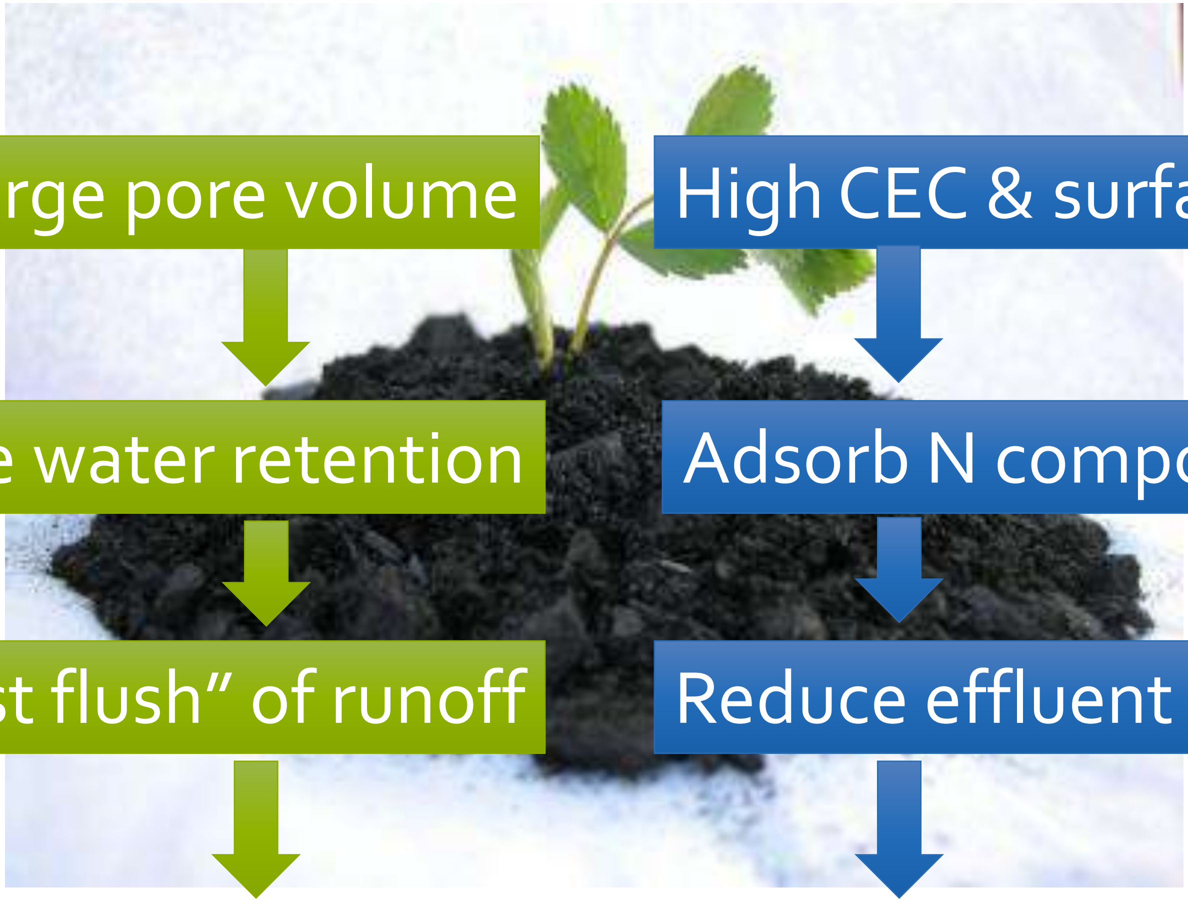
The management of stormwater runoff using natural ecosystems and/or engineered systems that mimic natural systems.

GREEN INFRASTRUCTURE SERVICES	
Water Runoff Reduction	Water Quality Enhancement
Efficient Water Storage	Ecosystems & Wildlife Habitats
Quality of Life Amenities	GHGs Emissions Mitigation

STORMWATER MANAGEMENT HISTORY	
Ancient Civilization (3000 BCE)	Urban Stormwater, Flood Control, Rainwater Collection
Roman Empire	Rooftop rainwater collection, flood mitigation, underground water storage
Post Roman Era – 1800's	Flooding mitigation and wastewater removal
19th Century - Present	Integrated urban water related problems
Best Management Practices (BMPs), Low Impact Development (LID), Water Sensitive Urban Design (WSUD), Sustainable Urban Drainage Systems (SUDS), Sponge Cities (2015)	

Biochar in Stormwater Management

Direct Benefits of Biochar



Large pore volume → Increase water retention → Capture "first flush" of runoff

High CEC & surface area → Adsorb N compounds → Reduce effluent concentration

- Enhance retention of N and water in the soil zone
- Increase rates of infiltration and chemical transformations

Biochar Enhanced Bioretention Media

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Photo Credit – Pacific Biochar

Biochar Enhanced Bioretention Media

Water Quality

- Good suspended solids, bacteria, heavy metal, phosphorus removal
- Poor Nitrogen removal: nitrification > denitrification

Runoff Hydrology

- Prone to clogging/fouling
- Water retention
- Flow reduction

Vegetative Value

- Poor vegetative support

Photo credit: Rain Dog Designs, Gig Harbor, WA

Biochar Enhanced Bioretention Media

Objective - How does biochar affect standard bioretention filter media on nutrient leaching and removal?

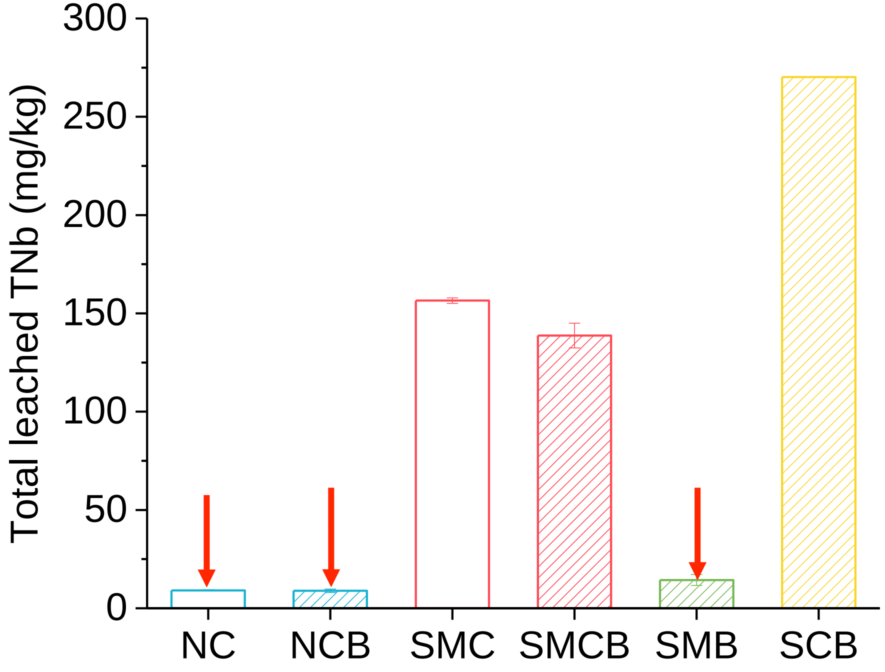
No.	Name	Filter medium mixture (by volume)
1	**NC**	62% Sand, 11% Fines, 27% Sawdust (**North Carolina bioretention filter media**)[1]
2	NCB	52% Sand, 9% Fines, 21% Sawdust, 18% Biochar (≈ 4% biochar by mass)
3	**SMC**	60% Sand, 30% Mulch, 10% Compost (**Delaware bioretention filter media**)[2]
4	SMCB	49% Sand, 25% Mulch, 8% Compost, 18% Biochar
5	SMB	60% Sand, 22% Mulch, 18% Biochar
6	SCB	60% Sand, 22% Compost, 18% Biochar

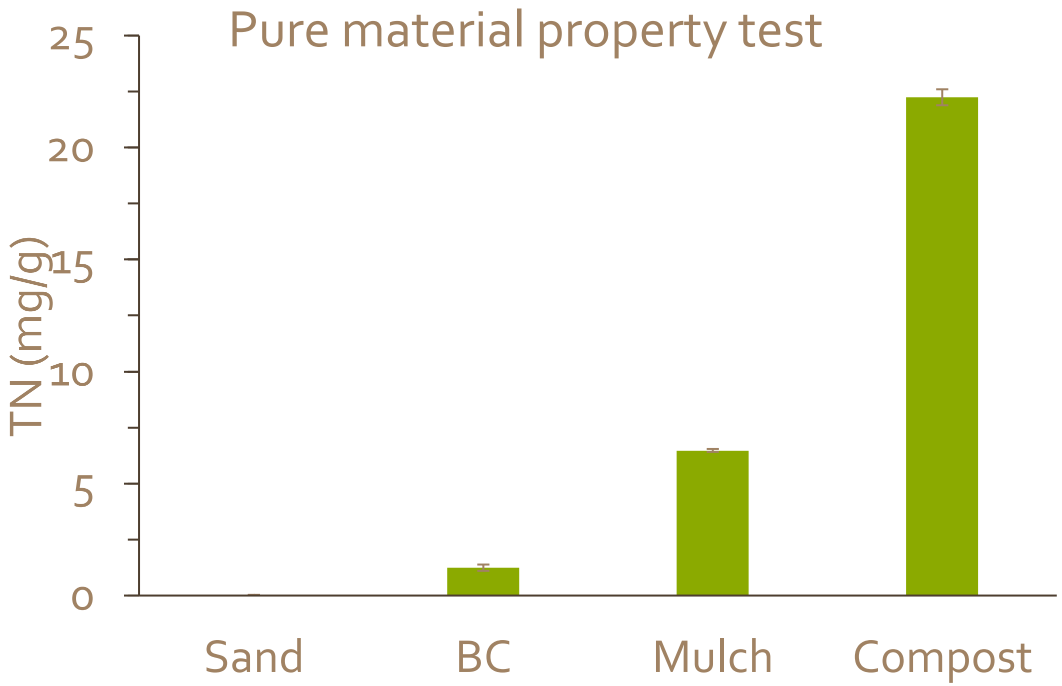
- Total 12 columns, 2 for each mixture

[1] NCDWQ. Chapter 12: Bioretention. Stormwater Best Management Practices Manual [2] DNREC. Post construction stormwater BMP standards and specifications

