Building Soil Organic Matter with Biochar: What are the connections between carbon sequestration and soil health? (and what are some opportunities for use in the forestry sector?)

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A little about me...

USDA Forest Service
Rocky Mountain Research Station

- Soil productivity
- Harvesting
- Fire
- Sustainability
- Decomposition
- Soil monitoring
Collaborators

- National Nursery Specialist
- University of Idaho, Michigan Technological University, University of Montana, Humboldt State University, Washington State University
- National Forests – Umpqua, Umatilla, Bitterroot, Idaho Panhandle, Beaverhead-Deerlodge, Humboldt-Toiyabe, Caribou Targhee
- Forest Products Lab
- Agricultural Research Station (Kimberly, ID; Florence, SC)
- Curlew National Grasslands
- Bureau of Land Management
- Cool Planet, Phoenix Energy
This talk will cover....

- Why is soil so important?
- What can go wrong with land applications?
- What’s right?
- Tree growth, forest nurseries, and biochar
To fix the climate, fix the soil!

Decades of soil overuse

• Intensive agriculture
• Deforestation
• Excess trafficking
• Invasive species

The Soil Fix!

• HEALTHY SOIL: most effective natural system for C sequestration
• Soils store about 3,000 billion metric tons of C
  • Double the amount stored in vegetation and the atmosphere combined
Soil considerations or... fun soil organic matter facts!

- Mineral Soil is ~5% organic matter
- More than 50% of soil OM has been lost from various ecosystems around the globe
- Loss of OM leads to reduced CEC, water retention, nutrient supply/retention
- Loss of OM is correlated with nutrient depletion – especially in tropical soils
- Overall reduced productivity with OM loss
Organic matter is the foundation of soil and ecosystem restoration

Soil services
- Less dust
- Less sediment
- Greater productivity
- Healthy ecosystem

Soil Function
- Cycle nutrients
- Regulate water
- Support plants
- Filter pollutants
- Support structures

Organic matter & soil properties
- Soil Biology
- pH
- Infiltration rate
- Water holding capacity
- Soil structure
- Buffer contaminants & Salinity
Soil resiliency: It’s all about organic matter

- Response to OM additions varies by soil texture
- Biochar contributes a recalcitrant form of carbon
- Other organic amendments contribute labile organic matter
- Both types can increase water (nutrient) holding capacity

Every 1% increase in soil organic matter results in up to 234,000 additional liters/hectare (25,000 gallons/acre) of available water!
Biochar in forest ecosystems

• Char is common in fire-adapted ecosystems
• Fire suppression decreased charcoal inputs
• Charcoal holds nutrients and water for microbes
• Biomass removal (restoration thinnings) decreases the likelihood of fire occurring
• Applying biochar as a co-product of pyrolysis removes wildfire hazard and retains or restores soil ecosystem function
What could go wrong?

• Sorption of limited available nutrients
• Dilution of limited native nutrients
• Pyrolysis oils contaminate sites
• Not all biochar is equal (or useful)
  • Wrong pH
• Naturally hydrophobic
### What could go wrong? Feedstock differences

<table>
<thead>
<tr>
<th>Source of raw material</th>
<th>Biochar pH</th>
<th>Biochar electric conductivity (µs/cm)</th>
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<tbody>
<tr>
<td>Fire salvage (Umpqua National Forest)</td>
<td>8.1</td>
<td>103</td>
</tr>
<tr>
<td>Fire salvage (Bitterroot National Forest)</td>
<td>7.5</td>
<td>136</td>
</tr>
<tr>
<td>Cedar</td>
<td>8.7</td>
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<tr>
<td>Madrone</td>
<td>4.9</td>
<td>789</td>
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<tr>
<td>Mixed conifer slash pile</td>
<td>8.1</td>
<td>91</td>
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<tr>
<td>Oak</td>
<td>7.9</td>
<td>181</td>
</tr>
<tr>
<td>Scotch broom</td>
<td>7.5</td>
<td>234</td>
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<tr>
<td>Hog fuel</td>
<td>7.4</td>
<td>319</td>
</tr>
</tbody>
</table>
On the positive side:

Biochar can...

• Sequester Carbon
  • Wood: C content of ~ 50%. Biochar: C content of ~70-80%
  • Mostly permanently sequester C (some say 1000’s of yr others say 100’s),
  • wood releases CO₂ as it decomposes

• Biochar may reduce N fertilization requirements

• Reduce methane production and other GHG’s

• Improve water holding capacity

• Increase symbiotic N-fixation
Opportunities to use biochar in forestry, range or mine soils?
Forest tree response to biochar
Thinned stands (big trees)

- 4 replicates
- 7 treatments
  - Masticated wood, fertilizer, 2 levels of biochar (with and without biochar), control
- No significant differences
Change in soil moisture—Bitterroot National Forest

![Graph showing soil moisture percentages for different treatments including Control, Slash retention, Fertilizer, 1.25 Biochar, 10 Biochar, 1.25 Biochar + Fert, 10 Biochar + fert.]
Not big trees
Small native plants/trees: Biochar added to nursery media

- Biochar can be added to or replace peat
- Biochar used to enhance nursery media properties
  - Adjust fertilizers
  - Reduce leaching
- Sequester C during outplanting
- Enhance seedling growth (boreal forests)
- Increase ectomycorrhizae
- Up to 25% biochar in plugs
Nursery soils and biochar

- Two species (long leaf and shortleaf pines)
- 4 replicates
- 6 treatments
  - 0, 2, 5, 10, and 20% biochar plus 1 in-soil treatment
- 15 seedlings/treatment
Longleaf seedling response to biochar

Cool Planet biochar

Mixed conifer biochar
Mine land restoration opportunities

• Approximately 160,000 abandoned mine sites in the western US
• Build OM using a mix of available products: biochar, wood chips, and biosolids
• Restoration of gas and oil pads (1.7 million wells in the U.S.)
• Capture toxic chemicals (mercury, lead, etc.)
Rangeland restoration opportunities

• Restoration of rangelands for increased forage
• Use piñon-juniper to create biochar
• Combine seeding with planting local species
• Extend plant growing season (lessen drought)
• Sequester C
Specialty markets

• **Food products (non-activated or activated charcoal)**
  • Drinks (Black Sand cocktails)
  • Pills to aid digestion

• **Beauty products (activated charcoal)**
  • Face masks
  • Cleansing gels
  • Shampoos
  • Soaps
  • Tooth paste
Summary

• Soil organic matter is important for healthy forests and range sites
• Biochar can increase soil organic matter and increase ecosystem services
• Soils matter (can you dig it?) – to fix the climate we must fix the soil
• Tree responses are small but other ecosystem services increase
Thank you

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