Converting Shelterbelt Biomass to Biochar

A Feasibility Analysis for North Dakota Forest Service

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A feasibility analysis by Wilson Biochar Associates for North Dakota Forest Service

Purpose and Need

Dead and dying woody biomass has become a problem on farms and ranches across the country. This material comes from a variety of sources, including trees and brush growing in shelterbelts and windbreaks. Other sources include red-cedar and juniper encroaching on rangelands. All present a time-consuming challenge for landowners to manage.

One solution to this problem is utilizing the wood to create biochar, which has a variety of uses on farms and ranches. The USDA-NRCS recently added an enhancement for biochar production to their Conservation Stewardship Program, providing a financial incentive for producing and applying biochar. Offering landowners an option to utilize this waste by providing cost shares, kiln rentals, training, burn supervision, or other services will help to avoid waste and smoke pollution from the open burning that is the usual practice for disposing of the material.

The market for such services is considerable, as any landowner who has woody waste faces the challenge of how to get rid of it. Landowners who are removing or renovating shelterbelts are one example of a situation where the biochar could be used on site for the next generation of plantings or for a variety of different on-farm uses including manure management and soil improvement.

This paper will examine three case studies using three different methods of low cost biochar production, analyzing production methods and costs. The information presented will help landowners, service providers, and government agencies to refine and adapt the proposed methods to actual projects. The information will contribute to the assessment of the costs and benefits of on-farm biochar production and the development of rate schedules for services and cost sharing.

Benefits of Biochar

Biochar is a modern technology that is based on a range of traditional agricultural practices that return carbon to soil in the form of long-lasting charcoal. Charcoal performs many important functions in soil, enhancing water holding capacity, retaining nutrients, improving soil tilth and increasing soil humus content, resulting in increased plant growth and vigor. Some of the most fertile soils in the world, including the midwestern Mollisols, contain large amounts (up to 50% of the total soil carbon) of charcoal from past prairie fires.

Traditionally, farmers had various methods of adding charcoal to soil through field burning methods and scattering of wood ashes that had a high content of char. Today, a modern biochar industry is forming that proposes to generate a charcoal residue useful for agriculture as a co-product from various bioenergy technologies. Biochar is also generated in fields and forests from crop waste and forest slash where it can be used on site with minimal processing.

Shelterbelt renewal is a good opportunity to realize the benefits of biochar at minimal cost. Dead trees have to be disposed of anyway, and they can be processed into biochar on site using low-cost technologies and standard forestry equipment. The resulting biochar is pathogen free and it can be incorporated directly into the soil, along with appropriate fertilizers, to prepare it for new plantings.

Biochar is especially helpful in establishing trees. It can help young saplings withstand drought, flooding, disease and other harsh conditions such as saline soils. One of the foremost tree service companies, Bartlett Tree Experts, uses biochar routinely in their tree care work. They have found biochar to be especially useful in high-stress environments. The US Forest Service is involved in biochar research at its Rocky Mountain Research Station and is interested in using biochar in forest restoration. Orchardists are also beginning to use biochar in orchard establishment. There is evidence that biochar can mitigate the effects of orchard replant disease.

Bryant Scharenbroch, a researcher at the Morton Arboretum, has done a series of investigations into the use of biochar for urban trees. Urban trees are often confined into small pits, limiting root growth. Biochar is very beneficial to such trees, as it helps to concentrate nutrients and water in the small space available. This could also be an advantage for trees planted as windbreaks in agricultural fields. According to Scharenbroch:

> "In an urban setting, we often want tree roots confined so that they do not interfere with infrastructure. However, if the space is too small, trees will be less stable in wind and more likely to blow over. Adding biochar to tree pits should help to confine roots because it will encourage root growth in an area where resources are optimal. We have been mixing biochar in a 1:1 ratio with biosolids or another high nutrient compost. This mixture gives good results." (Personal communication, 1-25-2017)

Scharenbroch also advised that for suppressing grass and sod formation in the tree row, a heavy mulch of 4-5 inches is useful. Mulch should have three components for best results: biochar, wood chips and high nutrient compost. Biochar applied as a mulch will help soil warm up as the black color absorbs solar radiation. A mulch of biochar alone could also help suppress grass and sod formation, if the mulch is thick enough.

Biochar is also very useful in animal agriculture. It is rapidly becoming known for its ability to manage manure. Biochar applied in animal barns, slurry pits and feeding areas will neutralize odors, reduce emissions of ammonia and greenhouse gases, and prevent leaching of nitrogen and phosphorus. The resulting compost is an extremely effective slow release fertilizer.

