



# A Minnesota Landowner Guide to Biochar



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*Biochar is a modern technology that returns carbon to the soil in the form of long-lasting charcoal. It's made by baking biomass (such as tree wood, plants, manure, and other organic materials) without the oxygen that could cause it to burn completely to ash.*

*This guide includes best practices advice for landowners using an Oregon kiln to produce and utilize biochar. However, variables on the production and intended uses make exact recommendations a challenge. Detailed best practices for both production and utilization remain a need as biochar production and uses increase.*



Biochar on the left is from 1x3" pallet boards; biochar on the right is produced with 1' diameter brush as feedstock.  
Photo courtesy of Carlton SWCD.

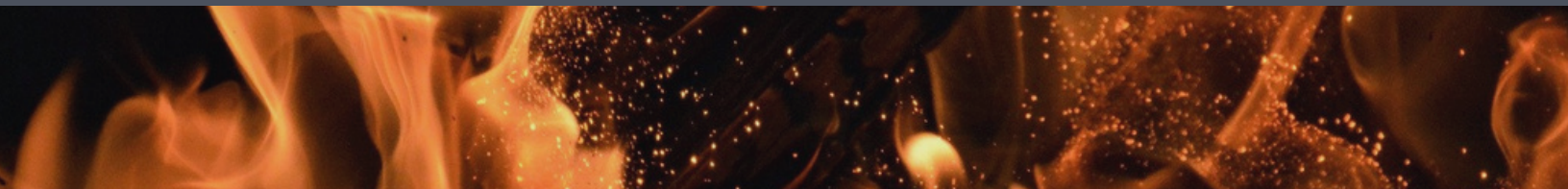
## Part I. Biochar Production Guidelines

These production guidelines are specific to use of the proven flame capped Oregon kiln design, but there are other designs that can work. Whatever type of vessel is used, it must be air tight. The key is to burn the biomass where the flame is on the top of the kiln, which burns particulates in smoke and limits oxygen flow to the char layers below the flame, preventing the char from burning all the way to ash. This process is called pyrolysis.

### HAVE A BURN PLAN

A burn plan is recommended for any biochar kiln burn project. Consideration should be given to availability for water for quenching and fire control, safe location for kiln away from combustibles, and adequate people and resources for a safe burn.

Check if burning permits are required for your project.



For best results, here are a few Guidelines for Biochar Production with the Oregon kiln:

1. **LOADING:** Always load up the initial kiln with dry stock. Packing it down by stomping can increase woody material density which can aid in developing an even flame cap. Green material can be mixed into feedstock additions once the kiln is burning as designed.
2. **FEEDSTOCK BATCHING:** Try to batch significantly different sizes of feedstock. 1"-3" branches and brush will burn faster than 4"-5" round wood. Batching similar size feedstock produces a more even burn throughout the kiln, and prevents smaller sized stock burning to ash while waiting for bigger stock to char.
3. **FLAME CAP:** The development and maintenance of the flame cap is critical to realizing the benefits of using a kiln to create biochar. The goal is an even flame across the entire surface of the kiln. When a good flame cap is obtained, there is very little smoke/ emissions as it is burned up as it rises out of the kiln. Another important factor in quality of biochar is the temperature achieved during the burn. Generally, 500- 800°C (900 - 1400° Fahrenheit) is considered as the optimum range for pyrolysis temperature in the production of biochar.



Biochar kiln with a good flame cap.

4. FEEDSTOCK ADDITIONS: The kiln is ready for feedstock additions when the flame dies down, but is not entirely out, and a bed of glowing coals is left. Add feed stock to the top of the kiln redeveloping a new flame cap. Subsequent feedstock additions can be made using this sequence.



Kiln with a bed of coals and ready for feedstock additions.

5. QUENCHING: Quenching the burning kiln is done to stop the burning process before the feed stock is burnt beyond biochar to ash. Similar to when the kiln is ready for more feed stock, it is ready to quench when the last feedstock addition burns down to glowing coals. The Oregon kiln takes about 65 gallons of water to quench when the kiln is about full of biochar. Snow can also be an effective quenching agent. Add quench to the burning kiln and mix with the biochar to stop the burning process. Keep mixing and adding water until the biochar is no longer steaming, and is cooled off. The kiln has a drain to remove excess water from the quenching step. Then the kiln can be tipped over to remove the biochar and any hot spots quenched. Your biochar is now ready to use!

