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RSDP Grant Project Biomass to Biochar for Landscape Health in Carlton County

Report by Brad Matlack, Carlton SWCD Manager—July 2022

Project Goal:

The Carlton SWCD received funding support through the U of M Regional Sustainable Development Partnerships to acquire a biochar kiln and demonstrate its use as a tool for landowners to utilize biomass (brush, tree limbs, and small logs) from conservation projects.

As an additional component of this project the SWCD coordinated building the kilns by High School Metal shop classes as an education tool on biochar but also a real world application of metal fabrication skills.

Partners!

U of M Extension Regional Sustainable Development Partnerships
Dovetail Partners
Utah State University
NRRI
Cromwell High School Metals Class
City of Carlton
Carlton County Land Department - Parks Department

After considerations to budget, available plans, and kiln weight, this project settled on building 2 Oregon kilns, each with unique adaptations aimed at mobility by 1-2 people. The plans are open source from Wilson Biochar and others, the kiln weighs around 250 lbs., and these kilns are proven through use in several western states.

Although offered to 2 schools, the Cromwell HS built both of the Oregon kilns for this project.

Kiln Costs (2021)	
14 ga. steel for 2 Oregon kilns	$ 1,090
Fabrication	Free by Cromwell HS
Mobility Enhancements	$ 105
Total	**$ 1,195**

Results Summary:

The first kiln was obtained in early February and the second more modified version in early March. The SWCD staff used brush from the City of Carlton's woody waste pile to gain knowledge in kiln use. With this knowledge, the kilns were demonstrated in burns with various audiences and different objectives meeting the goal of this project.

The education component of having students build the kilns was enhanced by doing a demo with the same schools science class that included some of the builders. This full circle education from building to use was both rewarding for the students and a source of pride for shop students.

Though there are many kiln designs in use, the Oregon design met this project's goals of being "usable" by 1-2 landowners, while providing a better option to open pile burning or biomass scattering for eventual decomposition. Exactly how clean burning these kilns are is still being researched but was not a goal of this project.

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Initial Kiln Testing

Objective—Gain Experience

Carlton SWCD staff tested the first kiln soon after it was acquired on February 8th. Using woody biomass accumulated by the city of Carlton stored in a stack 30’ high by 70’ long, we cut up a kiln full plus some additional stock to add. Unfortunately the first test was not successful mostly due to the feed stock was not dry. The City pulled some dry material out of the pile with a back hoe and we tried again. The second try was successful. The torch lit the kiln full of dry brush and branches in about 2 minutes, and the flame cap was established in about 8 minutes. After that material burnt down to mostly coals after about 20 minutes, we made a small material add of the original green material which burned up in about 15 minutes. We quenched with a small amount of snow scooped from around the kiln and produced about 25 gallons of biochar.

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Cromwell HS Student Demo Objective—Educate on Biochar Production

With the knowledge gained from our first 2 test burns, a demo was conducted on February 24 with the science classes at the Cromwell High School, the same school where the kilns were built. Feed stock was provided by students in the form of brush with additional wood shop scraps from students and the HS wood shop. The focus of this demo was to educate the students in the principles of a flame cap kiln and not so much the documentation of biochar production. 80 students from 5 classes took an active hands on role in feeding stock, recording temperatures, and quenching with snow. The torch lit the kiln of stock quickly and a flame cap developed nicely. Timing of feedstock additions was thrown off by class timing throughout the day but the fire was maintained even though optimal biochar producing parameters were not met. The result was a nice batch of char with good particle size distribution, and a great educational hands-on experience!

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Cloquet Forestry Center Demo Objective—Demonstrate Flame Cap Kiln Use

This demo was conducted on March 8 with a target audience of regional resource professionals. About 15 people assembled to see a flame cap kiln demonstrated. The Cloquet Forestry Center (CFC) staff assembled spruce and balsam branches along with 2-4 inch dia. round wood that mimicked a FireWise fuels reduction project. Unfortunately a test the week before the demo resulted in unsatisfactory flame cap development with these materials for a demo. This was again likely due to the stock not being dry. Because of deep snow conditions and accessible dry feed stock the kiln was filled with boards from waste pallets. Though this is not the intended use for the SWCD kilns (burning waste dimensional lumber) it is a legitimate feed stock for biochar production. The SWCD is focused on natural woody biomass produce in conservation practice implementation.

