Influence of Biochar Additions on Net Greenhouse Gas Production

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Biochar Research

- Benefits of biochar additions to oxisol soils are known

- What happens for other soils with the addition of biochars?
Biochar Research

• Part of new ARS multi-location Biochar and Pyrolysis Initiative

• 6 ARS locations:
  
  Ames, IA; Kimberly, ID; St. Paul, MN;
  Big Spring, TX; Florence, SC; Prosser, WA.

• Continuous corn (same crop for comparison)

• In addition to following crop yield and soil carbon:
  
  ✓ Soil gas concentrations and trace gas fluxes
  ✓ Continual subsurface CO$_2$ measurements (25 cm)
Rosemount Biochar Field Trials

• Small scale triplicate plots (16’ x 16’) largely due to the limited availability of biochar.
  (Application rate : 20,000 lbs/acre)
  • Fast pyrolysis biochar (sawdust, CQuest™ Dynamotive¹)
    • With and without manure addition (5,000 lb/acre)
  • Slow pyrolysis biochar (woodchip, Best Energies¹)
  • Slow pyrolysis biochar (macadamia nut, Biochar Brokers¹)

• Larger strip plots (16’ x 93’)
  • Hardwood charcoal (ground lump charcoal, Kingsford¹)
  • Slow pyrolysis biochar (macadamia nut, Biochar Brokers¹) (3 rates: 5,000, 10,000 and 20,000 lb/acre)

¹-Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.
Laboratory Studies

- 16 different biochars evaluated
- 7 different biomass parent materials
<table>
<thead>
<tr>
<th>BC #</th>
<th>Parent Material</th>
<th>Source</th>
<th>Pyrolysis Temp (°C)</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>Ash</th>
<th>Surface Area (m² g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Corn stover</td>
<td>Best Energies</td>
<td>815</td>
<td>45</td>
<td>0.5</td>
<td>1</td>
<td>55</td>
<td>4.4</td>
</tr>
<tr>
<td>2</td>
<td>Pine wood chip</td>
<td>EPRIDA</td>
<td>465</td>
<td>75</td>
<td>0.3</td>
<td>9</td>
<td>6</td>
<td>0.1</td>
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<tr>
<td>3</td>
<td>Peanut hulls</td>
<td>EPRIDA</td>
<td>481</td>
<td>59</td>
<td>2.7</td>
<td>12</td>
<td>15</td>
<td>1.0</td>
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<td>4</td>
<td>Corn stover</td>
<td>R. Brown – Iowa State</td>
<td>500</td>
<td>25</td>
<td>0.6</td>
<td>5</td>
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<td>11</td>
<td>54</td>
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<tr>
<td>6</td>
<td>N/A</td>
<td>Char C Group (Biosource™)</td>
<td>465</td>
<td>43</td>
<td>2.2</td>
<td>N/A</td>
<td>N/A</td>
<td>63.5</td>
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<tr>
<td>7</td>
<td>Turkey manure Woodchip</td>
<td>SWROC-Univ. of MN</td>
<td>850</td>
<td>1</td>
<td>0.1</td>
<td>3</td>
<td>89</td>
<td>4.8</td>
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<tr>
<td>8</td>
<td>Hardwood</td>
<td>D. Laird (USDA-ARS)</td>
<td>N/A</td>
<td>69</td>
<td>0.7</td>
<td>9</td>
<td>14</td>
<td>19.2</td>
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<tr>
<td>9</td>
<td>Pine woodchip</td>
<td>EPRIDA</td>
<td>465</td>
<td>71</td>
<td>0.2</td>
<td>11</td>
<td>9</td>
<td>0.2</td>
</tr>
<tr>
<td>10</td>
<td>Peanut hulls</td>
<td>EPRIDA</td>
<td>481</td>
<td>60</td>
<td>0.9</td>
<td>10</td>
<td>15</td>
<td>286</td>
</tr>
<tr>
<td>11</td>
<td>Corn stover</td>
<td>EPRIDA</td>
<td>505</td>
<td>66</td>
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<td>4</td>
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<td>0</td>
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<tr>
<td>13</td>
<td>Coconut shells (Activated)</td>
<td>Willinger Bros.</td>
<td>450</td>
<td>83</td>
<td>0.4</td>
<td>0</td>
<td>12</td>
<td>960</td>
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<td>14</td>
<td>Woodchip (pellet)</td>
<td>Chip Energy</td>
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<td>69</td>
<td>0.1</td>
<td>20</td>
<td>5</td>
<td>24</td>
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<td>15</td>
<td>Hardwood lump charcoal</td>
<td>Kingsford</td>
<td>538</td>
<td>53</td>
<td>0.4</td>
<td>10</td>
<td>27</td>
<td>7.2</td>
</tr>
<tr>
<td>16</td>
<td>Macadamia shells</td>
<td>Biochar Brokers (EternaGreen™)</td>
<td>N/A</td>
<td>84</td>
<td>0.6</td>
<td>2</td>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Weathered impact