Biochar Enhanced Bioretention Media – Leach Test

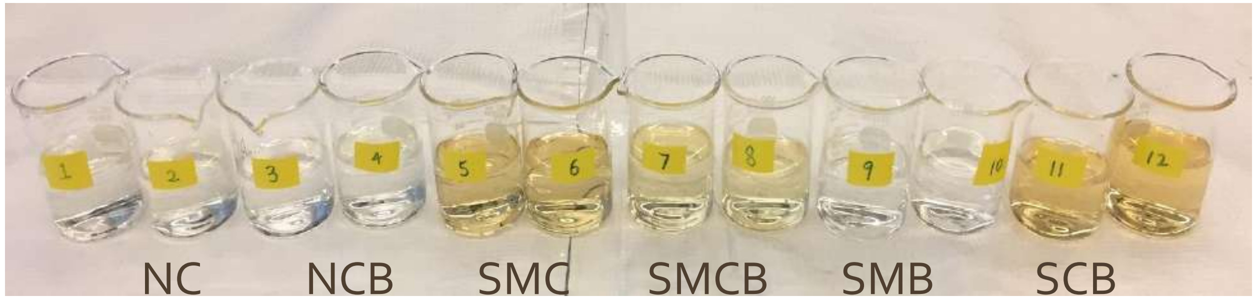
Compost is the major N source in the mixtures





1st

5th



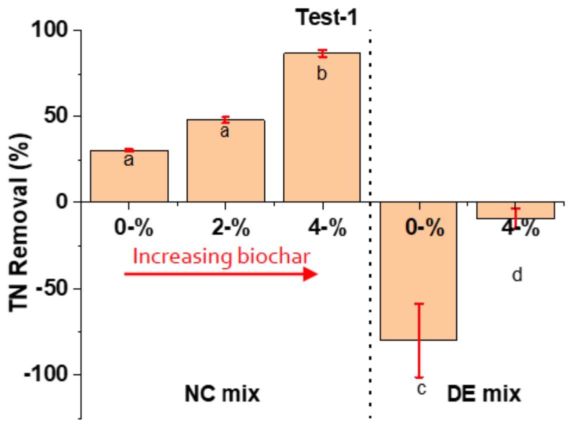
[1] NCDWQ. Chapter 12: Bioretention. Stormwater Best Management Practices Manual [2] DNREC. Post construction stormwater BMP standards and specifications

Biochar in Stormwater Management

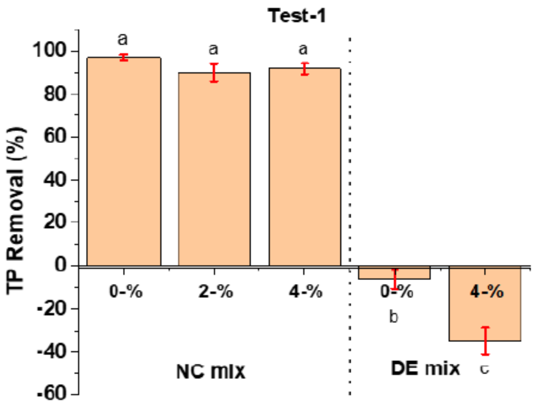
Biochar Enhanced Bioretention Media (BEBM) Conclusions

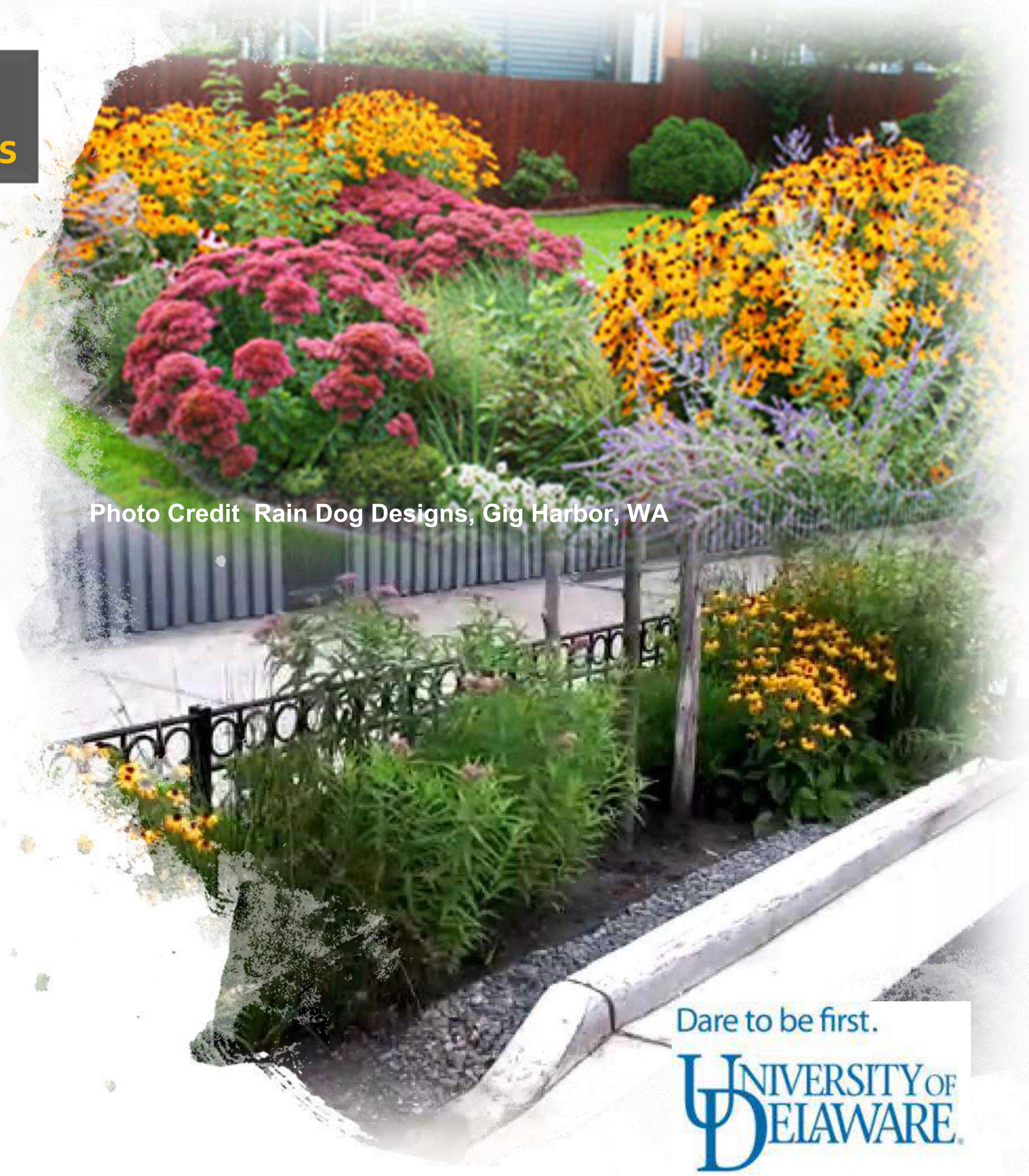
- Retained 11-27% more stormwater and more plant available water.
- Water retention time for higher redox
- Increased infiltration rates by 4 times
- After 1.5 yr, biochar increased infiltration rate by 50% (less clogging)
- Increased Nitrogen removal from 6% to 55% above control (all storms)
- Increased Nitrate removal 60-370% (Seasonality)
- Biochar increased Phosphorous release when **compost** in mix
- Improved plant health in typical bioretention mix