The boards took longer to light than previous brush demos but within about 35 minutes a good flame cap was developed. Red pine block firewood was added after the original stock burned down to coals in 40 minutes after flame cap development. Quenching was demonstrated on a mini scale by withdrawing several shovels full of coals from the kiln and quenching with nearby snow. Quenching took place about 2 hours after the kiln was lit.

The fire in the kiln was maintained after the demo ended to facilitate green stock addition. This additional feedstock burned quickly and completely, proving green stock can be added to a good established bed of coals but not used to start the kiln. The resulting biochar was bigger sized which is to be expected when using bigger stock.

Invasive Buckthorn Cutting Disposal Objective—Conservation Project Application of Kiln Use

Late in April, the SWCD sponsored a Buckthorn Blast in the city of Cloquet. A Conservation Corp of MN crew treated city property along the north side of the St. Louis River and neighboring residents signed up through the SWCD to have their properties treated. The buckthorn cuttings were transported under permit to the Carlton City Brush pile. The buckthorn was processed for the Oregon kiln and stored under a tarp to prevent any wild bird access, even though no berries were still on the brush. This burn was scheduled more as a learning burn for the SWCD and to get more project video footage to share on the SWCDs YouTube Channel. But Harry Groot, project partner with Dovetail Partners from Virginia, was scheduled to be in the area in June and the demo was set to coincide with his trip. 15 participants attended this full scale operational demo, from lighting and flame cap development to when to add feed stock, and quenching.

The Kiln was started with dry branches (5%) collected by SWCD staff. This was a mix of maple, oak, white pine, and hazel brush mostly under 1" dia in size. This material started and burned quickly. A good flame cap was established within about 7-8 minutes. The Buckthorn was cut to length and piled in the second kiln for about 2 months, under a tarp. The Buckthorn ranged in size up to about 2"dia and registered 35-45% on the moisture meter. It was added once the initial material had burned down (12 minutes), in two batches. It also burned quickly and the kiln was ready for quench in about 40 minutes total burn time from lighting. About 20 gallons of water was used to quench the fire from the tank in the back of the pickup using gravity flow. This would be an issue on a kiln with more biochar in it but worked ok on the 4" - 5" of accumulated biochar from the 2 kilns full of feed stock. A small sample of primarily buckthorn biochar was collected for analysis.

Project Challenges:

Project timeline

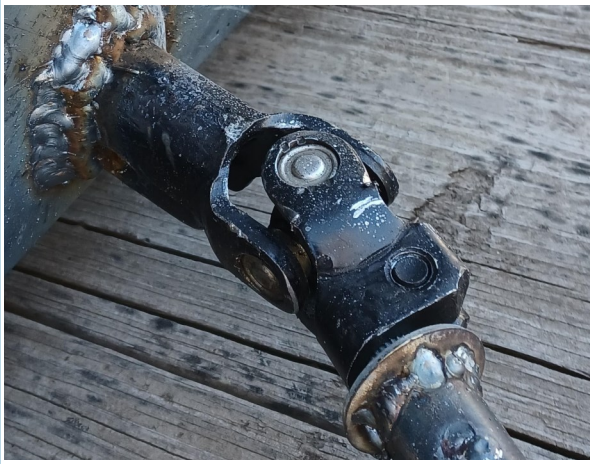
The construction of the kilns for this project by Cromwell HS students was affected by various factors. These included: student class coordination with existing welding class curriculum in October and high COVID 19 rates starting in November and lasting through February. Supply chain issues like welding gas delivery and plasma torch parts from October through January also slowed progress.

The first kiln was obtained in early February and the second more modified version in early March. By this time access to available kiln feedstock was limited by deep snow and good demo weather was hampered by cold temps.