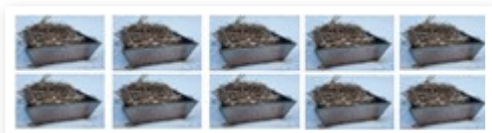
6. TIMING: Burning time will vary depending on type of stock and dryness. With a kiln full of dry brush to light, it takes only 15 minutes to get to a good flame cap. With a good bed of coals, brush stock additions also burn quickly, about 30 minutes per addition.

### Production VolumesEstimates:

Kiln of biomass: (brush stamped down to compact) The overall volume of the Oregon kiln is 40.5 cu.ft. Assuming about 35% of the volume is air voids, the approximate volume of actual woody material in a kiln full of brush is about 26 cu.ft.

Kiln of biochar: With the same volume of the kiln at 40.5cu.ft., there is about 1.7 cu.ft. of biochar per inch deep it is in the kiln.

Ratio of biomass in: biochar out - Expect significant reduction in volumes when making biochar.



7 - 10 kilns of biomass



1 kiln of biochar

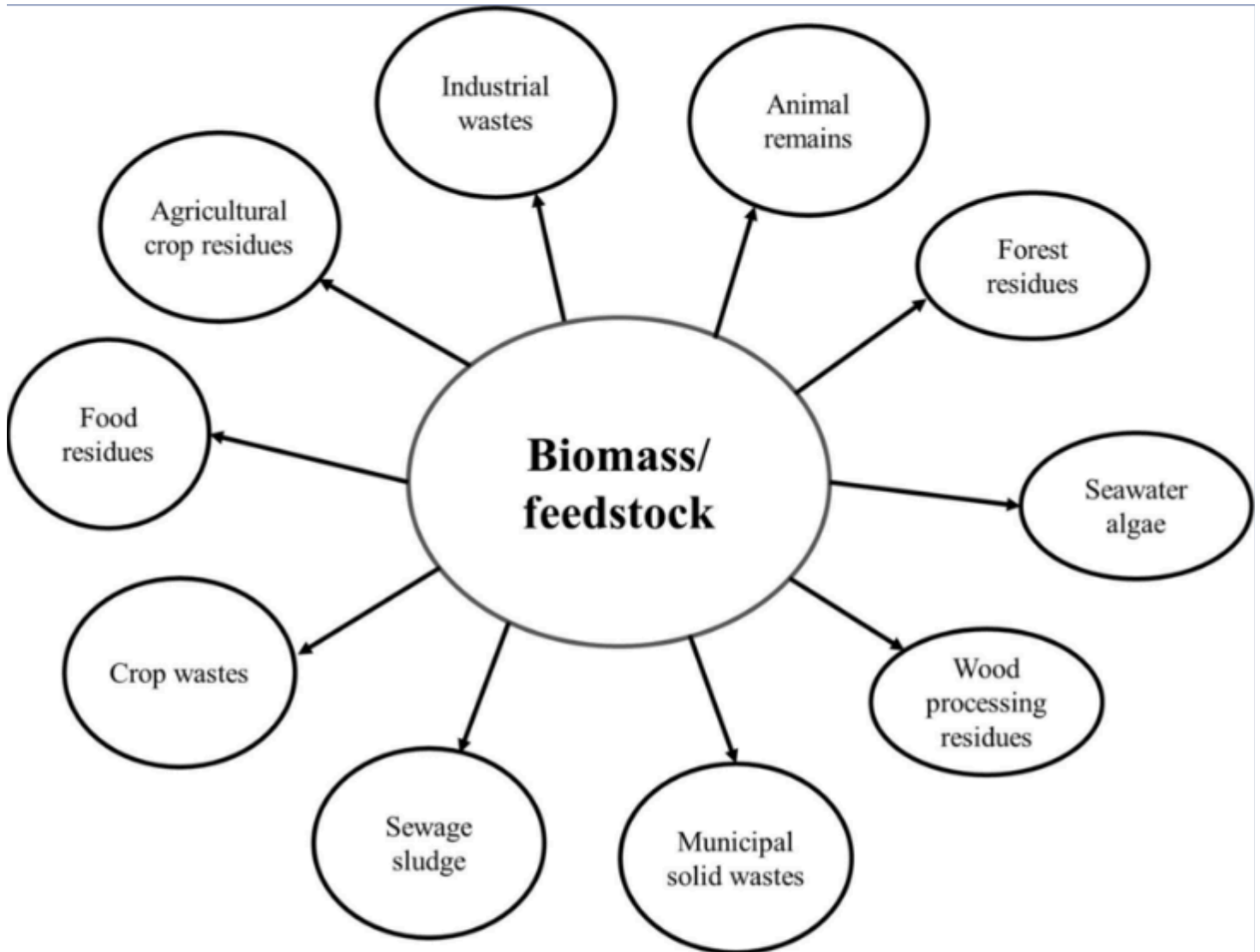
Brush - Expect a volume reduction of around **10:1 biomass in/biochar out.**

Boards - because boards can be stacked, significantly reducing air voids, expect a volume reduction of 3:1 biomass in/ biochar out when burning boards as fuel stock.

