UNDERSTANDING AND USING BIOCHAR PRACTICE GUIDELINES DEVELOPED BY THE UMPQUA BIOCHAR EDUCATION TEAM (UBET)

Kelpie Wilson
Wilson Biochar Associates

Part I: Production
AGENDA

1. Project Overview
2. Theory of Flame Carbonization
3. Simple Flame Carbonization Methods
4. Production Logistics
5. Biochar Job Estimating
On-farm production and use of biochar for composting with manure

- UBET - Umpqua Biochar Education Team
- Project of SURCP – South Umpqua Rural Community Partnership
- 2015 Conservation Innovation Grant - NRCS
UBET -- Umpqua Biochar Education Team
Jim Long and UBET

Jim Long was a Professor of Adult and Continuing Education at Washington State University, Pullman, for 27 years.

He was involved in more than two dozen community groups in Douglas County, OR.

Founder and president of UBET for many years.

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Jim Long – founder of UBET
In Memoriam, 1935-2016

“He surveyed the area, saw where
he could contribute, and did so.”
NRCS Biochar Farms & Manure CIG

- Conservation **Innovation** Grant
- Farmers in Oregon often have forest land and forestry residue that they burn for disposal
- Farmers with livestock have manure that can be a problem to handle
- Combine two waste streams to create value
Project Deliverables

• Design and build **kilns to make biochar**
• Test different biochar composts using **Pot trials and field trials**
• Produce **Workshops and Guidelines** on biochar production, biochar use, and monitoring.
• Provide input into **NRCS CSP 384 Biochar Enhancement**
Biochar Production Results

We made 70 cubic yards of biochar during the two year project, worth $8,750 ($125/yard)
Origins

Kelpie’s cone kiln

Den Morgan’s Ring of Fire kiln
Scott Mc Kain’s Ring of Fire Kiln
Design Parameters - the Oregon Kiln

- Sized for feedstock
  - Sticks or logs up to 4” diameter
  - 4 to 5 feet long
- Portable but Durable
  - Less than 200 lbs
  - 14 gauge steel
  - Sloped sides allow for stacking
- Ergonomic for loading
  - Only 2 feet high
- Capacity
  - Makes > 1 cubic yard of biochar in about 4 hours
- Cost
  - $950 for Kiln (2019 price)

Kiln Dimensions
- 5’ top base,
- 4’ bottom base
- 2’ high sides
Kiln Wrangling
UCC Welding Department

We hope this could be the start of a new industry in Oregon making biochar from forestry waste.
Theory of Flame Carbonization – Making Biochar in an Open Flame
Just another form of pyrolysis

Pyro-lysis: from pyro (fire) and lysis (separation)
Flame Carbonization
Making biochar in an open flame

- Biomass burns in 3 stages.
- To make char, stop the process before it goes to ash
Tools for Flame Carbonization

1. The Rick
   - Jack Daniels Distillery Rick Yard
   - Making char for filtering whiskey

2. The Flame Cap Kiln
   - Japanese Cone Kiln from the Moki Co. for charring bamboo
   - 3 sizes of stainless steel, open bottom cones - .5 meter, 1.0 meter and 1.5 meter diameter
Two Flow Regimes (air & fuel flows)

RICK - Concurrent Axial Flow – air and fuel gas flow in the same direction

FLAME CAP KILN - Countercurrent Flow – fuel gas rises and air is pulled down
The Rick - Concurrent Axial Flow

- No external limits on air entrainment
- Flame length limits radiative heat transfer to fuel bed
- Flame tips cool, causing soot to condense out from fuel gas
Flame Cap Kiln – Countercurrent Flow

- Pan excludes air from side and bottom
- Flame on top uses up all the oxygen
- Char is protected from air and does not burn
- No bottom air --- this keeps the flame close to the fuel
Counter-current flow

Passive counter-current flow as burning fuel draws air downward
Countercurrent flow – Big Box Biochar

The Tree Service, Brandon Baron, Burns, Oregon
Air Curtain Burner – active counterflow

- Active countercurrent flow using a blower
- Designed for complete incineration, not biochar
- To make biochar, turn off the blower
How to use the Flame Cap Kiln:

• Start with a top-lit rick
• Transitions to a flame cap
• Pile loosely
• Light on top
Once the first pile burns down, add more

- Add new material, one layer at a time
- Make sure each layer has the same size material
It’s all about the loading rate
Keep a Strong Flame on Top

- Especially important in wet conditions
- If you let the flame die down it can be hard to restart
Quenching Time

Quench when kiln is full and flame is gone
Water Quenching

Char holds heat amazingly well!