Commercially available biochar currently sells at a price of between \$200-\$400 a cubic yard. When landowners become aware that their waste woody debris can be turned into such a valuable soil amendment, they will have plenty of motivation to do the work to convert it to biochar.

Biochar Production Using Flame Carbonization

Biochar can be produced by many different methods. It is most beneficial if biochar is made as a co-product of bioenergy, however, economic conditions do not always support this biochar production pathway. A large factor is the cost of processing and transporting biomass to an energy facility. To address those costs, many different kinds of mobile biochar production kilns have been proposed, that can produce biochar at remote sites.

Often, however, such kilns are capital intensive to manufacture, challenging to operate, and are difficult and expensive to move. For these reasons, Wilson Biochar Associates and others have developed and promoted Flame Carbonization methods for making biochar.

Flame Carbonization differs from traditional low-tech charcoal-making methods that use covered pits and mounds. The covering serves to reduce the air available for combustion, producing a charcoal residue. This form of smoldering combustion produces lots of smoke and no flames. The charcoal is high in condensed volatiles – good as fuel, but not so good as biochar for application to soil.

Figure 1. Traditional charcoal making uses dirt covered mounds to exclude air.

Flame Carbonization uses the flame itself as a way to reduce air and preserve the char from combustion. This seems counter-intuitive, but when a full understanding of biomass combustion is provided, it makes sense.

Biomass burns in two stages: a gasification stage that burns volatile gasses in a flame, and a char combustion stage burns solid carbon without visible flames. If the combustion process is interrupted before the char combustion stage, the char can be preserved.

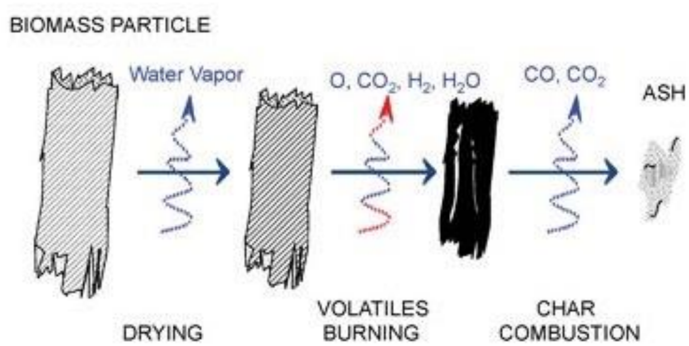

Figure 2. Stages of biomass combustion.

Figure 3. Japanese cone kiln diagram shows how the flame on top excludes air from hot char layers below.

Several different versions of the Flame Carbonizer method can be used to convert slash to biochar. All of the methods described are clean and safe. They are clean because they work by always keeping a flame on top of the fire. The flame burns the smoke so that there is only a very small amount of emissions. These methods are safe because they require water to quench the fire at the end in order to save the char, resulting in complete extinguishment of the fire. Below we will describe the basic procedures for the two Flame Carbonization methods most suitable for low cost on-farm biochar production. In the next section, we will develop specific case studies using variations on these methods.

Method 1. The Conservation Burn

The Conservation Burn method has three main characteristics:

- it is a loosely stacked burn pile
- all the material in a given pile is roughly the same thickness
- it is lit on the top

By lighting it on the top of the pile, the smoke is burned as heat is transferred from the flame into the wood below. The flame front travels downward through the pile until all the material is charred and it collapses into a bed of glowing coals. At that point, the coals are put out with water and the char is preserved.

The inspiration for the Conservation Burn came from the charcoal production method used by the Jack Daniels Distillery. They make charcoal used for filtering their whisky by flash burning dry maple boards stacked in an open rick under a hood, to help retain heat. The process is quick, and the char is quenched with water after the pile collapses.

Figure 4. Jack Daniels charcoal rick.

It is also possible to use this method to make biochar from rough material in the field, as long as it is dry and fairly uniform in size. The pictures below illustrate several types of Conservation Burn piles.

Figure 5. This very loose pile of small diameter brush burns fast and hot. As it burns down, it requires tending to move the loose pieces back into the fire. This sort of material can produce a large amount of biochar in a short time. These two piles produced a cubic yard of biochar. Photos: WBA

In Sonoma County, California, the Sonoma Biochar Initiative has worked with many vineyards to convert grape prunings to biochar using the Conservation Burn Method. The group provides ongoing training opportunities to help more producers take advantage of this cost-effective biochar production method.

