Potential Use of Biochar to Drawdown Atmospheric Carbon: A Preliminary Assessment for Washington State

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Biochar 2016
Corvallis, OR
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Overview

- Considerations for Drawdown of Atmospheric CO$_2$
  - Carbon Cycle Mechanisms
  - Evidence of Past Drawdown

- A Modern Drawdown Approach Using Biochar
  - Waste Woody Biomass in WA State
  - Conversion of Existing Capital Stock
  - Efficiency Relative to Biomass Combustion
  - Expected Net Drawdown
Average Temperature -80°F

Mars

Average Temperature 57°F

Earth

Source: NASA
Anthropogenic Climate Change has not always been a bad thing . . .

Ruddiman et al., 2007
Global Carbon Cycle

IPCC (2013), WG1 AR5 Chpt. 6
### The whale in the room . . .

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<thead>
<tr>
<th>Reservoir</th>
<th>Carbon, Pg</th>
<th>Heat Capacity, ZJ</th>
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<tbody>
<tr>
<td><strong>Atmosphere</strong></td>
<td>852</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Terrestrial</strong></td>
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<td></td>
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<tr>
<td>Vegetation</td>
<td>610</td>
<td>0.0</td>
</tr>
<tr>
<td>Soil (2 m)</td>
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<td>Surface (200 m)</td>
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Ocean Heat Content

- Oceans absorb 93% of global heat increase
  - 7x more than all the energy consumed by humans in a year!
- Annual increase is about 4.5 ZJ
  - About 260 ZJ have been absorbed
  - Temperature in top 2000 m has risen by 0.1 °C
Ocean Carbon Chemistry

\[ \text{CO}_2 + \text{H}_2\text{O} + \text{CO}_3^{2-} \leftrightarrow 2 \text{HCO}_3^- \]

- Oceans absorb about half of anthropogenic CO\(_2\) emissions
- Absorption is REVERSIBLE (over course of decades to centuries)

IPCC (2013), WG1 AR5 Chpt. 6
The Little Ice Age

Hendrick Avercamp (ca. 1608) Winter landscape with ice skaters.
Evidence for a drawdown in the Americas 1500-1600 AD

Factors contributing to Little Ice Age:
1) Pandemic followed by reforestation in the Americas (1500-1600)
2) Eruption of Huaynaputina volcano in 1600
3) Lower Solar Radiation (Maunder Minimum, 1645-1715)

Nevle and Bird, 2008
# Estimates of Drawdown Size (Pg C)

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<td>Terrestrial</td>
<td>37</td>
<td>17</td>
<td>5-10</td>
</tr>
<tr>
<td>Ocean</td>
<td>-29</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>-8</td>
<td>-8</td>
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</tr>
<tr>
<td>Efficiency %</td>
<td>22</td>
<td>47</td>
<td>80</td>
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![Diagram of reforestation and biospheric C storage](image)

- Land area occupied by indigenous agriculturists circa 1491 A.D. (~1.8 x 10^7 km^2)
- Area of reforested land required for biospheric C storage
  - 38 Gt C biospheric uptake (Joos et al., 1999)
  - 20 Gt C biospheric uptake (Faust et al., 2006)

Land available for reforestation due to abandonment by 35-90 x 10^6 people (1 ha/person)
The Lowdown on Drawdowns

“It is thus virtually certain that the removal of CO$_2$ by carbon dioxide removal methods (CDR) will be partially offset by outgassing of CO$_2$ from the ocean and land ecosystems. Therefore, returning to pre-industrial CO$_2$ levels would require permanently sequestering an amount of carbon equal to total anthropogenic CO$_2$ emissions that have been released before the time of CDR, **roughly twice as much** the excess of atmospheric CO$_2$ above pre-industrial level . . .”

