Appendix: In-Stand Surface Application of Biochar in Forestlands

Section 1: Introduction & Summary

Overview

This document serves as a proposed appendix to the *Methodology for Biochar Utilization in Soil and Non-Soil Applications* currently under review by Verra. Specifically, this appendix outlines a well-supported exception to the limitations of *Section 4. Applicability Conditions*: *Eligible biochar end-use criteria*, to allow for in-stand surface level application of biochar as a unique soil amendment. We propose a project-design, from waste biomass sourcing through production and application, that justifies this change specifically for forest application.[1]

Background & Reasoning

"For surface application, the biochar must be mixed with other substrates such as compost or manure."[2]
-Section 4. Methodology for Biochar Utilization in Soil and Non-Soil Applications, pg. 11.

We understand that the above language was intended to prevent loss of biochar to wind transport and erosion, likely in agriculture applications.[3] While relevant to application of biochar in an open field, this reasoning is not applicable to in-stand forest application for the following reasons:

1.1. *Protection from wind*: Unamended biochar will only be applied to the soil surface in forestland with adequate soil organic horizons. Biochar losses due to wind in such terrain are expected to be minimal. Furthermore, in accordance with best management practices to avoid wind loss, we will ensure that biochar is adequately wetted during the production and application process.[4]
1.2. *Protection from water and erosion*: It is well documented that biochar improves soil water retention, thereby decreasing the risk of transport due to water runoff.[5] In a large rain event, biochar can absorb up to twice its weight in water, which significantly reduces the risk of catastrophic flooding. Water transport has also been found to be a more significant issue when applied to sloping

[1] See Link to Methodology.

[2] The provision that "biochar must be mixed with other substrates" appears to restrict surface application of biochar to instances where compost or manure are available. However, the examples of compost and manure reveal that the methodology is intended to limit biochar surface application only in an agricultural setting. As explained below, in the case of forest applications, we believe that Section 4 does not intend to limit direct use of biochar to the forest floor. In a woodland setting, the forest floor itself functions as a substrate within the meaning of Section 4.

[3] See Exhibit A.1 for email correspondence with Verra representatives highlighting this reasoning.

[4] Major, J. (2010). Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems. 23.

[5] Amonette et al., 2021. *Biomass to Biochar: Maximizing the Carbon Value.* (53-54). Report by Center for Sustaining Agriculture and Natural Resources, Washington State University, Pullman WA

terrain.[6] However, as long as the soil is intact and there are organic horizons to catch biochar, soil scientists with the Rocky Mountain Research Station have found that biochar remains on site even on slopes up to 35 degrees.[7] Our methods are specifically aimed at minimizing disturbance to soil and our project area does not include slopes greater than 35 degrees.

1.3. *Size of biochar particles:* Our project design will yield large biochar pieces averaging 1-3 inches in diameter that will not undergo grinding or any additional processing to reduce their size. This will significantly decrease the amount of biochar "dust" that is created, and therefore the risk of transport.[8] It has also been noted that biochar is often lost during transportation and mechanical spreading (for example in a lime spreader), two steps that our project design will entirely eliminate.[9]

Given our project boundaries and precautions, losses due to wind or water erosion should be de-minimis. From an ecological standpoint, place based-production and in-stand application will reduce soil disturbance and prevent the introduction of foreign materials to the forest ecosystem.[10][11] Importantly, when biochar is applied as a unique soil amendment to forests it provides similar carbon, soil health, and other co-benefits compared to biochar amended with additional substrates, as long as the forest soil remains intact.[12] Therefore, our project will yield similar carbon sequestration and other benefits and can be calculated with the same metrics used in the *Methodology for Biochar Utilization in Soil and Non-Soil Applications.* As highlighted by biochar consultant and Biochar in the Woods committee chair for the US Biochar Initiative, Kelpie Wilson, the best use of biochar would be to leave it in forest soils.[13]

