Soil Amendment for Water Quality

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National Fish and Wildlife Foundation
Project Spotlight Seminar Series
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Overview

• Standard grading & topsoiling practices disturb and compact healthy urban soils

• Adapt soil decompaction and amendment to restore hydrologic & ecological landscape services

• Technical, commercial, & institutional feasibility

• Produces superior sustainable landscaping by restoring *ecosystem services of soil column*

• Transferable and transformative with appropriate credit, inspection, and maintenance protocols
Bay-Wise Landscapes

- **Plant vigor**
- **Infiltration Rate**
- **Plant Available water**
- **Bulk Density**
- **Organic Matter**
- **Plant avail. nutrients**
- **Root depth / density**
- **Bacterial / Fungal Activity**

**Sparse**
- Dense: High
- Low: High
- Limited: High
- High: Low
- Limited: High
- Low: High
- Shallow: Abundant, organic
- Low: Deep, dense
- Low: High / Active

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**Standard Topsoiling**

**Suburban Subsoiling**
Root-Limiting Soil Strength (BD)
Dense turf cover growing in thatch layer.
Design Sustainable Chesapeake Bay Landscapes

- Avoid disturbance and compaction
  Limit disturbance and vehicle traffic

- Minimize Disturbance and Compaction
  Light weight equipment
  Wide low pressure tires
  Avoid wet soil conditions

- **Restore Disturbed Compacted Soils**
  Suburban Subsoiling
  Complete Cultivation
  Loose Tipping
Suburban Subsoiling
adapting agricultural subsoiling practices to the urban landscape

Yorkwood Elementary School
Baltimore City impervious area removal project
Suburban Subsoiling

- Deep ripping
- Compost amendment
Standard topsoiling

Suburban subsoiling
Sunday 30 March 2014

>30x more runoff!
Decompress & Amend Soil Profile – *not just soil surface*

MD-SHA Taneytown, MD
ICC Mitigation project with Montgomery Parks
Complete Cultivation – Adapted From Open Pit Mine Reclamation

1. Strip top layer. This may be accomplished in two or more passes 15 to 25 cm in thickness depending on friability. Cultivate in an arc to a final working width of between 7 to 8 metres.

2. Place the spoil in front of the void. Drop material from height to further assist the break up. Large lumps may require further breaking up at this stage. Repeat [1] until final working width of between 2 to 4 metres is accomplished.

3. On completion of working width the next stage can be started. Cultivate second layer to required depth. If friable this may be broken up by simply lifting and raking the spoil. Long teeth on the bucket can assist in the breaking up process.

4. If material is not friable, scrape in 15 to 25 cm layers; lift and drop to assist break up. Spoil is replaced directly into the bottom of the void. Cultivate entire working length lifting spoil and dropping to increase the cultivating effect.


6. The finished profile.

Figure 2 Profile strip method (from Reynolds, 1999).

Reproduced courtesy of the Forestry Commission. © Crown Copyright.
Complete Cultivation + Compost
Standard Treatment: Rototill + fertilizer
<table>
<thead>
<tr>
<th></th>
<th>Yorkwood Elementary</th>
<th>SHA Taneytown</th>
<th>Turf Valley Country Club</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS</td>
<td>ST</td>
<td>SS</td>
</tr>
<tr>
<td>Infiltration (in/hr)</td>
<td>4.87 vs 0.05</td>
<td>3.25</td>
<td>7.55</td>
</tr>
<tr>
<td>Bulk Density (g/cc)</td>
<td>1.20 vs 1.61</td>
<td>1.25</td>
<td>1.71</td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>8.3 vs 3.4</td>
<td>9.39%</td>
<td>3.09%</td>
</tr>
</tbody>
</table>
Findings & Lessons Learned

• Means and Methods Matter!  
  \textit{Not your father’s rototiller!}

• Restore porous permeable organic soil profile – not just a planting bed!

• Rapid Vegetative Stabilization – essential for SEC, but \textit{not sufficient}

• Yields \textbf{Superior Sustainable Landscaping}

• Quantify hydrologic services by Rv or ECN 
  Journal of Hydrology 543:770-781
Findings & Lessons Learned

• Feasible with incremental changes in current practice
• Reduced Irrigation & Fertilizer = Short pay-back period
• Cost-effective when properly staged
• Life-Cycle costs superior now for long-term institutional land owners
  (e.g. transportation ROW, DOT, DOD, etc.)
• Revised compost specifications (maturity) for soil husbandry vs. fertilization
Next Steps (Institutional Feasibility)

• Consistent Site-Specific Credit
  - Rv or Effective Curve Number (ECN) for Sustainable Sites initiative (SSI)

• Inspection and Maintenance Protocols
  - just like every other BMP!
  - deep tyne hollow core aeration & topdressing
Conclusion