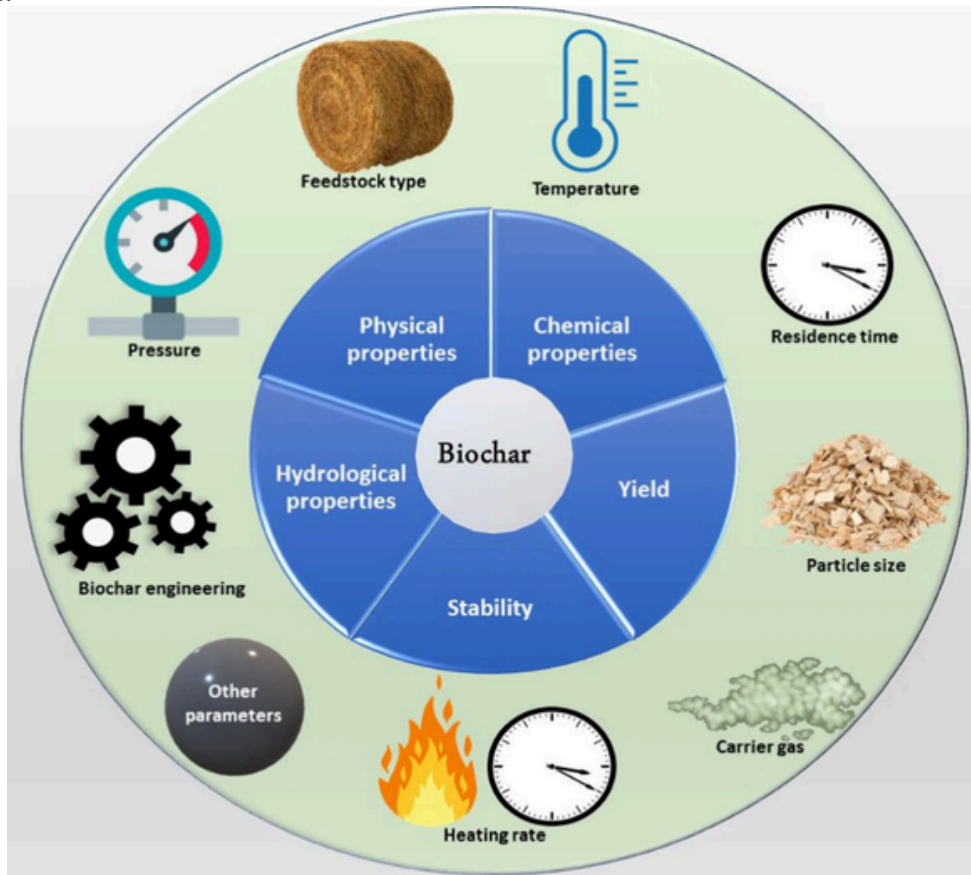
## Part II. Biochar's Beneficial Uses

The benefits of biochar are many and varied. These include improved soil health, enhanced soil water holding capacity, increased plant growth and vigor, cleaner air quality, and very importantly, the ability to sequester carbon for centuries. So much depends on the soils you are applying biochar to, the characteristics of the biochar you produce, and the parameters achieved during the production of the biochar.

Feedstocks:



Production Variables:



Kiln Types:

## PLACE-BASED BIOCHAR PRODUCTION

### ~Oregon Kiln~

- Flame Capped unit
- DIY or \$<2000 locally
- Blueprints available on-line
- 1.5 cubic Yard capacity

by Harry Groot



### ~Ring of Fire~

- Flame Capped unit
- DIY or \$<3500 from Wilson Biochar Associates
- ~ 3 cubic Yard capacity

courtesy of USBI



### ~Big Box Kiln~

- Flame Capped unit
- DIY or <\$5,000 local shop
- up to 20CY capacity

by John Webster



### ~Closed Retort~

- Various designs on line for purchase (COZ or Exeter design shown)
- DIY to \$20,000
- ~1.5 CY capacity

by Harry Groot



### ~Char Boss Jr~

- Air Curtain/Flame Capped unit
- \$150,000 by Air Burners, Inc.
- ~5% biochar from processing
- 2-3 Tons/hour of operation

by Harry Groot



### ~Carbonator~

- Air Curtain/Flame Capped unit
- \$750,000 by TigerCat
- ~5% biochar from processing up to 20 Tons/hour

by EarthFounderies, Inc.