Nitrogen



Phosphorus





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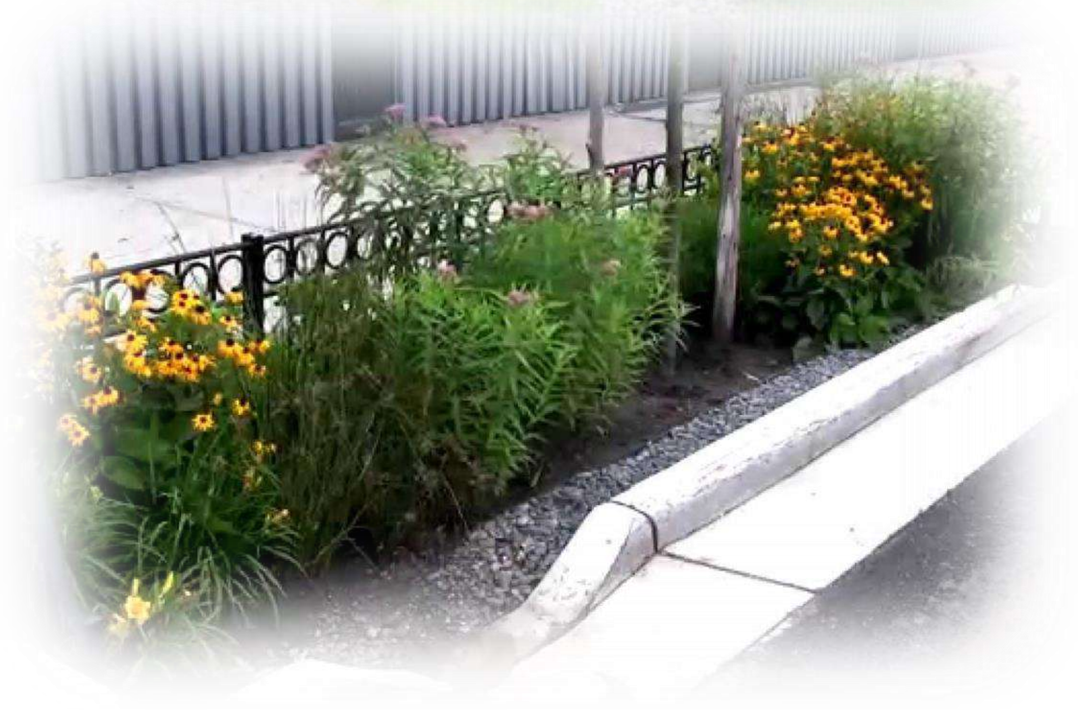
Biochar in Stormwater Management

Biochar Enhanced Bioretention Media (BEBM) Considerations

- Biochar particle size and distribution important in Ksat influence.
- Percent volume of biochar influences water holding capacity.
- Design BEBM blends to local needs – Metals, E. Coli, Nutrients. Don't look at wood biochar only. Manure char highly effective on metals.
- For quality control/product consistency better to have BEBM pre-mix. Some sorting does occur in transport.
- Biochar should be moistened prior to mixing to improve better blending
- Avoid over handling BEBM during placement to avoid grinding down of biochar particles.
- Design BMPs to avoid equipment compacting sub-base and BEBM upon placement.
- Test sub-base infiltration prior to installing BEBM. Subsoil as necessary.

Photo Credit: Rain Dog Designs, Gig Harbor, WA



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Biochar in Stormwater Management

Micro-Biofilters, Bioreactors &Bioswales

First Lady Frances Wolf Unveils Governor's Residence Rain Garden During Annual Earth Day Celebration

April 23, 2018

Governor's Residence Rain Garden, Harrisburg PA

Compost 1/8

Biochar (0-10mm) 1/8

Stockholm Structural Soils with Biochar

Stockholm Structural Bioretention Facility with Biochar

Pilgatan 2014

- Biochar and Stone for infiltration of stormwater
- 1 part biochar 0-10mm and 3 parts crushed granite size 4-8 mm 800mm deep.
- Magnolia and perennials

Recreation and Wellness Center at UNL – Biochar Green Roof

- Project size 18.5’x12’ in size, depths X - X
- Green roof project was installed XX
- Biochar was added at 7% and mixed at 50:50 for 2 weeks with compost.
- Roof substrate achieved a weight of 21.1 lbs/cf

NEBRASKA FOREST SERVICE University of Nebraska-Lincoln

N IANR

In-Situ Urban Soil Restoration

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Photo Credit – Pacific Biochar

Grass/Turf in the Chesapeake Bay Watershed

Opportunity exist to create lawns into large Carbon/Soil stormwater sponges through urban soil enhancement.

- ~40 Million Acres of Lawns in USA (2015)
- **3.8 Million Acres of Lawns in Chesapeake Bay watershed (Bay's largest crop)**
- ~ 75% of all turf is dedicated to lawns
- **An estimated 215 million pounds of nitrogen fertilizer is used each year**
- 6.1 million "Grass Farmers" spend ~$5 Billion/year
- 137 Million hours/year spent by homeowners
- 50,500 Professional Lawn Care Employees
- 57 Million Gallons of gasoline used
- **Compacted lawns produces a lot of extra polluted runoff to the Chesapeake Bay watershed.**

The Grass Crop of the Chesapeake Bay, Chesapeake Bay Stormwater Network, Technical Bulletin No. 8, June 2009

Turning "DIRT" into a "SOIL/CARBON" Sponge

We have hundred's of years of experience making "DIRT". - It's time to start using our knowledge and experience making "SOILS" on landscape level.

Soil Impacts

- Reduced Infiltration Rates
- Increased soil strength & bulk density
- Decreased soil physical fertility
- Decreased water storage & supply
- Reduced micro-organisms activities

SOIL COMPACTION – 70 TO 99% REDUCTION

Watershed Impacts

- Increased Stormwater Runoff
- Increased Flooding
- Decreased Water Quality
- Reduced Channel Base Flow
- Increased Stream Erosion

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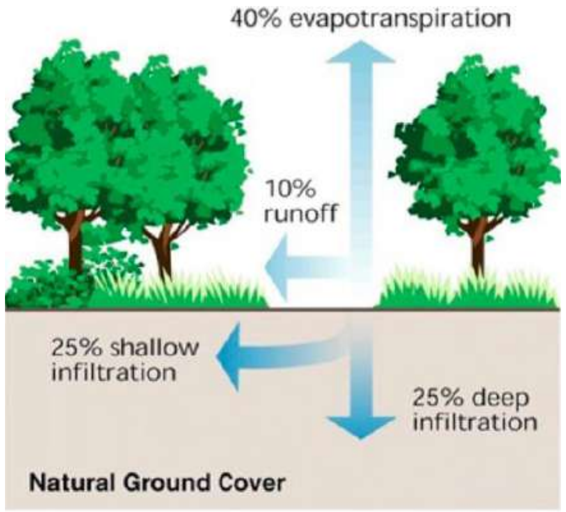
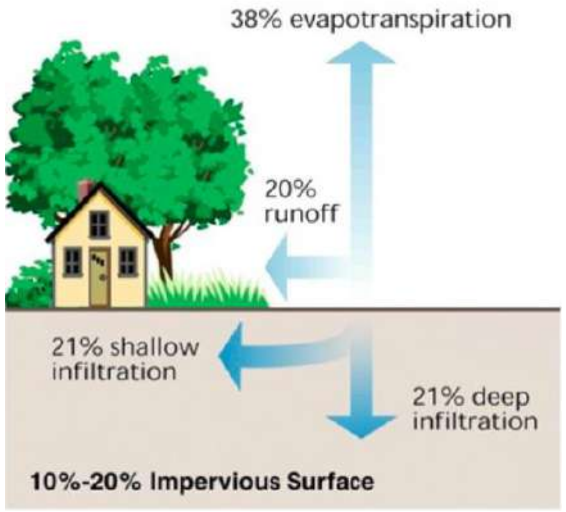
Scenario 'A'



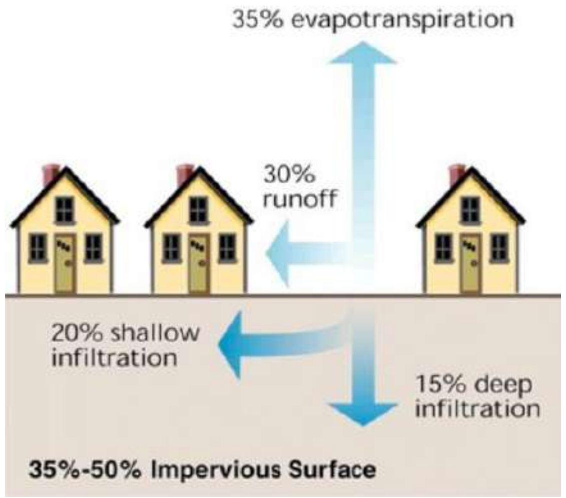
Mimic Meadow/Forest in Good Condition Goal

Scenario 'B'



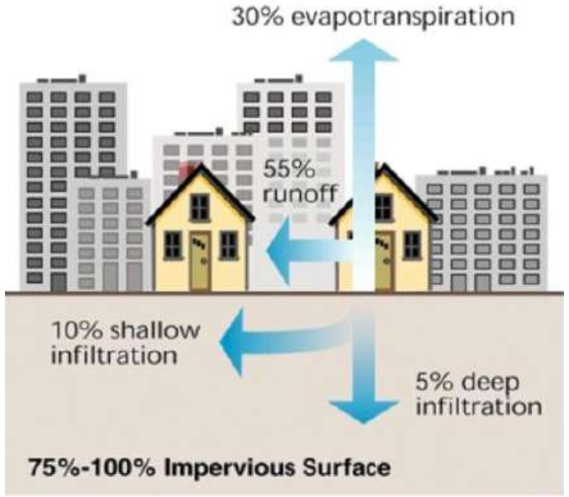
Hot Spot Treatments/Soil Decompaction, Surface Aeration, & Conservation Landscaping

Scenario 'C'



Scenario 'B' plus bi-annual biochar/compost treatment & infiltration practices (bioretention, swales etc.)