Figure 6. Conservation Burn of vineyard prunings conducted by Sonoma Biochar Initiative. Piles are built with similar sized material, covered to keep dry, and lit on the top once winter rains have started. Smoke emissions are far less than conventional piles. Dryness and top-lighting are the keys to reduced emissions. Photos: Raymond Baltar/Sonoma Biochar Initiative

Figure 7. Once the pile collapses, it is time to tend and consolidate it. Quenching uses a combination of water and spreading to cool the char. If the char is not spread out, residual heat can evaporate all the water and re-ignite the char. Photos: Raymond Baltar/Sonoma Biochar Initiative.

Advantages of the Conservation Burn method include:

- No special equipment required
- Greatly reduced smoke emissions as compared to conventional burning
- Reasonable char production for little extra effort – piles must burn anyway

Disadvantages of the Conservation Burn method as compared to other methods:

- Care needs to be taken when building piles to sort material by size and keep dirt out of the pile
- Char production is less than methods using a container
- Quenching can be time-consuming
- Char is difficult to gather up and remove if not used on site

The Conservation Burn method is well-suited to agricultural conditions in general, and we envision that it will work well in the Dakotas and other areas on the Great Plains. One important modification would be to conduct burns after winter snowfall and use snow to quench the char (see case study #1, below).

Method 2: Flame Cap Kiln

The Flame Cap Kiln method uses a container to exclude air from the bottom of a pile of burning biomass. This method starts by building a Conservation Burn type of loose pile in the container, lighting it on top, and letting it burn until coals are formed. However, it then switches to a second stage of layering new material on top of the coals until the container is full. As each new layer of material is added, it is enveloped in flame. The flame consumes all the air that might otherwise reach the char underneath. The combination of flame on top and container on the bottom preserves the char until it can be quenched and saved.

Another difference that can be observed between the two methods is the location of the flame. In the Conservation Burn, the flame starts on the top of the pile and gradually moves down. In a Flame Cap Kiln, the flame moves up in the container as new material is added.

Wilson Biochar Associates has developed and manufactured a kiln specifically designed for use in the forests of Oregon. Below is a series of pictures illustrating how the Oregon Kiln works.

Figure 8. The Oregon Kiln making biochar on a small goat dairy for use in the barn. Start the Flame Cap Kiln with a top-lit rick. Once the initial charge burns down, start adding new material in layers. The flame front moves down as the rick burns down, and then moves back up as the container is filled. Photos: WBA

Figure 9. When the Flame Cap Kiln is full of glowing coals, it is time to quench it. Flood quenching is most effective, but dry quenching can also be used. Here (above) a thin sheet steel lid is placed on top of the hot coals and sealed with dirt or clay. Photos: WBA

Figure 10. Left: A pit kiln used in Hawaii to produce commercial quantities of biochar (photo: Josiah Hunt, Pacific Biochar). Above: a cone-shaped kiln available from the Moki company chars bamboo in Japan.

While all of the kilns pictured above are relatively small, some limited experiments have been done to scale up this method. Scaling up shows promise, although more work needs to be done to design appropriate containers.

The Air Curtain Burner is a special case of Flame Cap Kiln for two reasons: first it is designed for complete incineration, not char-making, and second, it uses active counterflow air to speed combustion and burn smoke emissions. However, a recent job on the Rogue-Siskiyou National Forest showed that biochar was produced when the wood was green and wet and full of dirt. These conditions reduced the incinerating capacity of the unit, resulting in char.

The cost to deploy and operate a single Air Curtain Burner is estimated at $2000/day (Jack LeRoy, Forest Energy Group, personal communication). When wood is clean and dry, it may be more efficient and less expensive to use a simple steel container such as the one used by The Tree Service (Burns, Oregon) in the photo below.

Figure 11. Left: An Air Curtain Burner designed for complete incineration is able to make biochar if the air is controlled properly. This unit operating on the Rogue-Siskiyou National Forest made 20 cubic yards of biochar (Photos: WBA). Right: arborist Brandon Baron makes biochar in a modified 10,000-gallon water tank (Photo: The Tree Service, Burns, Oregon).