The work upon which this project is based was funded in whole or in part through a grant awarded by USDA Forest Service Wood Innovations (23-DG-11094200-453). This institution is an equal opportunity provider.

## Soil Amendment:

Biochar has many redeeming soil amendment qualities. By its nature, biochar is filled with pore spaces left from its original wood structure. These spaces can hold water in droughty soils but can cause additional water retention in tight soils. Biochar will increase soil health in multiple ways but results are less immediate than other forms of soil amendments. Biochar alone as a soil amendment is not recommended. Because of its porous nature, it tends to suck nutrients out of the soil when applied by itself. Mixing with some sort of “activating” medium charges the biochar with microbes, bacteria, and nutrients that will be a net positive as a soil amendment. Compost and livestock wastes are great activating mediums for a biochar mix. For best results allow mixture to “brew” for 2 weeks. Be sure the mix has plenty of water for this period.

### Online USDA web soil survey

(<https://websoilsurvey.sc.egov.usda.gov/>)

This soil survey maps soils on a broad scale and may not be accurate for home and garden sites where the natural soil horizon has been disturbed. But this is a good general tool to help plan biochar utilization on your property. A soil analysis is always recommended for specific site soil characteristics.

The rating class terms indicate the extent to which the soils are suited to biochar by all of the soil features that affect these uses. Numerical ratings indicate the degree of suitability of each soil or site feature.

Verbal ratings are defined as follows:

#### **Excellent response** (rating index equals 1.0)

*One or more dynamic soil properties present are suboptimal for the growth of crops and may be substantially improved with biochar application.*

#### **Good response** (rating index is greater than 0.75 but less than 1.0)

*One or more dynamic soil properties present are suboptimal for the growth of crops and may be substantially improved with biochar application.*

#### **Fair response** (rating index is greater than 0.25 but less than 0.75)

*One or more dynamic soil properties present may already be nearly optimal for the growth of crops and may not be substantially improved with biochar application.*

#### **Low response** (rating index is greater than 0 but less than 0.25)

*One or more dynamic soil properties present may already be nearly optimal for the growth of crops and may not be substantially improved with biochar application.*

#### **Unsuited** (rating index equals 0)

*The soil is rendered unsuitable for biochar application because the use invariant soil and site properties are limiting to crop production and cannot be overcome. The site may be too steeply sloping, too wet, flooded, or ponded.*

## Carbon Sequestration:

Leaving woody biomass to decompose or burning it in an open pile, allows almost all the stored carbon to release into the atmosphere. Producing biochar from that woody biomass in a limited oxygen environment such as the Oregon kiln, stores about half of the carbon in the wood for hundreds to thousands of years. In some places, carbon credits are now available for biochar production because of its ability to store carbon and reduce green house gas emissions.

## Livestock Bedding:

Biochar can be added to livestock or poultry bedding. It captures urea and nutrients, and can reduce odor. The biochar should be roughly 25% - 50% of the bedding mixture used. Some compaction can occur as the biochar is ground into fine particles so monitor the bedding pack and change as needed. This becomes an excellent soil amendment mix. Forest Management: Producing biochar from woody materials generated in forest management projects has many advantages besides the actual biochar produced.

- A. Forest Health: Burning the cuttings in a biochar kiln is an effective disposal strategy for diseased trees such as Oak Wilt and White Pine Blister Rust, and insect infected trees such as Emerald Ash Borer or Spruce Bud Worm. **Caution needs to be taken in transporting diseased or infected trees and tree parts, laws may apply.**
- B. Invasive Species: Burning invasive woody species such as buckthorn or oriental bittersweet is an effective onsite treatment to prevent the spread of these invasive plants. **Caution needs to be taken in transporting invasive plants and plant parts, some laws may apply.**



Buckthorn



Oriental Bittersweet

- C. Harvest Slash: Although leaving slash from timber harvests can have advantages for wildlife habitat and decomposition for forest soil health, this slash is available fuel for wildfires. Burning some of the slash to produce biochar to be added back to your forests soils can achieve safer forest health and enhance forest soil health.
- D. Brush Management: Managing brush is a never ending battle in small woodlots. But it is critical to eliminate brush that competes with more desirable tree species for water, nutrients, and sun light. Burning brush cuttings from brush management projects eliminates brush accumulation as wildfire fuel, and prevents development of diseases from decomposing material in your woodlot. The biochar produced can be applied to your woods as a soil health improvement amendment.
- E. Wildlife Habitat: Some wildlife species, both game and non game, need an open landscape. Sharptailed Grouse, Woodcock, Meadowlarks, and Bluebirds thrive in grassland and open areas. Alder, Hazel, and young Aspen excel at growing in these areas too, so managing this encroaching vegetation to maximize habitat for these species and other types of wildlife is critical to maintaining their presence on the landscape.