Weathered char (1 yr on outdoor storage pile):
- Minor changes in composition data (loss of N)
- Major change in surface area (286x)

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<tr>
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<td>481</td>
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<td>12</td>
<td>15</td>
<td>1.0</td>
</tr>
<tr>
<td>10</td>
<td>Peanut hulls (weathered)</td>
<td>481</td>
<td>66</td>
<td>0.9</td>
<td>10</td>
<td>15</td>
<td>286</td>
</tr>
</tbody>
</table>
Impact of degassing treatment on surface area

- Samples were degassed for 3 hrs at a temperature of 300 and 400 °C

<table>
<thead>
<tr>
<th>Parent Material</th>
<th>Surface Area (m² g⁻¹: 300 °C)</th>
<th>Surface Area (m² g⁻¹: 400 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut shells (activated charcoal)</td>
<td>960</td>
<td>976</td>
</tr>
<tr>
<td>Wood pellets</td>
<td>62</td>
<td>177</td>
</tr>
<tr>
<td>Hardwood lump charcoal</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>Macadamia shells</td>
<td>0.4</td>
<td>7</td>
</tr>
<tr>
<td>Hardwood chips</td>
<td>24</td>
<td>66</td>
</tr>
<tr>
<td>Sawdust (pine)</td>
<td>0.8</td>
<td>46</td>
</tr>
</tbody>
</table>

Increase in surface area: 2.5 to 57 times
Laboratory Incubations

Soil incubations used to assess the impacts of these 16 different biochars with soils from 3 different ecosystems:

- Minnesota agricultural soil
  - Waukegan silt loam
- Wisconsin forest nursery soil
  - Vilas loamy sand
- California landfill cover soil
  - Marina loamy sand
Assessment of Gas Production

• 5 g of soil mixed with 0.5 g biochar (10% w/w)
• Headspace periodically monitored with GC/MS.
• Production rates estimated from the change in concentration with time.
• Length of incubations 25 – 100 days
• Requirement: $O_2$ concentrations >15%
Biochar CO$_2$ Production
Biochar CO₂ Production

Red line represents average soil basal respiration (3 soils) 8 above; 7 below; and 1 no difference
Methane: Biochar alone

- Dry
- Wet (1 ml H2O/0.5 g)
Only 3 biochars were significantly different than control (no char) – 1 produced N$_2$O and 2 consumed N$_2$O (sorption or denitrification?)
Ethane and Ethylene Production

BC-16 macadamia shell biochar

- Observable production of ethane and ethylene...as well as other hydrocarbons (not currently identified)

- Production rates:
  - Ethane: $200 \pm 4.7 \text{ ng } C_2H_6 \text{ g}_{\text{char}}^{-1} \text{ d}^{-1}$
  - Ethylene: $82 \pm 9.7 \text{ ng } C_2H_4 \text{ g}_{\text{char}}^{-1} \text{ d}^{-1}$

- In soils – reduced by 40 - 73%, potentially due to microbial oxidation
CO₂ Production
(ug CO₂ g soil⁻¹ d⁻¹)

Soil Control
BC-1
BC-2
BC-3
BC-4
BC-5
BC-6
BC-7
BC-8
BC-9
BC-10
BC-11
BC-12
BC-13
BC-14
BC-15
BC-16

Agricultural Soil
Forest Nursery Soil
Landfill Cover Soil
Soil Control BC-1

CH$_4$ Production (ng CH$_4$ g soil$^{-1}$ d$^{-1}$)

-25 -20 -15 -10 -5 0 5 10

Agricultural Soil

Forest Nursery Soil

Landfill Cover Soil

CH$_4$ Production/Oxidation (ng CH$_4$ g soil$^{-1}$ d$^{-1}$)

-4 -2 0 2 4 6 8

Uncorrected Corrected
Closer look at CH$_4$ oxidation
Landfill cover soil elevated CH$_4$ levels

15 biochars significantly reduced CH$_4$ oxidation; 1 non-significant decrease.
Conclusions

- Positive effect observed so far in laboratory
  - Reduction in $N_2O$ production potential

- No consistent trends in $CO_2$
  - Majority reduced basal $CO_2$ respiration

- Majority of biochars reduce $CH_4$ oxidation activity
  - Soil methanotrophs are the only known biological sink for atmospheric methane

- Preliminary lab results – field plot research is ongoing…
Not all biochars are the same:
Creation process, original feedstock, temperatures, etc..

Greenhouse gas production:
Complicated by biochar production, release, or sorption – this is particularly important for CO$_2$

Overall, greenhouse gas impacts function of both char and the soil
Acknowledgements

We would like to acknowledge the cooperation:

**Dynamotive Energy Systems** – Fast pyrolysis char through non-funded CRADA agreement

**Best Energies** – Slow pyrolysis char through a MTA agreement

Biochar Brokers, Chip Energy and David Laird for their assistance in acquiring various biochars.

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