Three options for quenching:

• Flood
• Spread very thin and spray with water until heat is gone
• Snuff
Snuff Quenching

Ring of Fire Kiln

Oregon Kiln
Failed Flood Quench

- Oregon Kiln can quench with 50 gallons water **IF** you stir
- Otherwise, you need to completely flood it, or come back the next morning and find this:
Crushing Char

- Drive over it with a truck or tractor
- Use a lawn roller on a hard surface
- Chipper-shredder
- Roller mill
- Hammermill
- Leaf vacuum
Crushing with DR Leaf Vacuum

Leaf vacuum produces a more consistent particle size than rolling or crushing with vehicle tires.

Biochar before and after crushing with DR leaf vacuum.
Hammermill

Tips for using a hammermill:

1. Wet char will get very sticky and plug up a hammermill screen
2. Dry char will make a horrible, choking dust cloud!
3. There is a sweet spot of moisture that prevents dust without making sludge
Biochar Quality

- Flame Carbonization chars are mostly high T biochars
- 500 – 1000 degrees C
# Biochar Test Results

<table>
<thead>
<tr>
<th>Biochar Sample</th>
<th>Notes on sample origins</th>
<th>Date</th>
<th>pH</th>
<th>EC (mmhos/cm)</th>
<th>ash %</th>
<th>Volatile Matter %</th>
<th>Fixed Carbon %</th>
<th>Neutralizing value (% CaCO3)</th>
<th>Water Holding Capacity (ml water per 100 g dry char)</th>
<th>Butane Activity (g/100g dry ash free char)</th>
<th>Dry Bulk Density (lb/cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Boiler Ash 1</td>
<td>Tipton Ranch</td>
<td>4/4/16</td>
<td>7.2</td>
<td>0.562</td>
<td>40.9</td>
<td>16.5</td>
<td>42.6</td>
<td>14.6</td>
<td>68.5</td>
<td>44</td>
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<tr>
<td>2. Boiler Ash 2</td>
<td>Michaels Ranch</td>
<td>4/4/16</td>
<td>8.4</td>
<td>1.485</td>
<td>57.8</td>
<td>13.4</td>
<td>28.8</td>
<td>25.2</td>
<td>73.3</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>3. Morrison madrone</td>
<td>wet quenched</td>
<td>4/4/16</td>
<td>8.1</td>
<td>1.672</td>
<td>10.2</td>
<td>13.5</td>
<td>76.3</td>
<td>5.6</td>
<td>81.3</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>4. Morrison mixed conifer</td>
<td>wet quenched</td>
<td>2/21/18</td>
<td>9.2</td>
<td>0.61</td>
<td>8.6</td>
<td>20.4</td>
<td>71</td>
<td>6.2</td>
<td>107.9</td>
<td>7.5</td>
<td>11.7</td>
</tr>
<tr>
<td>5. Morrison mixed conifer</td>
<td>dry quenched</td>
<td>2/21/18</td>
<td>9.5</td>
<td>0.82</td>
<td>30.3</td>
<td>17.4</td>
<td>52.3</td>
<td>1.6</td>
<td>113.2</td>
<td>7.5</td>
<td>10</td>
</tr>
<tr>
<td>6. Morrison mixed conifer</td>
<td>composted (dry quenched)</td>
<td>2/21/18</td>
<td>9</td>
<td>1.9</td>
<td>14.1</td>
<td>0.26</td>
<td>85.6</td>
<td>14.9</td>
<td>124</td>
<td>2.8</td>
<td>12.5</td>
</tr>
<tr>
<td>7. Siskiyou Alpaca oak</td>
<td>wet quenched</td>
<td>2/21/18</td>
<td>10.1</td>
<td>0.55</td>
<td>5.4</td>
<td>21.5</td>
<td>73.1</td>
<td>7.4</td>
<td>90.1</td>
<td>7.1</td>
<td>10.1</td>
</tr>
<tr>
<td>8. Siskiyou Alpaca oak</td>
<td>composted</td>
<td>2/21/18</td>
<td>8.5</td>
<td>0.19</td>
<td>1.8</td>
<td>14.8</td>
<td>83.4</td>
<td>2.4</td>
<td>102.7</td>
<td>2.7</td>
<td>9.5</td>
</tr>
<tr>
<td>9. Daisy Hill grape vines</td>
<td>wet quenched</td>
<td>2/21/18</td>
<td>10.1</td>
<td>0.49</td>
<td>10.4</td>
<td>9.7</td>
<td>79.9</td>
<td>6.4</td>
<td>119.2</td>
<td>5.9</td>
<td>10.5</td>
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<tr>
<td>10. Oregon Biochar Solutions</td>
<td>commerical biochar</td>
<td>2/14/18</td>
<td>10.5</td>
<td>1.212</td>
<td>8.7</td>
<td></td>
<td></td>
<td>11.1</td>
<td></td>
<td>10.2</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Daisy Hill Farm – Grape Prunings
Page Creek Ranch – fuel reduction thin