Scenario 'D'



Scenario 'C' plus structural practices (permeable pavement, green roof etc.) & quantity control (i.e. Cisterns)

Green Infrastructure - The management of stormwater runoff using natural ecosystems and/or engineered systems that mimic natural systems.

Urban Development Hydro-modifications

Scaling Biochar in the Urban Environment

Roadway Biochar Amendment (Pilot Study)

Field Study Location, Middletown, DE

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Note – 30 cm depth not 60 cm stated in narration

- Biochar reduces runoff volume and peak flows
- Side-by-side comparison if biochar-amended and un-amended roadway soils

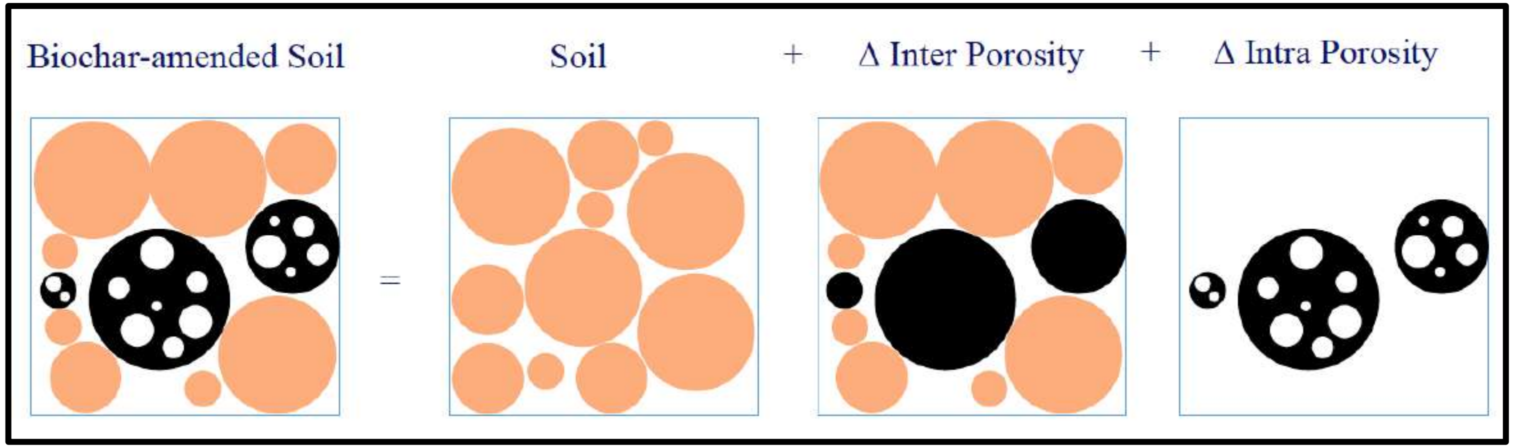
Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017

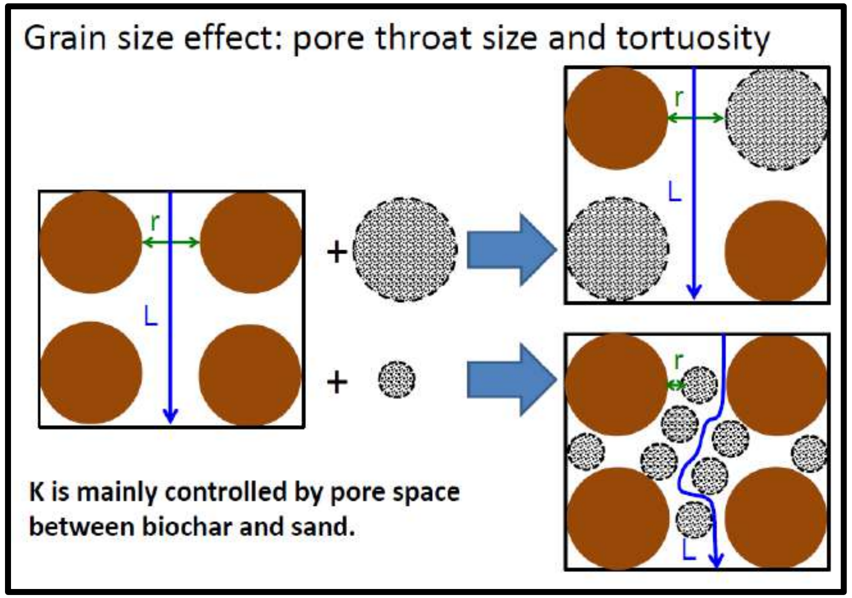
Research conducted by Joe Brown, PE, MS, ABD

Control Strip - Tilled

4% Biochar Strip

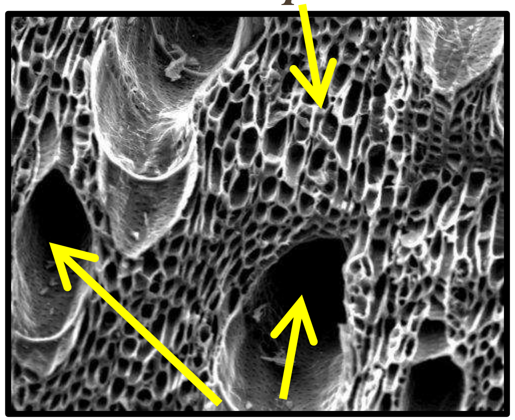
Grain Size Interaction Potential Mechanism






Irregularly Shaped

Micro-pores


Macro-pores


Existing Soil


Existing Soil with 4% Biochar

Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017

Liu, Z. et al, Rice University, 2012 Power Point - Hydraulic Conductivity and Soil Water Retention of Soil-Biochar Mixtures

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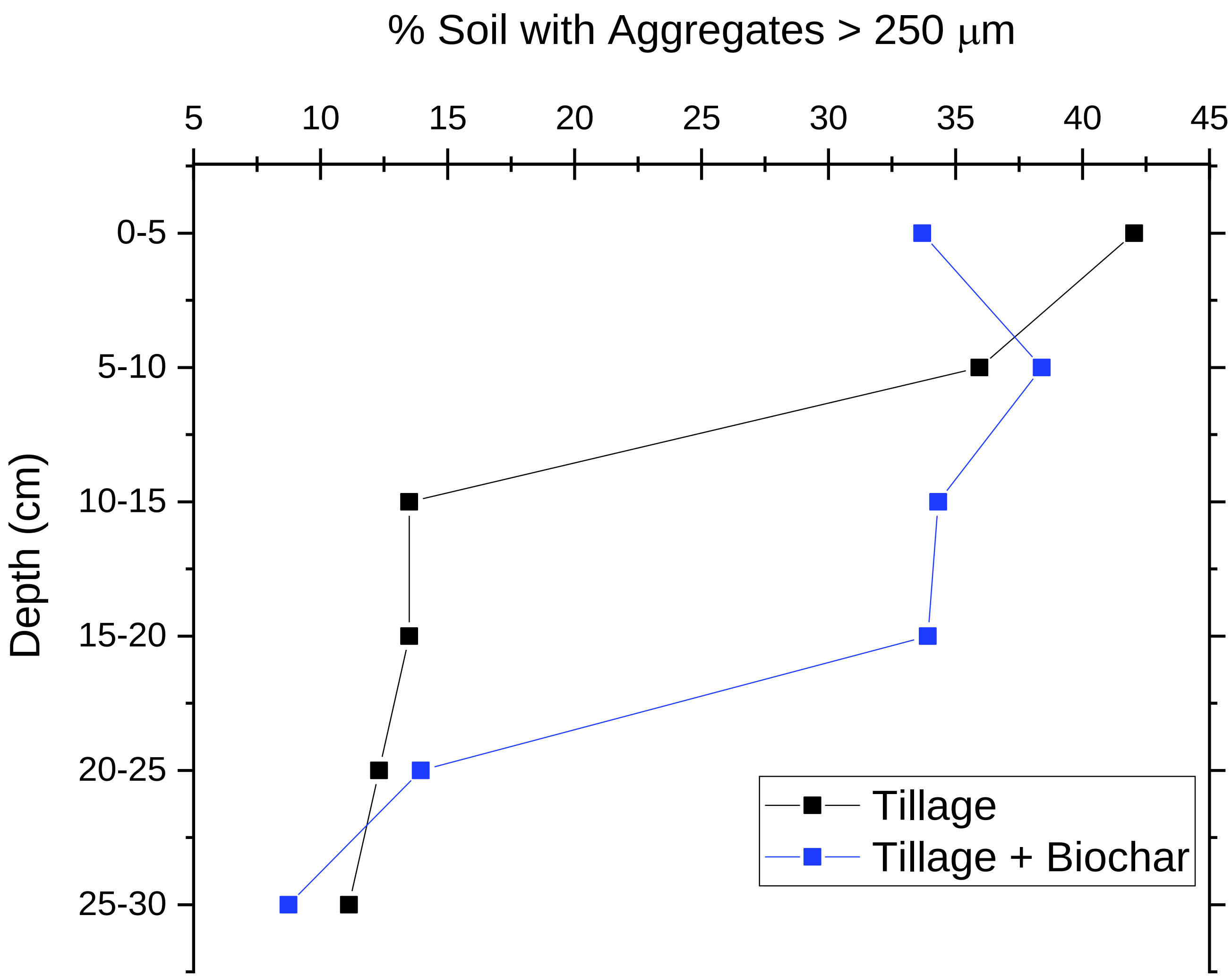
More Macropores with Biochar