Advantages of the Flame Cap Kiln include:

- Greatly reduced smoke emissions over conventional burning or traditional charcoal making
- Char production efficiency comparable to industrial methods
- Low cost equipment as compared to industrial methods

Disadvantages of the Flame Cap Kiln as compared to other methods:

- Quenching can require a large amount of water
- Scaling up will be challenging

Case Studies for Converting Windbreak Biomass to Biochar

Wilson Biochar Associates looked at a number of windbreak projects in North Dakota and chose three jobs that represent typical conditions:

1. Remove and replant 1000 lineal feet of tree row in farmstead tree rows
2. Remove a half mile of field tree row
3. Harvest 1000 lineal feet of coppice Caragana

We chose an appropriate flame carbonization method for each case and developed spreadsheet models that include estimates for labor, equipment, productivity and outputs. Any of the input values can be changed to better reflect actual conditions.

These case studies are estimates based on the biochar research literature and the experience of Wilson Biochar Associates and WBA collaborators in producing char using the methods.

Project managers should be cautious in using these models to plan projects as they are mostly based on smaller scale systems than the ones envisioned in the models. Many values are estimates that are extrapolated from smaller scale versions and may not hold up at larger scale or in variable local conditions. Before planning large projects, the values in these models should be validated by conducting well-documented pilot projects.

Case Study #1: Remove and replant 1000 lineal feet of tree row using the Conservation Burn Method

A typical job in windbreak renovation is to remove a dead and dying row of Siberian Elm and prepare the site for replanting. This example will use the Conservation Burn method to convert material to biochar in place.

This reduces the requirement to move feedstock and eliminates the need to collect and move biochar, as the char will remain on the tree planting site and merely needs to be mixed or tilled into the soil. This method is also very similar to the current practice of piling and burning, with one major exception, the material needs to be sorted by size so that each pile contains similar sized material.

Implementing the Conservation Burn technique in the Dakotas and other parts of the Great Plains can also take advantage of the snow resource for quenching. As long as piles are kept dry by covering with plastic, they can be burned in the winter when all fire danger has passed.

Figure 12. Left: typical North Dakota pile with mixed sizes. Right: Conservation Burn piles (pine) in California with mostly similar sized material and very small material on top for ignition.

Rowdy Yeatts of High Plains Biochar has used the snow quenching technique on some smaller piles. He reports that it is not enough to just pile snow on top, but mixing is needed to prevent flare ups later on. He also describes a technique for separating material that is charred from larger uncharred pieces and quenching it:

> "We typically burn the pile down and push the larger unburned pieces to the top until we feel like we are losing char. Then we pull the unburned pieces out and let them burn in a small pile we refer to as a "side pile". At that point the char is quenched with snow and piled so it can be retrieved or you could simply spread in the surrounding area." (personal communication, January 12, 2017).

Figure 13. Snow quenching in Nebraska. Rowdy Yeatts of High Plains Biochar uses snow to quench Conservation Burn piles.

Production Steps for Conservation Burn Piles

Steps for using the Conservation Burn method to accomplish this job are listed:

- Remove trees as usual
- Separate branches from boles and stumps
- Set aside boles > 8" for firewood recovery

- Make 20’x40’ piles that are about 10’ high in the new tree rows – each pile should use similar sized material, eg – make a pile of 4” and less diameter and another pile of 4”-8” material
- Cover piles with plastic and weight down with large tree boles or tires
- Let piles dry and wait until there is snow on the ground to burn
- Light piles using propane or drip torch
- Tend piles with skid steers – one skid steer for each 3 or 4 piles – tending means consolidating material as it falls out of the pile and mixing charred material with snow to quench
- When all flame is gone, quench remaining char by mixing with snow and spreading evenly across the row as part of site preparation for replanting

Spreadsheet Model Values

The sources for values used in the spreadsheet model are given in the notes below:

