The Case for Biochar

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Amazonian *Terra preta*

*Terra preta* (dark earth) soils
- High plant productivity
- High organic carbon
- stable char (black carbon)

Source: www.biochar-international.org
Recreate *Terra preta*?

Pyrolysed biomass as a soil amendment

*Source: Adriana Downie Pacific Pyrolysis*
Dynamotive - fast-pyrolysis

Splainex – Waste Pyrolysis

EEA Continuous Flow System - scrap tyres

Pacific Pyrolysis
Figure Key:
frequency distribution all samples

Feedstock groups:
minimum - average - maximum
- Grass
- Wood
- Bovine-manure
- Poultry-litter
- Green-waste

National Biochar Initiative: E Krull CSIRO
Terrestrial Carbon Cycle

Photosynthesis → Particulate carbon → Humification → Humified carbon → Labile carbon: Microbial biomass, Soluble C → Respiration → Atmosphere

Humification

Charcoal

After J. Skjemstad, CRC Greenhouse Accounting
0.5% to 8.9% of biochar C mineralized over 5 years.
Biochar stability - a function of feedstock and pyrolysis conditions

BP Singh et al. 2012 (EST)

Pyrolysis temperature

Least stable (~100 years)
- 550°C leaf (A)
- 550°C poultry (A)
- 550°C cow (A)
- 400°C wood (A or NA)
- 400°C leaf (A)
- 550°C paper sludge (A)??
- 400°C manures (poultry, cow) (NA)

Most stable (~2000 years)
- 550°C wood (A or NA)

Carbon content

Fused aromatic rings

Mineral nutrient content

Synthesis: “after E. Krull”
Biochar can reduce soil $\text{N}_2\text{O}$ emissions

BP Singh et al. 2010 (JEQ)
Nitrous oxide measurement
### N₂O emissions

**Graph:**
- Y-axis: N₂O (kg.ha⁻¹.hr⁻¹)
- X-axis: Dates from 09 Dec to 03 Feb
- Three lines represent different treatments:
  - Biochar + Urea
  - Urea
  - Poultry litter
- Rain (mm) is shown on the bottom X-axis.
- Temperature (°C) is shown on the bottom X-axis.

**Table:**
<table>
<thead>
<tr>
<th>Treatment</th>
<th>N₂O-N (kg.ha⁻¹)</th>
<th>Calculated Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochar + Urea</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Urea</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>4.9</td>
<td>8.4</td>
</tr>
</tbody>
</table>

**Additional Information:**
- Standard error = 1.0
- Least significant difference (5% critical value) = 2.5

Biochar impact on soil porosity

% biochar | Percent (%) connectivity of largest pores
<table>
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<tbody>
<tr>
<td></td>
<td>Sept 2011</td>
<td>April 2012</td>
<td>Increase</td>
</tr>
<tr>
<td>0</td>
<td>55.7</td>
<td>68.1</td>
<td>12.4</td>
</tr>
<tr>
<td>1</td>
<td>70.1</td>
<td>81.4</td>
<td>11.3</td>
</tr>
<tr>
<td>5</td>
<td>93.8</td>
<td>94.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

National Biochar Initiative: Peter Quin et al UNE/NSW DPI
Cumulative priming of soil C by biochar

Singh & Cowie (Unpublished)

- Biochar initially enhanced mineralisation of native soil C
- Native soil C was stabilised as biochar aged
GHG mitigation benefits of biochar

- Delayed decomposition of biomass
- Reduced nitrous oxide emissions from soil
- Increased soil organic matter
- Avoided fossil fuel emissions due to use of syngas as renewable energy
- Increased plant growth, plant health
- Avoided emissions from N fertiliser manufacture
- Reduced fuel use in cultivation, irrigation
- Avoided methane and nitrous oxide emissions due to avoided decay of residues
Life cycle GHG emissions

Maize
Wheat

kg CO2-e/kg biochar

Factors contributing to mitigation

Greenwaste biochar applied to canola

Poultry litter biochar applied to broccoli
Interactions between herbicide and biochar

- 0% biochar
- 0.5% biochar
- 1% biochar

Ryegrass dry mass (mg pot⁻¹) vs Atrazine (kg ha⁻¹)

Calcarosol (SA)

Ferrosol (NSW)

National Biochar Initiative, Rai Kookana CSIRO
Contamination risk?

Feedstock groups:
- minimum
- average
- maximum

Grass
Wood
Animal wastes
Food wastes
Sustainability issues for biochar – direct (1)

- Biomass procurement
  - Residues:
    - Soil erosion
    - Soil compaction
    - Nutrient depletion
    - Soil carbon loss (GHG, productivity impact)
  - Purpose grown:
    - Water use
    - Biomass and/or soil carbon decline
    - GHG balance - N$_2$O emissions
Biochar production
- GHG emissions
- particulate emissions

Biochar application
- dust
- contamination (if feedstock contaminated)

Whole system:
- net mitigation benefit (incl transport, plant construction)
- Compared with reference use
Sustainability issues for biochar – indirect

Indirect land use change – Deforestation
- GHG emissions: loss of biomass carbon, soil carbon
- Biodiversity
- Air pollution
- Water quality

Social – community displacement, food security

Economic – competing uses of biomass
How can we encourage sustainability?

Sustainability framework approach:

- Institutional systems:
  - Regulation
  - Incentives
  - Standards
    - Guidelines
    - Certification
- Monitoring, assessment and reporting
  - Criteria and Indicators
- Adaptive management
What do we know about biochar?

- Biochar can increase plant yield
  - But not all plants / all soils
- Biochar is resistant to decomposition
  - But some biochars are more resistant than others
- Biochar can reduce nitrous oxide emissions
  - But not from nitrification
- Biochar can deliver net greenhouse gas mitigation
  - Other options may give greater mitigation; each situation must be assessed separately
- Biochar could contaminate soil
  - But only if made from contaminated feedstock
- Some unintended consequences
  - Biochar can reduce efficacy of herbicides
Biochar can...

- Contribute significantly to climate change mitigation
- Enhance agricultural productivity
- Restore degraded soils

BUT ONLY IF

- produced in a facility that controls emissions and harnesses heat for efficient beneficial use
- applied with care, to responsive soil type / crop
- made from sustainably harvested and renewable biomass resources
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More information:
International Biochar Initiative
http://www.biochar-international.org/