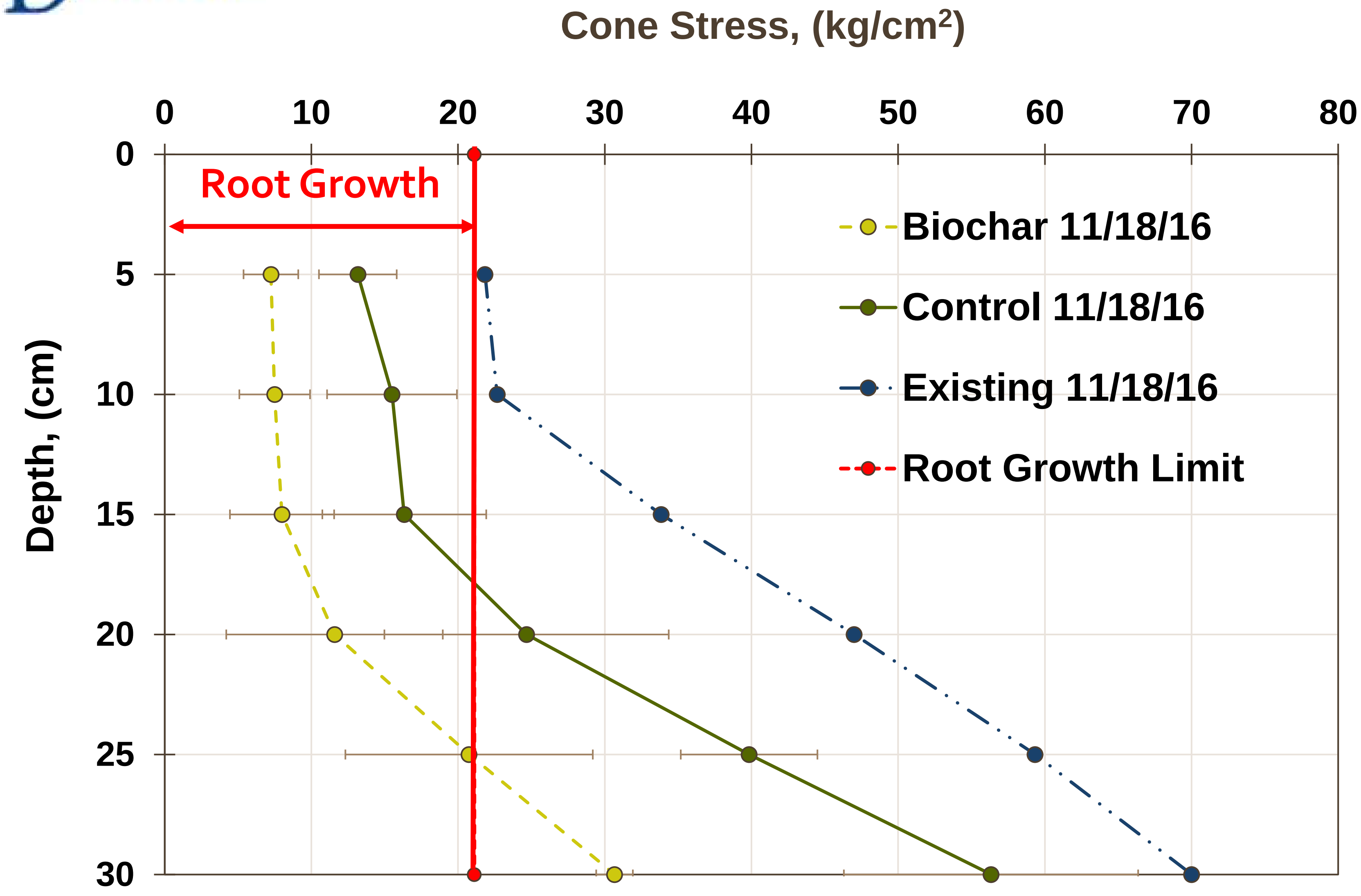
Aggregates

Grains



Biochar enhances aggregation

Biochar Decreases Soil Compaction



Dry Bulk Density:

Undisturbed: 1.63 g/cm³

Control: 1.46 g/cm³

Biochar: 1.22 g/cm³

Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017

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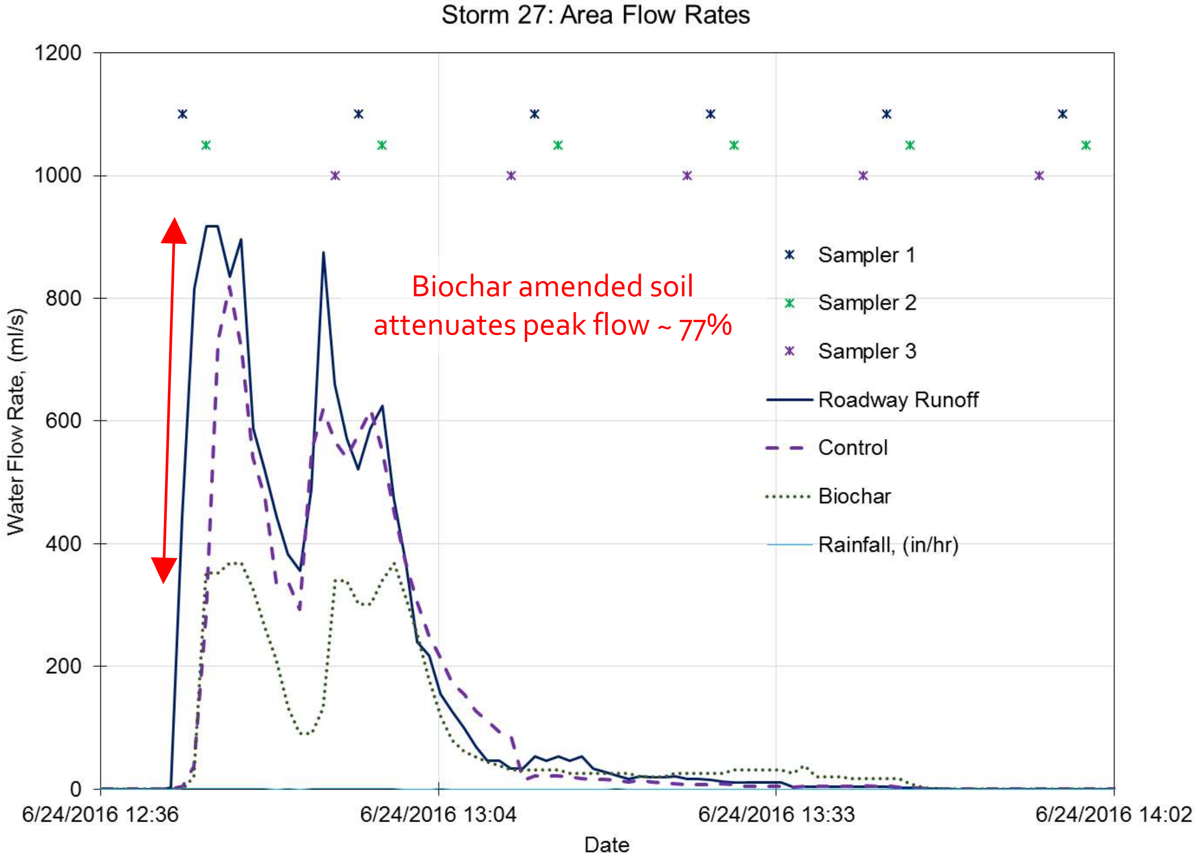
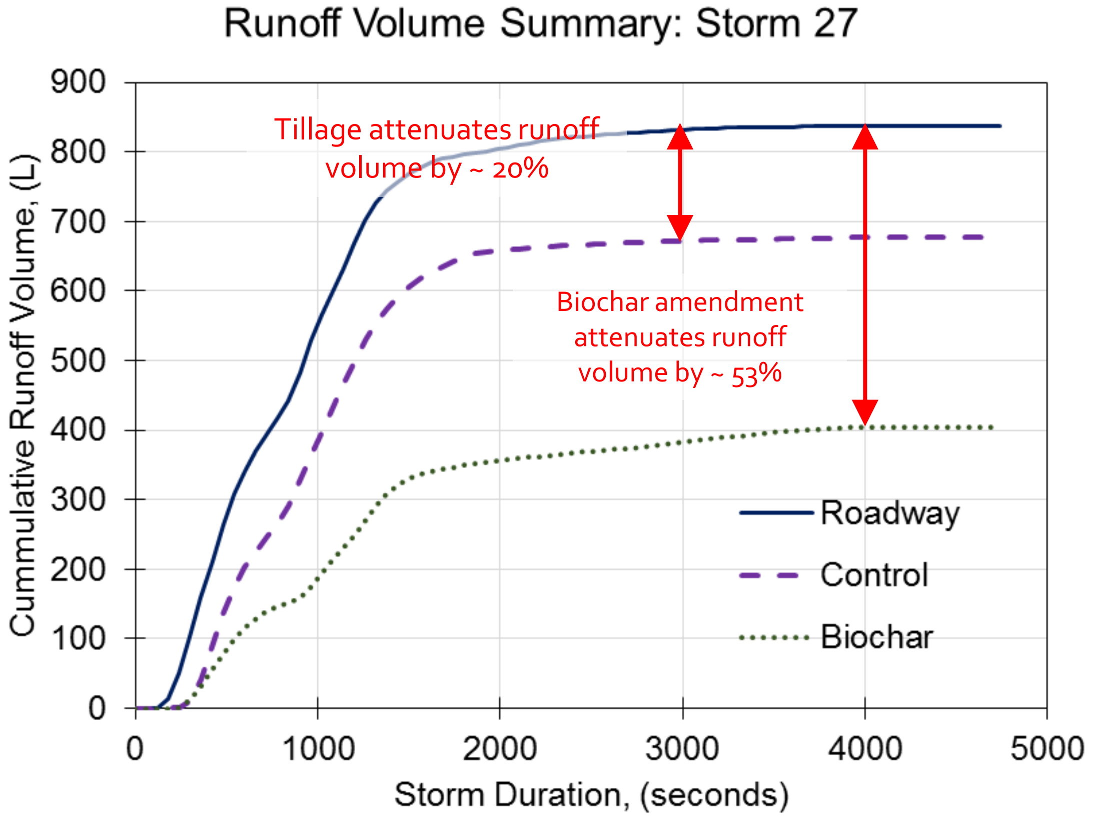
Roadway Biochar Amendment (Pilot Study)