1. Number of Siberian Elm trees per half mile: Clyde Reilly, Shelterbelt Solutions, personal communication, January 4, 2012.
2. Average biomass of one tree, from Canadian National Forest Inventory, value for American Elm https://nfi.nfis.org/en/biomass, based on estimate from Clyde Reilly of average size tree of 50cm dbh and 12 meters tall.
3. Conversion efficiency assumptions based on personal experience and Cornelissen, G., Pandit, N. R., Taylor, P., Pandit, B. H., Sparrevik, M., & Schmidt, H.-P. (2016). Emissions and Char Quality of Flame-Curtain “Kon Tiki” Kilns for Farmer-Scale Charcoal/Biochar Production. *Plos One*, *11*(5), e0154617–16. http://doi.org/10.1371/journal.pone.0154617
4. Biochar bulk density based on personal experience and Brewer CE, Levine J: *Weight or Volume for Handling Biochar and Biomass?* the Biochar Journal 2015, Arbaz, Switzerland. ISSN 2297-1114 http://www.biochar-journal.org/en/ct/71
5. Biomass per pile based on US Forest Service burn pile biomass calculator available at: https://depts.washington.edu/nwfire/piles/
6. Pile burn rate based on personal experience.
7. Feedstock prep cost estimate based on the following assumption: A bid to remove and cleanup a 4420-foot row of elm trees was $8840, the equivalent of $18/ton of biomass processed. We assumed that removing branches from boles and sorting by size would add 25% more to the cost, for an additional $4.5/ton to prepare the feedstock.

We assume that two thirds of the material will be branches and stems that are under 8” in diameter, leaving one third that will not be processed in the conservation burn. We assume that boles can be sold to a firewood processor who will come and pick them up and pay a certain amount per ton for them (assume $10). Stumps will not be processed and need to be disposed of separately. However, if an economical method of size reduction is used – perhaps by splitting or cracking large material – then the larger boles could be processed as well. The stumps will likely have too much dirt mixed in to be useable.

Spreadsheet Model for Conservation Burn Piles

The entire model is presented below with given values:

TABLE 1. Conservation Burn Pile Model

Biomass Estimates	
Number of Siberan Elm trees per half mile row ***(1)***	275
Average tree dbh, cm	50
Average tree height, m	12
Average tree biomass, kg ***(2)***	967
Total tree biomass per 1000 ft row, tons	111
Percent of biomass less than 8" diameter	0.67
Biomass available to char/1000 ft, tons	74
Biomass requiring size reduction to char, tons	37
Required Equipment & Supplies	
Skidsteers with loading and saw attachments	4
Black polyethylene film, 20 ft wide, lineal feet	523
Biochar Production Quantities	
conversion efficiency assumption ***(3)***	15%
biochar bulk density (lb/cy) ***(4)***	500
Unprocessed biomass, >8" diameter, tons	37
Total biochar production, tons	11.1
Biochar Production Rate Estimates	
Pile height (feet)	10
Pile width	20
Pile length	40
biomass per pile, tons ***(5)***	5.68
Time to ignite, hrs/pile	0.25
Time to ignite piles	0.8
Pile burn rate, feet/hour ***(6)***	3
Time to complete charring, 1 pile	3.3
Time to complete all piles, hrs	4.2
Workers available to light piles	4
Number of skidsteers/operators	4

Labor & Equipment Estimates	
hourly rate (skidsteer+operator)	75
hourly rate for manual labor	40
Feedstock Prep	
Separate branches from boles, $/ton ***(7)***	4.5
piles per 1000 ft	13
space between piles, ft	37
time to cover 1 pile with plastic, hr	0.5
Total pile covering labor hours	6.5
Biochar Production, Quenching & Application	
Burn pile tending, total labor/equip hours per operator	4.2
Quenching and spreading with skidsteers, hrs/pile	0.5
Total quench/spread labor/equip hours	7
Quench/spread hours per operator	1.6
total hours per operator from burn to quench	5.8
Application Rate to New Tree Row	
Width of tree row, feet	20
Length of tree row, feet	1000
Acreage of tree row, ac	0.5
Application rate, tons/ac	24.3
Total Costs	
Feedstock prep	$498.61
Covering piles, labor	$261.40
Plastic, 4 mil polyethylene, $1/foot	$522.80
Lighting piles	$130.70
Tending piles	$1,245.06
Quenching and spreading	$490.12
Total cost for biochar production & application	$3,148.69
Value of firewood from 8"> material, $/ton	$10.00
Subract recovery value of firewood	$(365.65)
Total cost for biochar after firewood value	$2,783.05
Cost per ton of biochar/applied	$249.92
Cost per cubic yard of biochar/applied	$62.48
Cost per ton of biomass processed	$25.12

Case Study #2: Remove a half mile of field tree row – Flame Cap Kiln

Another typical case in windbreak renovation is to completely remove a field row of Siberian Elm without replanting. In this case, another row may be replanted elsewhere and biochar made from the removed row can be used there, or the biochar can be saved for another use on or off the farm. This example will use the Flame Cap Kiln method to convert material to biochar in containers. This makes it easier to quench the char and to move it to another location.