Fire danger was a factor in conducting burn demos between snow melt and green up time when fire hazard is lessened.

Education Component

The vision of this component was to engage the students in design work to "invent" mobility adaptations and brainstorm on final kiln designs to meet the mobility parameters of the SWCD and then build the kilns. Due to class time constraints and COVID 19 concerns, the SWCD was not able to fully realize this design collaboration idea. Some design on the fly did happen but it was led by the shop instructor and not as collaborative as envisioned.



The U joint in this photo was the idea of a student and supplied to the project by that student. This gave the handle/hitch some movement to allow for turning the kiln over rough terrain.

At Right - Cromwell HS shop teacher Pete Johnson, and the lead student builders. The SWCD organized a small pizza party for these students as an appreciation for their work.

Biochar Production Best Practices:

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 project used the proven 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 type of burning process is called pyrolysis.

For best results, here are a few guidelines:

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

1. 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. Try to batch significantly different sizes of feedstock. 1"-3" branches and brush will burn faster then 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.

Biochar from 1x3 pallet boards

Biochar from 1" dia. brush

3. The development and maintenance of this 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. (at right) 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 Production Best Practices (continued) :

4. 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. (at left) Add feed stock to the top of the kiln redeveloping a new flame cap. Subsequent feedstock additions can be made using this sequence.

5. 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 SWCD's 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. 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 Volumes Estimates:

Kiln of biomass: (brush stamped down to compact) The overall volume of the SWCD's 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.

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

7 - 10 kilns of biomass = 1 kiln of biochar

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.

This report includes best practices advice for landowners using the SWCD's Oregon kiln to produce and utilize biochar. However, variables on the production and intended use side make exact recommendations a challenge. Detailed best practices for both production and utilization remains a need as biochar production and uses increase.

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. In depth information is available to dive deep into these factors, but for a landowner to benefit from the use of biochar, here are a few basic guidelines to follow:

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: 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 order. The biochar should be roughly 10% 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.**

Biochar's Beneficial Uses (continued) :

Forest Management: Producing biochar from woody materials generated in forest management projects has many advantages besides the actual biochar produced.

A. 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. 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. 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. 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. 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 there 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.

General Biochar Utilization Best Practices

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, and even the species of wood used. The SWCD is focused on woody biomass from conservation related projects. The following recommendations are based on brush size (1-4" dia) biochar. There is detailed information available in many places, but for the DYI landowner making some biochar with the SWCD's Oregon kiln, here are some basics to follow.

1. 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 analyzed before application planning. The SWCD uses Soil Control Lab in California and has their proximate analysis done for $75 (2022 price).

2. 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. The ratio of biochar in the mix can be adjusted according to how much biochar is available. As little as 10% can be used all the way up to around 25%.

3. Application of biochar/compost mix can be challenging on larger scales like ag fields. Try to maintain the 10–25% ratio in mixing with compost or livestock manure. Mix with loading equipment and apply with a surface spreader. Incorporative 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. 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.

Type of Use	Type of User	Rate	Method
Biochar to compost ratio can be 10-25% for soil amendment applications			
Potting soil	Homeowner	10-25% mixed	Use mix for starting plants
Ag field soils	Commercial Producer	10-25% mixed **3 tons/ac or 1.5 lbs/10 sq.ft. of the mix.**	Surface apply and incorporate as soon as possible.
Garden	Homeowner	10-25% mixed **3 tons/ac or 1.5 lbs/10 sq.ft. of the mix.**	Broadcast and dig in by hand or with a tiller or apply in row/in bed.
Orchards	Homeowner	10-25% mixed	Dig 8"-12" deep holes 3'-5' apart just inside the dripline of the tree and fill with biochar/ compost mix
Forests	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 trans-plant holes	Homeowner	25% biochar 25% compost 50% native soil	Fill the transplant hole with layers of bio-char/compost mix and soil from the hole
Livestock bedding	Commercial & Homeowner	10-20 %	Adding biochar to bedding helps capture urea and nutrients, and reduces order.