Runoff Peak & Volume Modification

Typical Storm – Water Flow Hydrograph



Typical Storm – Water Flow

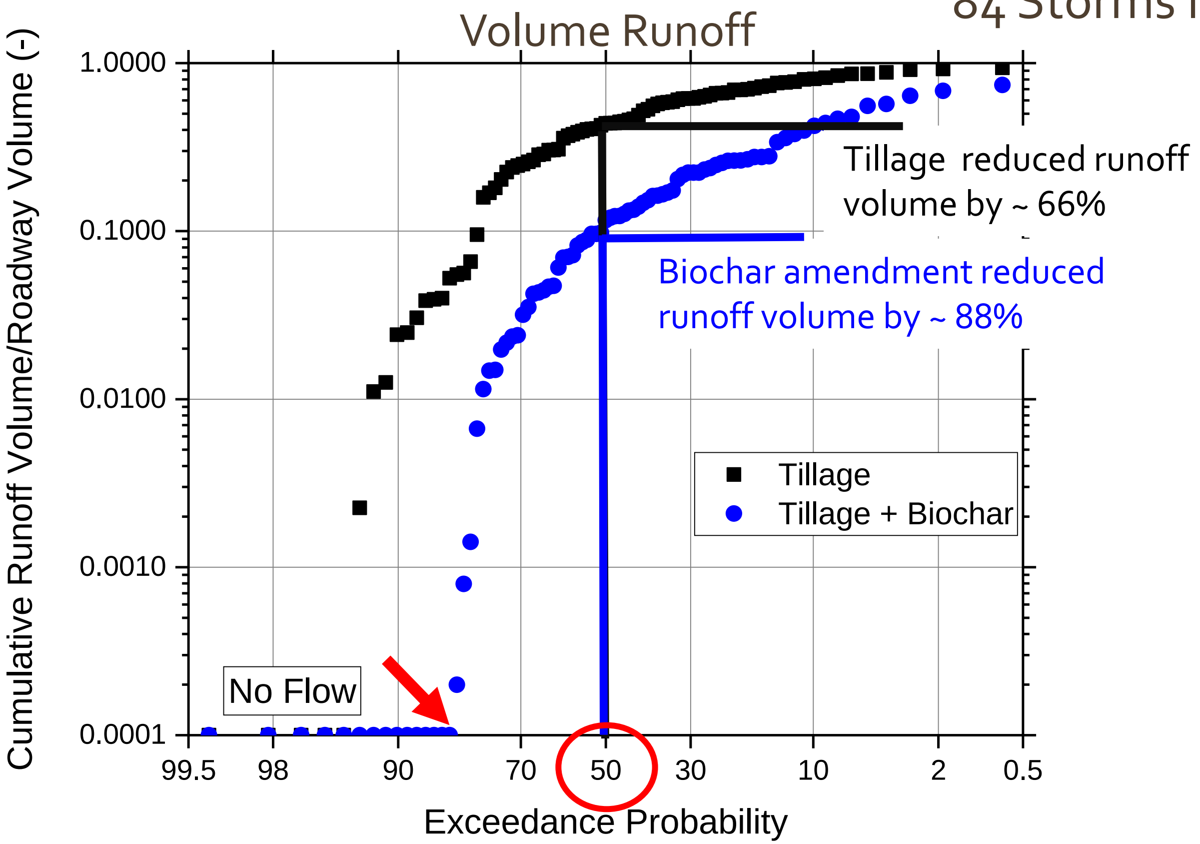


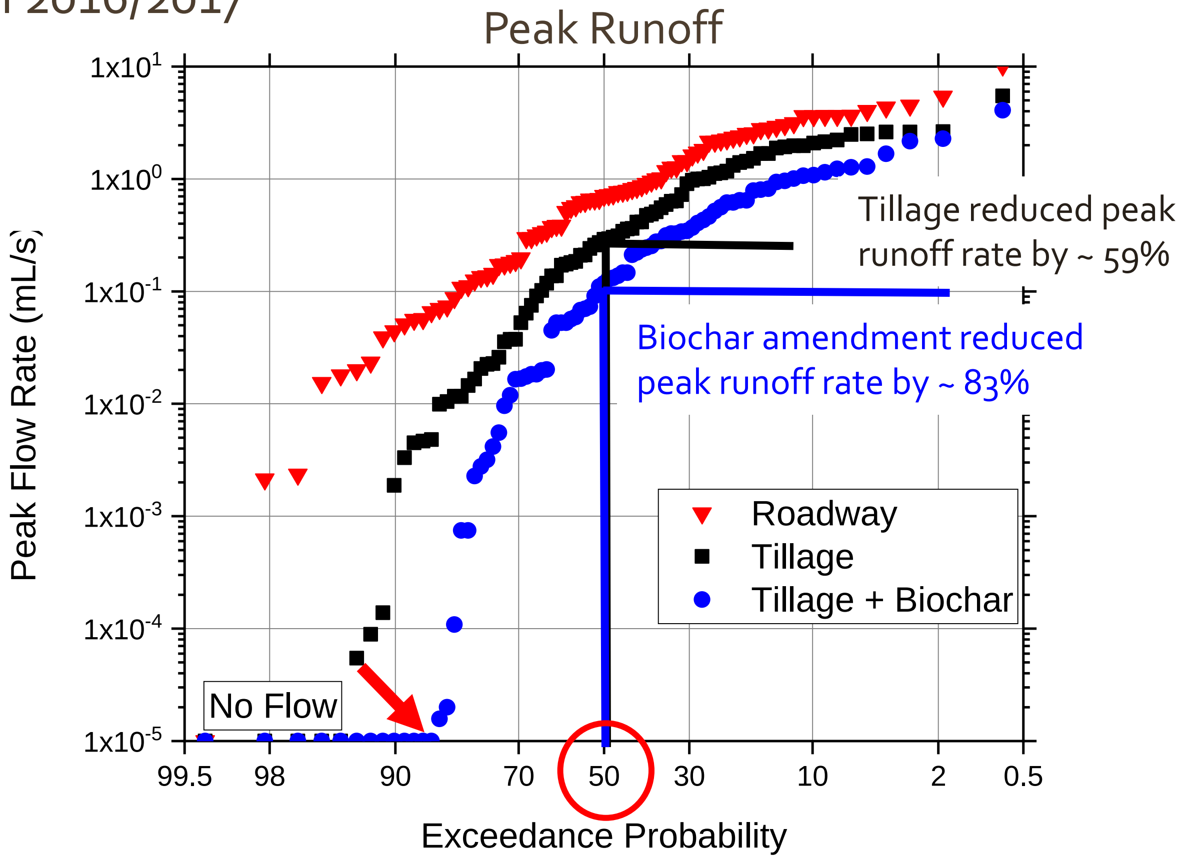
Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017