The biggest challenge for using this method is acquiring an appropriate container that has a capacity of 20 cubic yards or more. Containers must be heat resistant and sealed against water and air. They must also be fitted with drains to drain quenching water. Time efficient production also requires multiple containers to be used at the same time. Transporting multiple empty containers is more cost effective if the containers can nest.

There are two options for nesting containers: bathtub style dumpster bins with gates and custom built slant-sided containers. It is possible to get dumpster bins with sealed gates, but the sealing material must be able withstand temperatures up to 800 degrees F. Bins will also need to have drain holes with plugs installed. One advantage of dumpster bins is ease of unloading by means of the gate end. A 20-cubic yard sealed container can be purchased new for about $5,000. Standard construction used in this style of dumpster should be heavy enough to withstand the heat generated during burning, if it can be modified with heat-proof seals. It would also be possible to seal the gates with a weld, but then the gates would no longer function for unloading the char and for stacking the bins.

The cheapest option may be to build custom bins that can be stacked on a flat-bed trailer for transport but can also load onto a roll-off trailer so that bins full of char can be moved to different locations on or off the farm. Until the concept is fully proven, it may be best to look for cheap or free containers that can be re-purposed, such as water tanks. The pictures below illustrate some of these options.

Figure 14. Left: Nesting 12-yard dumpster with roll-off trailer transported on lowboy. Right: Nested 20-yard dumpsters.

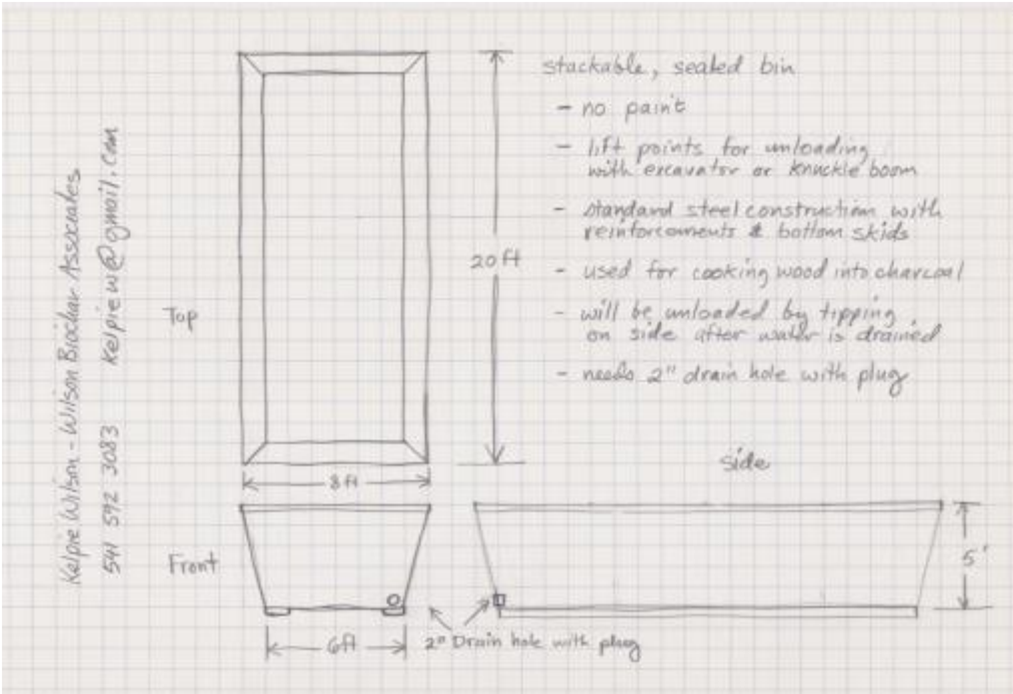

Figure 15. Drawing by Wilson Biochar Associates of custom 20-yard bin to use as Flame Cap Kiln. Pyramidal shape ensures that it will nest and multiple units can stack for transport. Copyright 2017, WBA.

Production Steps for Flame Cap Kilns

Steps for using the Flame Cap Kiln method to accomplish this job are listed:

- Remove trees as usual
- Separate branches from boles and stumps
- Set aside boles > 8" for firewood recovery
- Roughly sort material into categories of 4" and less diameter and of 4"-8" material in one long pile.
- Let material dry and wait until conditions are safe for burning in early fall. Do not allow feedstock to get too wet, greater than 20% moisture.
- Distribute the containers along the feedstock pile
- Load each container, loosely, with same-size material
- Light on top using propane or drip torch
- Wait until initial charge burns down into pile of coals
- Load piles with skid steers – one skid steer for each 2 containers. Add a new layer about every ten minutes – longer for larger material and shorter for smaller material. Add new material when previous layer begins to ash.
- When containers are full and all flame is gone, quench by completely flooding the container and allowing to sit overnight.
- The next day, drain the container before transporting and unloading char.