• Hydrologically Impoverished Pervious landscapes are ubiquitous in the urban environment - *by design*

• Urban Soil Husbandry can restore hydrologic function

• Superior Sustainable Landscaping & Hydrologic Services

• Transferable and transformative with appropriate credit, inspection, and maintenance protocols
Bay-Wise Landscapes

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**Standard Topsoiling**
- Sparse
- Low
- Limited
- High
- Low
- Limited
- Shallow
- Low

**Suburban Subsoiling**
- Dense
- High
- High
- Low
- High
- Limited
- Deep, dense
- High / Active
Thanks!

Questions?
Reducing Stormwater Volume and Nutrients with Biochar

University of Delaware Faculty and Students
  • Paul Imhoff, Pei Chiu and Julie Maresca
  • Joseph Brown and Sriya Pant

Collaborators
  • Chuck Hegberg, reGENESIS Consulting Services, LLC
  • Larry Trout, RK&K, Inc.

Supporting Partners
  • Delaware Department of Transportation
  • Maryland Transportation Authority
  • City of Charlottesville, VA
Historical Data

- Biochar addition to Terra Preta soils of Amazon Basin
Hypothesis

- Large pore volume
- Increase water retention
- Capture “first flush” of runoff
- High CEC & surface area
- Adsorb nitrogen compounds
- Reduce effluent concentration

- Enhance retention of nitrogen and water in the soil zone
- Increase rates of infiltration and chemical transformations
University of Delaware Research

- Laboratory studies – biochar’s influence on
  - Soil hydraulic properties – NFWF study
  - Nitrogen fate
- Field studies – biochar’s influence on
  - Bioretention media
    - Water retention
    - Nitrogen removal
  - Roadway soils – NFWF study
    - Reduction in runoff volume and peak flows
    - Nitrogen removal
Design

- Selection of field site – intersection of DE 896 and Bethel Church Road
Design

- Roadway soil amendment
  - Amend top 30 cm with 4% by mass wood-based biochar
  - Measure runoff volume and quality

- Bioswale amendment
  - Amend top 30 cm with 4% by mass wood-based biochar (base)
  - Amend top 30 cm with 4% by mass wood-based biochar (side slopes)
  - Measure in situ water volume and quality

- 1.3 acres treated region
Roadway Soil Amendment

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

Roadway site in Delaware also in Chesapeake Bay Watershed
Field Study – Roadway Soils
Field Study – Roadway Soils
Biochar amended soil attenuates peak flow ~ 50-60%
Field Study – Roadway Soils

Typical Storm – Water Flow

Biochar amended soil attenuates runoff volume by ~ 70%
Field Studies – Roadway Soils

Typical Storm – Water Quality

Storm 44: Area Flow Rates Log Scale

Water Flow Rate Log Scale (ml/s)

Date

9/19/2016 4:48

9/19/2016 12:00

Sampler 1
Sampler 2
Sampler 3
Roadway Runoff
Control
Biochar
Field Studies – Roadway Soils

Typical Storm – Water Quality

Biochar unexpectedly reduced nitrate concentrations
Field Studies – Roadway Soils

Storms in 2016

4% wood biochar addition reduced peak runoff rate by ~ 48%
Storms in 2016

4% wood biochar addition reduced runoff volume by ~ 75%
Why Reduction in Runoff?

Measurements of Hydraulic Conductivity with Disc Infiltrometer

Measurements for: biochar, control and undisturbed regions
Why Reduction in Runoff?

• Biochar increased mean $K_{sat}$ by approximately 30%, similar to increase observed in lab data

• Mean $K_{sat}$ in field approximately 3 times larger than lab measurements (identical bulk densities).
Why Reduction in Nitrate?

Biochar facilitates denitrification through electron storage

Electron storage capacity (ESC) of wood and grass biochar is up to 2 mmol e−/g (Klüpfel et al., 2014).

Results from Bioretention Study

- **Biochar increased nitrate removal by between 60% and 370% over the standard bioretention media, depending on season.**
Lessons Learned

• Construction design longer than anticipated

• Difficulty with soil heterogeneity – removal of cobbles required

• Dry soil conditions – delayed biochar addition

• Training in use of samplers/analysis equipment longer than anticipated

➢ In-house analysis of ammonium, nitrate, nitrate, total nitrogen, total organic carbon, and total suspended solids
Conclusions

• Biochar amendments can significantly improve hydraulic properties for SOME soils

• Reductions in runoff volume and peak flow consistent with increases in saturated hydraulic conductivity

• Reductions in nutrient concentrations in stormwater unexpected – ongoing data collection

• Future work must evaluate longevity and cost-effectiveness of treatment
Thank You
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