Roadway Biochar Amended Soils (Pilot Study)

Volume & Peak Runoff Exceedance Probability Curves

84 Storms in 2016/2017





- Biochar increased geometric mean Ksat by ~ 50% over control (tilled)
- 41% reduction in runoff peak flow rate over control (tilled)

Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017

Research conducted by Joe Brown, PE, MS, ABD

Roadway Biochar Amended Soils (Pilot Study)

Biochar Soil Temperature Moderating Effect

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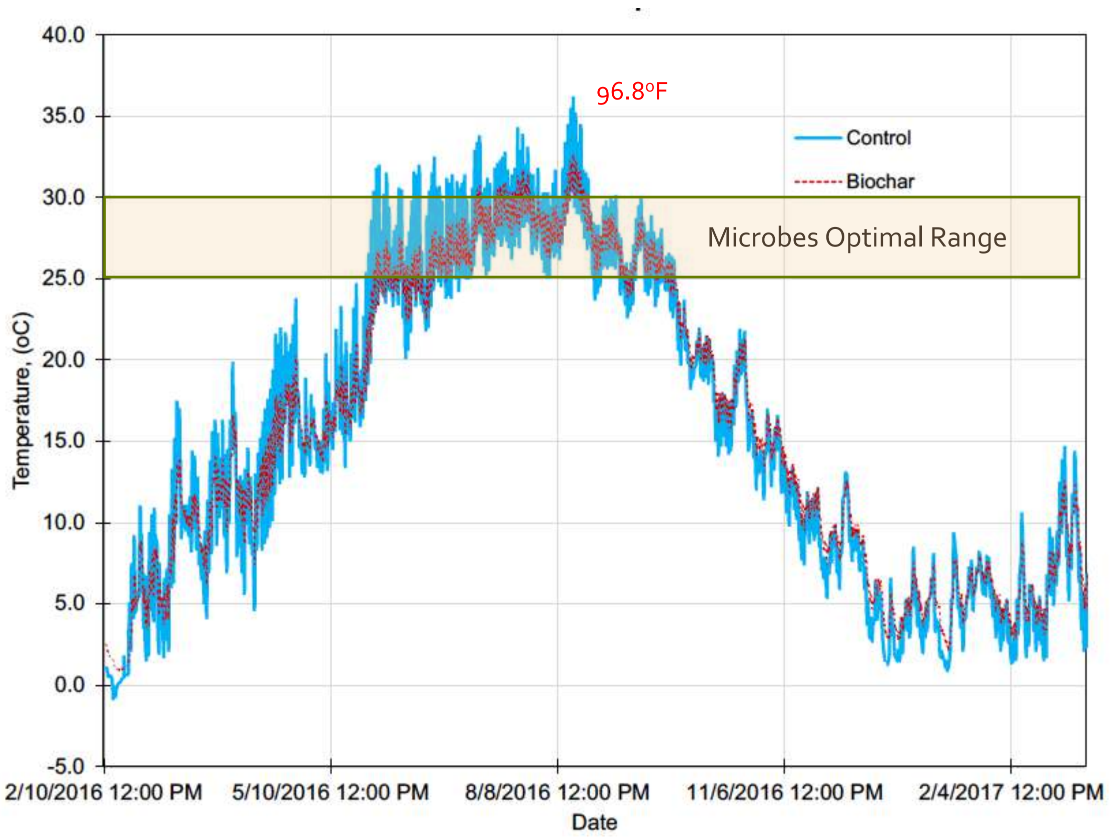

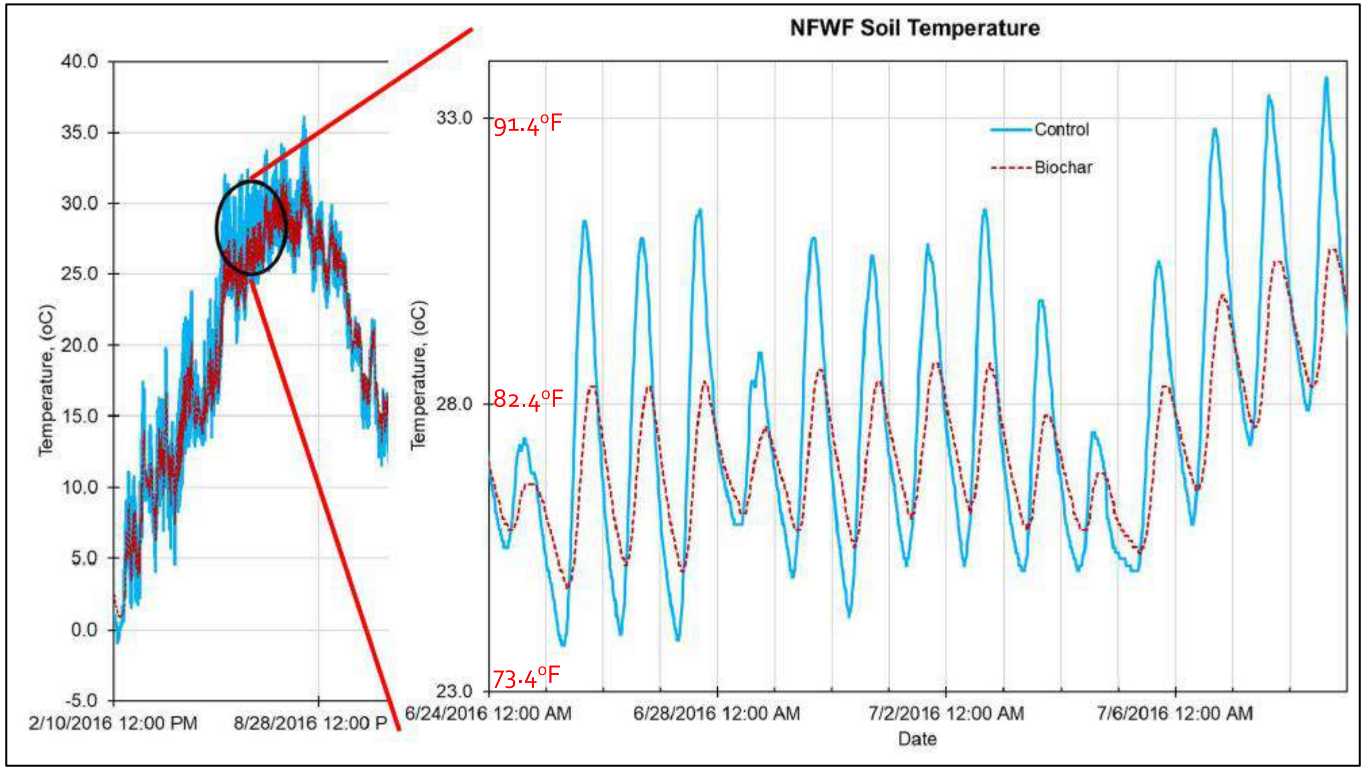

- Warms quicker & Cools slower
- Summer (Cooler) / Winter (Warmer)
- Less Wild Extremes in Temperature Shifts
- More Extremes in the Spring & Summer
- Increased water holding capacity & microbial activities

Imhoff, P.T., et al. University of Delaware, Reducing Stormwater Runoff and Pollutant Loading with Biochar Addition to Highway Greenways, Final Report for NCHRP Idea Grant 182 October 2017
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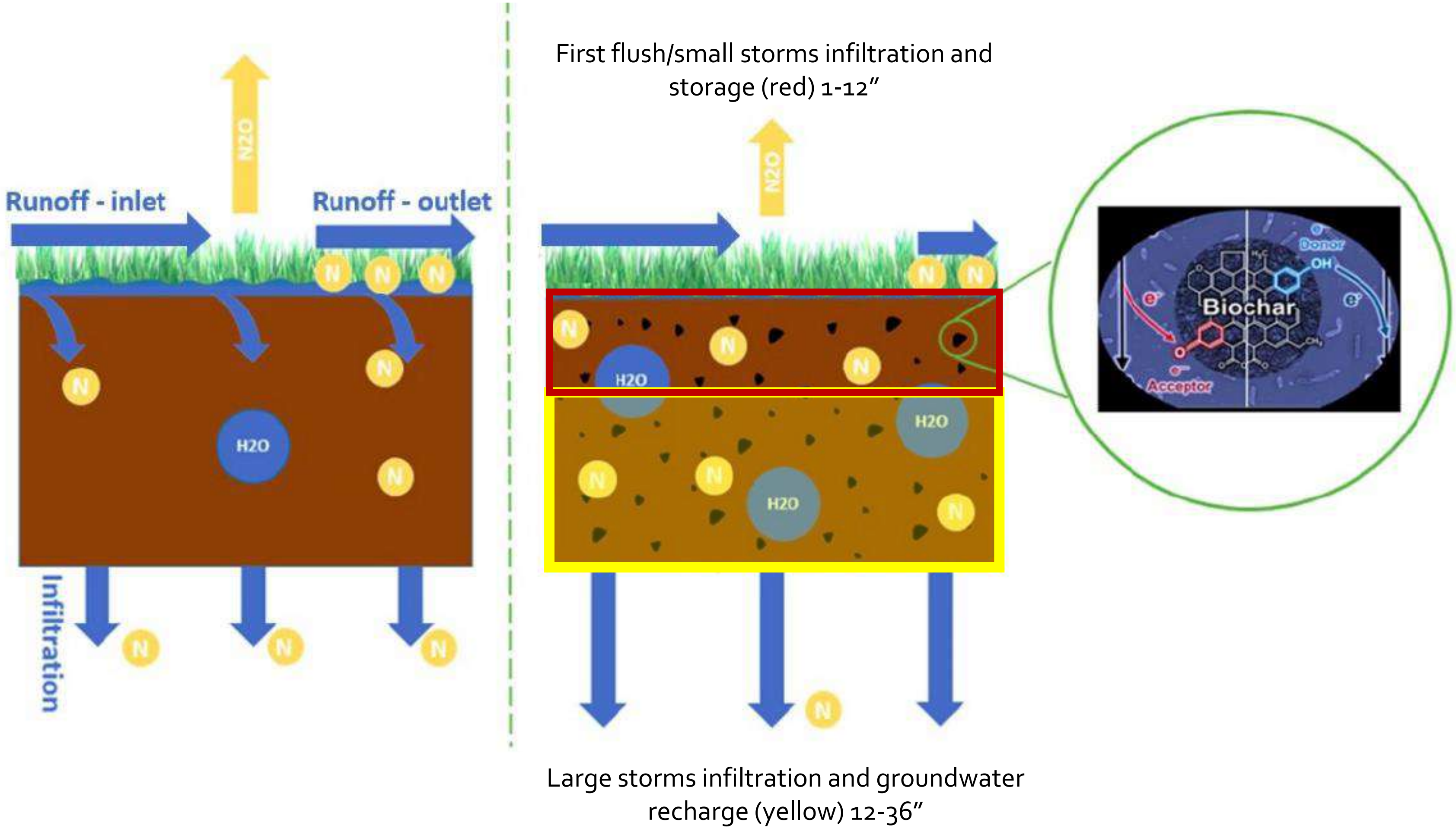
Biochar in Stormwater Management