Spreadsheet Model Values

The sources for values used in the spreadsheet model are given in the notes below:

1. Production rate, minutes per inch – from personal experience. Variable with feedstock type, feeding rate and feedstock moisture content.

Additional assumptions concern the cost and amortization of the dumpster bins and equipment for moving them. We used the following formula for equipment cost recovery: (total cost)(5%)(13)(80%) = cost per year

If each bin costs $5000 then the depreciation cost per year is $2600. If a bin is used 20 times a year, then a rental charge of $200 per use should cover depreciation and bin transport. These values subject to change according to requirements of each contractor.

Spreadsheet Model for Flame Cap Kiln

The entire model is presented below with given values:

TABLE 2. Flame Cap Kiln Model

Biomass Estimates	
Number of Siberan Elm trees per half mile row	275
Average tree dbh, cm	50
Average tree height, m	12
Average tree biomass, kg	967
Total tree biomass per half mile row, tons	293
Percent of biomass less than 8" diameter	0.67
Biomass available to char/half mile row, short ton	196
Biomass requiring size reduction to char, short ton	97
Required Equipment & Supplies	
Skidsteers with loading and saw attachments	4
Sealed waterproof, heat resistant rolloff bins	8
40 foot flatbed trailer, bin transport	1
20 foot rolloff trailer to move full bins on farm	1
Water truck or irrigation water, gallons	16,000
Biochar Production Quantities	
conversion efficiency assumption	20%
biochar bulk density (lb/cy)	500
Bin capacity, cy	20
Batch biochar production, ton/bin	5
Biomass processed per bin, tons	25
Unprocessed biomass, <8" diameter, tons	-4
Unprocessed biomass, >8" diameter, tons	97
Total unprocessed biomass, tons	93
number of bins/half mile	8
Total biochar production, tons	40

Biochar Production Rate Estimates	
Bin height (inches)	48
production rate, minutes/inch ***(1)***	10
Production time to fill bin, hours	8
Labor & Equipment Estimates	
hourly rate (skidsteer+operator)	75
hourly rate for manual labor	40
Feedstock Prep	
Separate branches from boles, $/ton	4.5
Biochar Production	
Bin equipment cost/bin/day	200
skid steer loaders/bin	0.5
daily loading hours	8
Quenching time/bin	0.5
Biochar Application	
Transport bin to site, hr	1
Unload and spread/bin, hr	2
Application Rate to New Tree Row	
Width of tree row, feet	20
Length of tree row, feet	2640
Acreage of tree row, ac	1.2
Application rate, tons/ac	33.0
Total Costs	
Feedstock prep cost	$1,319.09
Total labor+equip for charring	$4,000.00
Labor for bin transport	$320.00
Total labor+equip for quench, unload & spread	$1,360.00
Total cost for biochar production & application	$6,999.09
Value of firewood from 8"> material, $/ton	$10.00
Subract recovery value of firewood	$(967.34)
Total cost for biochar after firewood value	$6,031.76
Cost per ton of biochar/applied	$150.79
Cost per cubic yard of biochar/applied	$37.70
Cost per ton of biomass processed	$20.58

*** A negative number indicates that bins have not been filled to capacity. A positive number indicates the amount of biomass that is left over after bins are full. A large positive number means more bins should be used.***

Case Study #3: Harvest 1000 lineal feet of coppice Caragana

Caragana arborescens, or Siberian peashrub, is a widely-used windbreak species that has great potential for coppicing as a feedstock for biochar. As a small stemmed shrub, it can be converted to biochar relatively quickly and easily, as long as it is dry. Farmers and ranchers can potentially produce a constant supply of biochar by planting Caragana windbreaks and harvesting them continually.

In this scenario, we look at a smaller job that may best be done by farmers rather than contractors, depending on the amount of material and the farmer's time commitments. The method used is the Flame Cap Kiln, but rather than purchase a container, we specify an excavated pit of the same dimensions as a 20-yard bin. The pit can be used to store the biochar until needed, serving as a sort of biochar "mine" on the property. The pit can also be re-used many times, even starting new biochar burns on top of old char if the pit is not full. It can be loaded by machine or by hand.