- This fuels project was paid for by a Community Fire Plan grant
- Biochar labor was contracted to Rogue Ecological Restoration Service
Do you take the feedstock to kiln or the kiln to the feedstock?
Deluxe Ring of Fire Kiln

Don Morrison designed a more durable ROF kiln with quenching lid
Double-walled Ring of Fire

- Inner ring dimensions:
  - 6 ft diameter
  - 42” high
  - 3.7 cu yd capacity
- Outer rings serves as an effective heat shield:
  - Improves conversion efficiency
  - Protects operator
- Modular, light weight, easy to transport
- Cost – similar to Oregon Kiln
Tractor Kiln version with fork pockets

- Farmers were using tractors to move kilns with mixed results
- UCC Welding students made 4 new tractor-movable kilns
More Innovations:
You can carbonize old boards with no smoke!

• Build a rick of old boards
• Light kindling on top
• Quench with water
Drew Biochar Project – Umpqua Biochar Education Team

- 17 acres of thinning
- Removal of small trees
- Umpqua National Forest

Stewardship Contract awarded to South Umpqua Rural Community Partnership – www.surcp.org
- Three days, 166 cubic yards of forest slash, 28 cubic yards of biochar
- **16% conversion efficiency** (by volume)
Cost Scenario for Planning  
Based on Drew Veg Biochar Project

<table>
<thead>
<tr>
<th>Project size and volumes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>project size, ac</td>
<td>17</td>
</tr>
<tr>
<td>tree/ac</td>
<td>800</td>
</tr>
<tr>
<td>volume of piled slash, cy</td>
<td>396</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labor crew size</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>crew size, # of kiln tenders (each tender operates 2 kilns)</td>
<td>6</td>
</tr>
<tr>
<td>crew size, # of machine operators</td>
<td>1</td>
</tr>
</tbody>
</table>

Total crew size: 7 people
Labor Time and Machine Hours

<table>
<thead>
<tr>
<th>Machines and machine hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>loader to place kilns and move slash, hrs/day</td>
<td>6</td>
</tr>
<tr>
<td>water tender for quenching, hrs/day</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labor hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>crew set up time, hrs</td>
<td>1</td>
</tr>
<tr>
<td>biochar burning time per kiln batch, hrs</td>
<td>4</td>
</tr>
<tr>
<td>quenching and unloading, hrs</td>
<td>2</td>
</tr>
</tbody>
</table>

Total daily job time, including setup and quench, 7 hours
## Outputs

<table>
<thead>
<tr>
<th>Production volumes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>assumed conversion efficiency, biomass to biochar, by volume</td>
<td>16.70%</td>
</tr>
<tr>
<td>volume slash consumed per kiln batch, cy</td>
<td>6</td>
</tr>
<tr>
<td>biochar output per kiln batch, cy</td>
<td>1</td>
</tr>
<tr>
<td>number of kilns</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Daily output</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>total biochar output per day, cy</td>
<td>12</td>
</tr>
<tr>
<td>total slash processed per day, cy</td>
<td>72</td>
</tr>
</tbody>
</table>

- 5.5 days to process all slash
- 66 cy of biochar produced
Results

• Assume one cubic yard of biochar weighs 200 pounds
• $66 \text{ cy} \times 200 \text{ pounds} = 6.6 \text{ tons of biochar}$
• $6.6 \text{ tons} \times 80\% \text{ fixed carbon fraction} \times \frac{44}{12} = 19.4 \text{ tons of CO}_2 \text{ sequestered from one 17 ac thinning project.}$

Average American emits approx. 20 tons CO$_2$ per year
## Biochar Farm Economics

<table>
<thead>
<tr>
<th>Farm</th>
<th>Biochar cost/cy</th>
<th>Burning anyway?</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Fork Farm</td>
<td>$87</td>
<td>Yes</td>
</tr>
<tr>
<td>Daisy Hill Farm</td>
<td>$190</td>
<td>Yes</td>
</tr>
<tr>
<td>Michaels Ranch</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td>Morrison-Fontaine</td>
<td>$100</td>
<td>Yes</td>
</tr>
<tr>
<td>Page Creek Ranch</td>
<td>$100</td>
<td>Yes</td>
</tr>
<tr>
<td>Siskiyou Alpaca</td>
<td>$90</td>
<td>No</td>
</tr>
<tr>
<td>Tierra Buena Worm Farm</td>
<td>$100</td>
<td>No</td>
</tr>
<tr>
<td>Willow Witt Ranch</td>
<td>$150</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- Based on labor costs of $20-$25/hr
- Cost is similar to cost of purchasing biochar
- But most of the labor cost is for processing brush and slash that needs to be burned anyway
How Much Biochar Do Farmers Need?