IPCC (2013), WG1 AR5, Chapter 6, p. 546-547.
Biochar: A Better Way to Draw Down CO$_2$

- No pandemic required!
- Multiple benefits
  - Rural Economic Development
  - Enhanced Agricultural Production
  - Water Use Efficiency
  - Forest Health
  - Filtration of Contaminants
  - Climate Change Mitigation
A State Level Approach: Washington State

- Large agricultural land area for incorporation
- Moderate soil fertility
- Adequate feedstock supply
- Need for more efficient irrigation methods
- Low carbon intensity of energy supply
Available Feedstock

5.8 M tons dry woody waste potentially available in WA
  - Logging, thinnings, mill residue, land clearing, orchard debris

3.3 M tons accounted for in 2010 solid waste survey
  - 0.9 M tons sent to landfill or incinerator
Possible Biochar Production Methods

✶ Pyrolysis (slow or fast pyrolyzers, absence of oxygen, 350-550°C, highest char yields and climate benefit, but technically complex and expensive)
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Possible Biochar Production Methods

- Pyrolysis (slow or fast pyrolyzers, absence of oxygen, 350-550°C, highest char yields and climate benefit, but technically complex and expensive)
- Gasification (small units with substoichiometric levels of oxidants, 600-1000°C, lowest char yields)
- Boiler Conversion (alteration of existing wood combustion units to minimize char oxidation to ash. This can be achieved by reducing the residence time of the char inside the boiler)
  - Simpler and more economical than some of competing options
  - Alter feedstock moisture content and particle size, oxygen ratio, and biomass residence time
  - Char yields potentially comparable to other options
  - Flexible, so can maximize energy or char production as needed.
Boilers in Washington State

- Two WA Ecology surveys have been done
  - 1997 survey of all wood-waste boilers
    - 85 wood-waste boilers in 1997
    - burned 3.3 M tons wood annually
    - other feedstocks burned about 1/3 of time
    - 72% in lumber/wood products, 22% in pulp/paper products
    - Primarily spreader-stoker and pile burner (Dutch oven, fuel cell) boilers; only 3 fluidized-bed boilers
  - 2009 survey of pulp/paper mill boilers only
    - 11 mills operational
    - Biomass boilers burn 1.4 M tons annually
    - Additional 0.3 M tons biomass needed to replace all fossil fuel
    - Mix of stoker-fired and fluidized-bed boilers
    - Recovery boilers use black liquor 2/3 of time, biomass for most of rest
Stoker-fired Boiler
Fluidized-Bed Boilers

Bubbling-Bed

Circulating
Biochar is twice as effective as bioenergy for climate change mitigation in Washington after Woolf et al. (2010)
Carbon Budgets and Assumptions

- Produced biochar contains 58% C
- 1.1 t C offset/t C fixed as biochar (energy and primary productivity enhancements)
- 1 t CO$_2$ offset requires 1.02 bdt biomass
- Available biomass suggests 1.3-2.2 Mt biochar produced annually
- 2.2 Mt/yr x 100 years = 0.52 Pg CO$_2$ offset
- = 0.07 ppm CO$_2$ drawdown (0.02-0.03 ppm after degassing)
Biochar storage capacity

- 50 t biochar C (86 t biochar) applied to top 15 cm of agronomic lands
- 86 t biochar * 3.1 Mha = 265 Mt biochar maximum storage capacity
- 220 Mt biochar produced over 100 years
- Washington has a 120-year capacity for biochar and a maximum offset of 0.62 Pg CO$_2$ (ca. 0.08 ppm)
- Application to forested and pasture lands (11 Mha) and at greater depths could increase total drawdown by as much as 10-fold.
Conclusions

- Drawdown of atmospheric CO$_2$ is essential, but will require removal of all emitted (i.e., ca. 500 Pg C) due to buffering from oceans and land stocks.

- Washington state is well-positioned to demonstrate large-scale economical production of biochar using existing boilers with slight modifications to maximize char production.

- This large-scale production could increase agricultural productivity, improve water-use efficiency, and stimulate a new industry.

- Total drawdown in Washington state over a century is on the order of 0.62 Pg CO$_2$, but could be as much as 6 Pg CO$_2$ with application to agronomic, forested, and pasture lands and development of deep injection technology.
**Acknowledgments**

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Anthropogenic Methane

Ruddiman et al., 2007
Anthropogenic Carbon Dioxide

Ruddiman et al., 2007