Another alternative to a pit could be the use of cattle panel windscreens to make a temporary enclosure around a pile. Additional material can be loaded into the enclosure. Windscreens could also be placed around a pit for greater air control. With windscreens in place, a shallow, rather than a deep pit could be used. Various combinations of windbreaks and pits of different dimensions may prove to be optimal.

Figure 16. Cattle panel windbreaks can be deployed as a "Burn Corral" to improve burning efficiency of a pile.

Production Steps for Caragana Burn Pit

Steps for using the Burn Pit method to accomplish this job are listed:

- Harvest Caragana and leave to dry
- Excavate a pit – 20'x8' by 4 ft deep
- Fill pit with loose pile of Caragana
- Light on top using propane or drip torch

- Wait until initial charge burns down into pile of coals
- Load additional material by hand or with machines. Add a new layer about every five minutes or whenever previous layer begins to ash.
- When pit is full and all flame is gone, quench flood the pit as completely as possible.
- Prevent re-ignition by covering the char with sheets of old roofing steel. Pile dirt on top of that to seal off air.
- Char may take several days to cool completely. Dig out and use when cool.

Spreadsheet Model Values

The sources for values used in the spreadsheet model are given in the notes below:

1. Coppice Caragana biomass per mile given by Alberta Agriculture and Forestry: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng9864

Spreadsheet Model for Caragana Burn Pit

The entire model is presented below with given values:

TABLE 3. Caragana Burn Pit Model

Biomass Estimates	
Coppice Carragana biomass per mile, tons ***(1)***	95
Biomass per 1000 feet, tons	18
Required Equipment & Supplies	
Skidsteer with loading attachment	1
Excavator or skidsteer	1
Water truck or irrigation water, gallons	4000
Used steel roofing material, 20 ft lenghts	4
Biochar Production Quantities	
conversion efficiency assumption	25%
biochar bulk density (lb/cy)	400
Total biochar production, tons	4.5
Total biochar production, cy	22.5
Biochar Production Rate Estimates	
Pit depth (inches)	48
production rate, minutes/inch	5
Production time to fill bin, hours	4
Number of skidsteers/operators	1

Labor & Equipment Estimates	
hourly rate (skidsteer+operator)	75
hourly rate for manual labor	40
Pit excavation 8'x20' by 4' deep	
Excavation labor/equip hours	8
Biochar Production	
Pit loading total labor/equip hours	4.0
Biochar Quenching	
Flood with water, labor hours	1
Place roofing steel, labor hours	0.5
Move dirt on top, labor/equip hours	1
Total Costs	
Pit excavation, ammortized at 25% per use, 4 uses	$150.00
Burn tending, loading	$300.00
Quenching	$60.00
Total cost for biochar production	$510.00
Cost per ton of biochar	$113.38
Cost per cubic yard of biochar	$22.68
Cost per ton of biomass processed	$28.35

Conclusions

Incinerating woody biomass for disposal contributes to smoke pollution, greenhouse gas emissions and the waste of resources. These problems can be avoided by using low cost and clean methods to convert woody waste to valuable biochar. Biochar can improve soils by increasing their carbon content and capacity to hold both water and nutrients, saving money for farmers. Biochar markets are immature as yet, but bulk totes of biochar generally sell for between $200-$400 a cubic yard.

Using the methods described here to produce biochar on the farm, we project that biochar can be produced at a cost of between $23 and $63 per cubic yard (see Table 3). Biochar produced on the farm avoids transportation costs, which can be high for this low bulk density material. In addition, methods 1 and 2 include the cost of spreading the biochar on a tree planting site as part of the quenching or unloading process.

TABLE 4. Biochar Technology Comparison

Biochar technology	Biochar post-production needed	$/cubic yard	$/ton biomass processed
1. Conservation Burn	Till into tree-planting ground	62.48	25.12
2. Flame Cap Kiln	Till into tree-planting ground	37.70	20.58
3. Burn Pit	Unload, spread and till	22.68	28.35

It is important to realize that the costs in Table 3 are additional costs and the tree removal cost must be added for the total cost of the biochar. However, it is also important to quantify the benefits of biochar to the farmer or landowner. These benefits may include increased soil water holding capacity, better nutrient retention, improved soil tilth and a boost to soil microbial life, among others.

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