- We have learned that it is best to add biochar in small amounts to compost.
- This means that the amount of biochar that a farmer needs to make is smaller than we had initially thought.
- For instance, a farmer with a small herd of 20 goats might only need to make two cubic yards of biochar per year in order to improve the barn environment and make better compost.
- Two cubic yards of biochar would require two days to make using one kiln and a labor force of 2 people. It would require up to 20 cubic yards of brush or slash to be hauled, cut to size, dried and covered. This is where the biggest labor effort is needed.
NRCS CSP Biochar Activity

**Conservation Enhancement Activity**
E384135Z

Biochar production from woody residue

Conservation Practice 384: Woody Residue Treatment

**Applicable Land Use:** Forest, Associated Ag Land

**Resource Concern Addressed:** Degraded Plant Condition

**Enhancement Life Span:** 10 years

**Enhancement Description**

Uses woody debris remaining after fuel reduction harvests or wildfires to create biochar. Biochar stores carbon and is a useful soil amendment that improves Soil Organic Matter (SOM) and water-holding capacity.
Criteria

- States will apply general criteria from the NRCS National Conservation Practice Standard Woody Residue Treatment (Code 384) as listed below, and additional criteria as required by the NRCS State Office.

- The enhancement will be applied to sites where woody debris presents a fire risk or interferes with land management objectives or planned activities (e.g., impedes regeneration, limits access, interferes with livestock movement, etc.).

- Woody debris that does not have a commercial use is suitable for biochar creation.

- Where this enhancement can be coordinated with a fuel reduction treatment, woody debris should be separated by size classes if possible.

- Biochar will be created on site in kilns designed for the purpose.

- Kiln operators shall be properly trained in procedures for creating biochar, and shall adhere to state safety precautions at all times. A plan for quenching biochar will be in place.

| E384135Z Biochar production from woody residue | December 2017 | Page 1 |

- Requires enrollment in NRCS CSP – contact your local NRCS office for more info
- As of 2019, per acre payment for biochar production up to $4600/acre
Lems Ridge, California
Yew Creek Land Alliance, Oregon
Steel panels bolted together into 12’ x 6’ box
Easier loading of big logs
Bin holds about 6 cubic yards of biochar
Scaling up for better economy

- Tanks
- Shipping Containers
- Grain Bin Bottoms
- Rail Cars
- Dumpsters
- ????????
North Dakota – NDSU & Menoken Farm

- Half pipe kiln
- Made from old water tank
- 3 ft diameter
- 11 ft long
- 5.7 cy capacity
- Quenched with manure
Oil Field Tank Kiln

- 12 ft diameter; 20 ft long; 42 cy capacity
- How to quench? Dirt would make it very heavy to unload
- Let’s just flip it! Problem solved.
Grain Bin Bottom Cone Kiln

- 10.6 cy capacity
- Would require 1000 gals of water to flood quench
- Needs a lid for snuff quenching
- How do you unload it?

We did not have enough water to flood quench the kiln, so the char was not saved.
Growing Number of Projects and Partners

- NRCS
- USFS
- USDA-ARS
- Oregon Department of Forestry
- North Dakota Forest Service
- Nebraska Forest Service
- Kansas Forest Service
- Utah State University Extension
- Oregon State University Extension
- South Umpqua Rural Community Partnership
- Long Tom Restoration Council
- Illinois Valley Community Development Organization
- Two Rivers SWCD
- Ridge to Reefs

Charring Pinyon-Juniper in Utah
Biochar Job Estimating

Considerations

• Yarding methods
• Diversion to post, pole or firewood
• Feedstock volume estimates
• Feedstock moisture content and size
• Equipment needs: kilns, loaders, hand tools
• Biochar production rates*
• Water or other quenching method

*10 minutes per inch of biochar accumulation in flame cap kiln when using dry fuel
Questions?

Wilson Biochar Associates specializes in biochar technology and market development. We provide strategic advice and services to businesses and organizations.

- Technology Assessment
- Research and Analysis
- Project Development

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