Urban Soil Treatment Options (Passive versus Active)



Deep Harrow Tilling (2"-12")

Pneumatic Technology (3' – 6')

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Biochar in Stormwater Management

In-Situ Soil Restoration

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Traditional Horizontal Tilling (2”-6”)

Deep Harrow Tilling (2”-12”)

Pneumatic Technology (3’ – 6’)

- Use of harrow rather than horizontal tiller – Deeper treatment, Limits rock exposure, Mixes biochar deeper
- Particle size distribution is critical as part of bulk density and Ksat modifications
- Biochar functions as an aggregate in the soil prior to microbial aggregation begins
- Biochar must be moistened to increase density in order to mix thoroughly into soil profile

DelDOT Highway Shoulder In-Situ Treatment

Biochar in Stormwater Management

In-Situ Soil Restoration

Do Not Turn the Soil

Damages soil profile, structure, soil organic carbon and microbial community further impacting restoration efforts.

Many States have requirements to repair impacted soils from construction -

The technique involves the **excavation or tilling of the compacted soils** and amending the tilled soils, typically with compost. (Maryland, June 2020)

...tilling, which **involves the digging, scraping, mixing, and ripping of soil** with the intent of circulating air into the soil mantle in various layers (Pennsylvania, December 2006)

USE SUBSOILER WHERE POSSIBLE

- **Slices, Lifts and Fractures Soils Hardpan**
- **Improves aerobic conditions through Air/Water Exchange**

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Standards &
Specifications
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Photo Credit – Pacific Biochar

Biochar in Stormwater Management

Standards Specification/Special Provisions

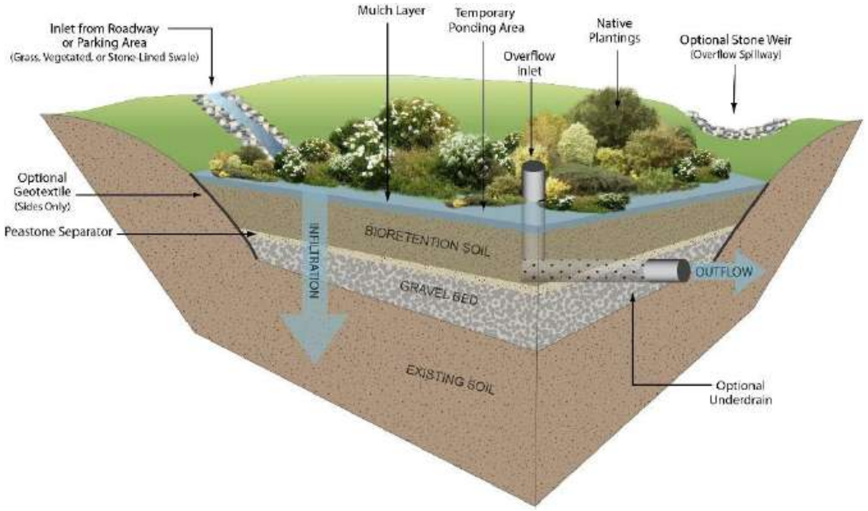
- Lack of Biochar Standard Specifications (SS) has limited the adoption & wide-spread consistent use nationwide.
- Numerous DOTs have invested in biochar research (DelDOT/MDOT/NCDOT (Nutrients/Runoff Reduction), CalTrans (Metals), VDOT (Salt) conducted pilot and demonstration projects using biochar. None have yet committed to developing SS.
- DOTs are the best agency to lead the efforts on a State level.
- MNDOT team currently developing SS for biochar which will benefit other DOTs.
- Engineered media/composts blends are a good starting point.
- Special Provisions (SP) is best option for projects until SS are approved.
- SPs are best for special situations like in-situ soil modifications due to site variability.


mn DEPARTMENT OF TRANSPORTATION

STANDARD SPECIFICATIONS FOR CONSTRUCTION

2020 EDITION

VOLUME 1



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Biochar in Stormwater Management

Special Provisions

- Clearly define the Special Provision Purpose
- Biochar Requirement - IBI Biochar Certification and/or lab results that meet IBI certification including PAHs, Dioxins/Furans and PCBs.
- IBI Biochar Certification ensures feed-stock sustainability. Without the certification have supplier provide proof
- Biochar Characteristics – Remember biochar's are not created equal. Specify what is best fit not what is local. Local is a bonus
- Clearly define biochar physical/chemical/Particle Size Distribution requirements
- Establish Sequence of Construction - Means & Methods can be recommended via onsite oversight or as design/build
- Provide method of measurement and basis of payment. Recommend CY or Incidental NOT tons unless using a high ash char.

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BIOCHAR ENHANCED BIOREACTOR
SPECIAL PROVISION

Description: This work consists of furnishing and installation of a biochar enhanced bioreactor in accordance with this specification, notes and details on the plans. Biochar consists of a solid carbon-based material obtained from thermo-chemical conversion of biomass in an oxygen-limited environment.

The biomass feed-stocks shall be limited to the woody by-products from forestry operations, including cut residues left after a timber harvest, cut trees that are not marketable as lumber and wood chips from biomass reduction operations (i.e. power-line maintenance) and urban tree management operations.

The biomass feed-stocks shall not be sourced from post-consumer or post-industrial sources treated with any paint, sealer or potentially toxic chemical. Biochar must have an International Biochar Initiative (IBI) Certification and/or has been tested using the IBI Biochar Standards (23 November 2015) for Testing Category A (Basic Utility) and Category B (Toxicant Assessment) properties. As part of Category B testing, Polycyclic Aromatic Hydrocarbon (PAHs), Dioxins/Furans (PCDD/Fs), and Polychlorinated Biphenyls (PCBs) results must be provided upon request.

Materials: Biochar shall conform to the following requirements:

Criterion	Requirements	Test/Method	
Bulk Density	<10 lb/cu ft		
Organic Carbon	>80%	Proximate Analysis (ASTM D1762-84)	
Total Ash	<10%	Proximate Analysis (ASTM D1762-84)	
Hydrogen/Carbon (H:C)	<0.5 Molar Ratio		
pH Value	<10	4.11USCC:dil.Rajkovich	
Electrical Conductivity	Report	4.11USCC:dil.Rajkovich	
Surface Area Correlation	>400 m2/g dry	McLaughlin, Shields, Jagiello & Thiele's 2012 paper	
Liming (CaCO3)	Report	AOAC955.01	
Carbonates (CaCO3)	Report	AOAC955.01	
Particle Size Distribution			
<0.5mm	<5%	0.5-1 mm	<5%
1-2 mm	30-40%	2-4 mm	40-60%
4-8 mm	<5%	>8 mm	0%

Sequence of Construction (SOC):
SOC shall be in accordance with all specifications, notes and details on the plans and as follows:

Method of Measurement:
The quantity of biochar placed and accepted on a/an **[per cubic yard basis, or incidental to the installation.]**

Basis of Payment:
Biochar Amendment will be paid at a **[contract lump sum price, per cubic yard or incidental]**. Price and payment will constitute full compensation for furnishing all labor, tools, equipment, and materials necessary to complete the work.

Thank You

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