Section 2: Place-Based Production Methods

Place-based biochar involves both the production and application of biochar from feedstock originating on site. This sector uses leftover biomass residuals from a range of landscape management practices including logging, thinning, and other forestry activities. Place-based methods often utilize technologies with lower capital and operating costs, yet require a larger workforce to implement at scale. This provides a unique opportunity for green job creation, especially when implemented in conjunction with ongoing fuel reduction and vegetation management projects. By converting "waste" biomass into a valuable resource, place-based biochar has the potential to provide new economic opportunities in the form of eco-credits and to improve ecological benefits of current forest management practices. Importantly, the creation of biochar alone is not an ecologically beneficial practice unless it is anchored

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[6] Rumpel et al. (2006). Preferential erosion of black carbon on steep slopes with slash and burn agriculture. *CATENA*, *65*(1), 30–40. https://doi.org/10.1016/j.catena.2005.09.005

[7] See Exhibit A.2.

[8] Major, J. (2010). Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems. 23.

[9] Husk, Barry. (2009). Preliminary Evaluation of Biochar in a Commercial Farming Operation in Canada. Blue Leaf Incorporated: Biochar Field Trial.

[10] Page-Dumroese et al., (2016). Opportunities and Uses of Biochar on Forest Sites in North America. In V. J. Bruckman, E. Apaydın Varol, B. B. Uzun, & J. Liu (Eds.), *Biochar* (1st ed., pp. 315–335). Cambridge University Press. https://doi.org/10.1017/9781316337974.016

[11] Neukirch, Alexis (2022). Biochar Basics: An A to Z Guide to Production, Use, and Benefits. *Science You Can Use Bulletin* (54). Rocky Mountain Research Station, United States Department of Agriculture.

[12] Wilson, K. (2022, January 27). Biochar in the Woods [Webinar]. Wilson Biochar. https://wilsonbiochar.com/resources

[13] WIlson, Biochar in the Woods, 5:58.

within sustainable, regionally appropriate, regenerative land management systems that support overall ecosystem function, biodiversity, and sociocultural wellbeing.

Conservation Burns

Conservation burns are a low-tech pyrolysis option that involve open pile burning without a kiln.[14] If water is available, this is the simplest and most accessible way to produce biochar. When managed appropriately, conservation burns prevent incineration of the organic soil horizon associated with conventional slash pile burns.[15] In doing so, conservation burns curb the growth of invasive species, protect soil microbial life, and decrease carbon emissions.

Consistent with place based production best practices the following methods will be employed:[16,17,18,19]

2.1. *Description of piles*: Conservation burn piles will be constructed using feedstock of relatively consistent diameters, with a maximum diameter of approximately six inches. This will ensure that all materials will convert to char at approximately the same rate. All feedstock will be thoroughly dried prior to burning in the field and protected from rain using methods such as Kraft Paper coverings. The majority of the material must have a moisture content of 25% or less, as measured in the field. Piles will be largely free of dirt and rock. Optimal pile construction will vary according to the moisture content, size and species of the material. Piles will be widely distributed across the project area to decrease labor costs and emissions from transporting feedstock, and to retain forest nutrients in place. Project proponents must conduct appropriate background research to determine which construction methods are best suited to their local conditions.

2.2. *Description of pyrolysis*: Unlike conventional burns, conservation piles will be ignited in such a way that a strong flame is developed, forming a cap on the top of the pile. The flame burns smoke emissions, reducing particulates. Piles will be tended to ensure the flame cap is maintained. As long as a strong flame is maintained, biochar production temperatures will range from 1100 to 1400 degrees F. Once the pile is reduced to mostly glowing coals and strong flaming has stopped, the coals will be quenched with water and raked to a thin layer to lose heat. Quenching prevents ash formation and ensures maximum carbon sequestration. Quenching also protects underlying soils from incineration. Some larger or wetter logs will remain incompletely charred. These will be extinguished and set aside and not counted as biochar production.