Other promising uses for biochar in the United States are still in the research phase. These include stormwater filtration and as a feed additive for livestock to improve digestive health.

The Carlton SWCD has specialist in forests, invasive species control, native plant restorations, agriculture, wildlife habitat, urban runoff treatment, and general soil health to assist landowners in planning their projects and exploring biochar use in its role to support all these conservation projects through improving soil health.

Partners in developing the biochar projects of the Carlton SWCD have included U of M Extension Regional

Sustainable

Development Partnership, Dovetail Partners, Utah State University, NRRI, Cromwell High School Metals Class, City of Carlton, and the Carlton County Land Department.



## Part III. Best Practices for Biochar Utilization

There are many factors that affect maximizing the benefits of using biochar. These include soil characteristics where the biochar is applied, parameters met in the biochar's production, the activating medium and mix rates of your biochar/compost mix, the materials used to make your biochar.

The following recommendations are based on brush size (1-4" dia) biochar. There is detailed information available in many places, but for the DIY landowner making some biochar with an Oregon kiln, here are some basics to follow when utilizing biochar.

1. **SOIL TEST & BIOCHAR ANALYSIS:** A soil test is recommended before any soil amendment application. Soil tests are available from the University of MN lab with base rates starting at \$15. Additionally, Biochar characteristics can vary depending on production temperatures, feed stock species, and other production variables. It is good to have a sample of the biochar analyzed before application planning. The Soil Control Lab in California and has their proximate analysis done for \$75 (2022 price).
2. **CHARGE THE BIOCHAR:** Mix biochar with compost or livestock manure to charge it before adding to garden or field soils. Allow the mix to brew for 2 weeks with plenty of water and turn the mix pile once in the 2 weeks. The ratio of biochar in the mix can be adjusted according to how much biochar is available, soil amendment goals, and biochar content. As little as 10% can be used for annual amendments all the way up to around 50% for one time amendments.

3. **APPLICATION FOR FARM OR GARDEN:** Application of biochar/compost mix can be challenging on larger scales like ag fields. Try to maintain the 25%–50% ratio in mixing with compost or livestock manure. Mix with loading equipment and apply with a surface spreader. Incorporate as soon as possible for maximum benefit and to minimize runoff into nearby waters. The mix should be worked into the soil either by hand or with a tiller on smaller plots or disked with a tractor on field scale plots.
4. **APPLICATION FOR FORESTS:** Biochar application on forest soils is more challenging because incorporation is difficult. Results are less definitive, and indicate biochar additions alone are not harmful, but do not significantly increase forest soil productivity. Incorporation is recommended to speed up the benefits of a biochar application.

**Table 1. Biochar Utilization Types, Rates, and Methods**

Type of Use	Type of User	Rate	Method
<b>Biochar to compost ratio can be 10-25% for soil amendment applications</b>			
Potting Soil	Homeowner	10-25%	Use mix for starting plants.
Ag Field Soils	Commercial Producer	25% - 50% One time applications: 50% biochar in mix and start with 10 tons/ac. Monitor soils tests for subsequent applications	Surface apply and incorporate as soon as possible.
Garden	Homeowner	10-25% 3 tons/ac or 1.5 lbs/10 sq.ft. of the mix.	Dig in by hand or with a tiller.
Orchard	Homeowner	10-25%	Dig 8"-12" deep holes 3'-5' apart just inside the dripline of the tree and fill with biochar/compost mix.
Forest	Commercial & Homeowner	Up to rates: Biochar alone - 5 lbs./10 sq.ft. Biochar/compost mixed - 10 lbs./10 sq.ft.	Incorporate to accelerate benefits.
Tree Transplant Holes	Homeowner	25% biochar 25% compost 50% native soil	Fill the transplant hole with layers of biochar/compost mix and soil from the hole.
Livestock Bedding	Commercial & Homeowner	10% - 20%	Adding biochar to bedding helps capture urea and nutrients and reduces odor.

Even with incorporation, biochar amendments can take 1-2 years to begin to affect soil health parameters such as microbial life and soil carbon:nitrogen ratios.

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