Biochar’s impact on soil carbon sequestration and sustainability of crop residue harvesting for bioenergy

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# Effect of cultivation on SOC

Soil organic C in top 15 cm (6 inches) of adjacent native prairie and cultivated sites (across the fence)

<table>
<thead>
<tr>
<th>Site</th>
<th>Prairie (lb-C/Ac)</th>
<th>Agriculture (lb-C/Ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hayden</td>
<td>162,636</td>
<td>112,692</td>
</tr>
<tr>
<td>Chipera</td>
<td>151,500</td>
<td>60,820</td>
</tr>
<tr>
<td>Larson</td>
<td>130,785</td>
<td>72,801</td>
</tr>
<tr>
<td>Kalsow</td>
<td>127,659</td>
<td>84,694</td>
</tr>
<tr>
<td>Doolittle</td>
<td>95,255</td>
<td>63,938</td>
</tr>
<tr>
<td>Ketelsen</td>
<td>87,757</td>
<td>42,580</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>125,932</strong></td>
<td><strong>72,921</strong></td>
</tr>
</tbody>
</table>

Average difference = 53,011 lb-C/Ac  -42%
### Effect of residue removal on SOC

#### Soil Organic Carbon (%)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Grass</th>
<th>Fallow</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5</td>
<td>4.00</td>
<td>2.38</td>
<td>-40.6****</td>
</tr>
<tr>
<td>5-15</td>
<td>2.47</td>
<td>2.23</td>
<td>-9.5</td>
</tr>
<tr>
<td><strong>Chisel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5</td>
<td>2.95</td>
<td>2.47</td>
<td>-16.5****</td>
</tr>
<tr>
<td>5-15</td>
<td>2.78</td>
<td>2.47</td>
<td>-11.1****</td>
</tr>
<tr>
<td><strong>Plow</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5</td>
<td>2.71</td>
<td>2.45</td>
<td>-9.4***</td>
</tr>
<tr>
<td>5-15</td>
<td>2.72</td>
<td>2.32</td>
<td>-14.8****</td>
</tr>
<tr>
<td><strong>No-till</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5</td>
<td>3.17</td>
<td>2.58</td>
<td>-18.5*</td>
</tr>
<tr>
<td>5-15</td>
<td>2.67</td>
<td>2.60</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

Laird and Chang, 2013

After 19 years: >7.8 Mg-C ha\(^{-1}\)
**Biochar Literature**

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**Consensus**
- Sequesters C (>100 yr half life)
- Reduces soil bulk density
- Increases soil porosity
- Increases soil water retention
- Recycles nutrients
- Liming agent (most biochars)
- Increases nutrient cycling
- Enhances soil quality/health

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**Knowledge Gaps**
- Value proposition for farmer (Problem: ecosystems services discounted)
- Optimum management strategies (Problem: diverse soils/climates/crops)
- Defining/grading biochar quality (Problem: biochar diversity)
- System level LCAs (Problem: systems diversity)

**Solution:** Agronomic and Environmental modeling & field trials
Biochar impact on SOC:
(A) Column study, +/- manure, 500 days. 
(B) Field study, crop rotations. 
(C) Field study 6 rates of biochar.

Laird et al. 2010: Aller et al.


Priming

Slope (mg CO$_2$-C/day)

<table>
<thead>
<tr>
<th>Biochar treatment</th>
<th>Control</th>
<th>Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>8.89</td>
<td>8.95</td>
</tr>
<tr>
<td>C5</td>
<td>10.56</td>
<td>9.38</td>
</tr>
<tr>
<td>C10</td>
<td>12.10</td>
<td>9.99</td>
</tr>
<tr>
<td>C20</td>
<td>13.84</td>
<td>11.85</td>
</tr>
</tbody>
</table>

Difference in cumulative CO$_2$-C emissions between manure and no-manure columns for the same biochar level.

Rogovska et al. 2011
Negative Priming from Biochar

Biochar impact on soil organic C stocks (change between 2011 and 2017)

Large scale field trials in SW Iowa

Biochar C added in 2011 = 7.25 Mg ha\(^{-1}\)

New biogenic SOC = 6.75 Mg ha\(^{-1}\)

Change in soil C stocks 2011 to 2017 (Mg ha\(^{-1}\))

Blanco-Canqui et al., 2019
Residue required for sustainability (continuous corn)

Wilhelm et al., 2007, Agron. J.
Impacts on Soil Organic Carbon

% Soil Organic Carbon vs Years

- Residue returned

Biochar Additions and Residue Harvesting
Biochar Additions and Residue Harvesting

Impacts on Soil Organic Carbon

% Soil Organic Carbon

Years

0 20

Remove residue
Residue returned
SOC loss
Residue removed
Biochar Additions and Residue Harvesting

Impacts on Soil Organic Carbon

% Soil Organic Carbon

Years

0 20

Add Biochar

Biochar + residue returned

Residue returned

New SOC

Biochar C
Biochar Additions and Residue Harvesting

Impacts on Soil Organic Carbon

% Soil Organic Carbon

0 1 2 3 4

Years

0 20

Add Biochar
Remove residue

Biochar + residue removed

Residue returned

Biochar C

Biochar C
Vision for Pyrolysis Biochar-Bioenergy Industry

Local pyrolyzer → Bio-crude sugar → Renewable energy → CBOT carbon trading

Bio-crude sugar → Biochar → Cellulosic biomass

Cellulosic biomass → Perennial biomass on HEL → Riparian buffer

Riparian buffer → Improve water quality

Cellulosic biomass → Mitigate climate change

Mitigate climate change → Build soil quality

Build soil quality → Mitigate climate change

Mitigate climate change → Reduce nutrient leaching

Reduce nutrient leaching → Recycle nutrients

Recycle nutrients → Grain

Grain → Grain market

Grain market → Feed the world

Feed the world → Jobs and entrepreneurial opportunities strengthen local economies