2.3 *Additional considerations:* Our first burns are scheduled for October, 2022. According to U.S Climate Data, Whatcom County averages 3.27 inches of rainfall in October. This is enough to help dampen biochar and reduce wind loss. Flooding is unlikely during October, which will reduce the risk of flood loss. Burns will only be executed on rainy days or within 2 days of at least .15 inches of

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[14] Hoffman-Krull, K. (2018). Biochar Production for Forestry, Farms, and Communities. *Northwest Natural Resource Group.*

[15] Amonette, *Biomass to Biochar,* 62-63.

[16] Amonette, *Biomass to Biochar.*

[17] Hoffman-Krull, *Biochar Production.*

[18] Neukirch, *Biochar Basics*.

[19] Wilson, *Biochar in the Woods.*

rain.[20] No burn activities will occur if the weather predicts more than 14 mph. We will use the [CalTopo](#)wind forecast mapping tool to choose an appropriate burn date for our project area.

Surface Application Considerations

Surface application of biochar, when managed appropriately to prevent wind or water loss, provides important ecological benefits to the forest. Surface application does not disturb the soil or introduce new substrates to the forest ecosystem. Maintaining soil structure and surface organic horizons is essential for maintaining soil health and storing carbon.[21]

Consistent with place based production best practices the following application methods will be employed:[22,23,24,25]

2.5. *Application rates:* Application rates will vary depending on how much excess fuel needs to be removed to achieve forest management objectives. A common threshold is between 1-3 tons of biochar per acre, or about 8-24 cubic yards/acre. More importantly, biochar should be dispersed back out onto the same acreage that the feedstock originated.
2.6. *Application process:* For the pilot project, biochar will be manually applied and spread with rakes. This will minimize soil disturbance and costs. Other hand tools and buckets may be appropriate as well.

Section 3: Benefits of In-Stand Surface Application of Biochar

It is estimated that temperate-zone forests remove about 3.4 tonnes CO_2 per hectare per annum, of which 69%-92% is ultimately stored in soils.[26,27] It is thus imperative that we maintain healthy and productive forests to mitigate climate change, as well as keep our air and water clean, reduce wildfire risk, and provide habitat for wildlife. Forest health varies widely depending on location and forest type, and it is thus critical that land managers and practitioners of this methodology demonstrate a knowledge of the local forest type and management objectives first, before producing biochar. Though biochar will be integrated into these strategies differently depending on location, place-based production and subsequent surface application of biochar will reliably enhance forest health in the following ways:

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[20] Wind and water parameters adapted from a conservation burn plan developed by the Island County Conservation District Project Manager. "Orcas Fire and Rescue Burn Permit Appendix: Conservation Burn Methodology". Our project is similar in scale and ecosystem.

[21] Page-Dumroese, D. S., Jurgensen, M. and Terry, T. (2010). Maintaining soil productivity during forest biomass-to-energy thinning harvests in the western United States. Western Journal of Applied Forestry, 25, pp. 5–11.

[22] Amonette, *Biomass to Biochar.*

[23] Hoffman-Krull, *Biochar Production.*

[24] Neukirch, *Biochar Basics*.

[25] Wilson, *Biochar in the Woods.*

[26] Gough, C. (2011). *Terrestrial Primary Production: Fuel for Life | Learn Science at Scitable*. https://www.nature.com/scitable/knowledge/library/terrestrial-primary-production-fuel-for-life-17567411/

[27] Pan et al. (2011). A Large and Persistent Carbon Sink in the World's Forests. *Science*, *333*(6045), 988–993. https://doi.org/10.1126/science.1201609

improve soil health, mitigate erosion, improve water quality, curb invasive species growth, and aid reforestation.[28] While burying biochar may be appropriate in some agricultural settings, it increases costs for forest managers and harms soil structure in forest settings. Surface application, however, requires fewer inputs and causes less disturbance to forest soils. Maintaining soil structure is key to keeping carbon in the ground. Surface application also mimics the way that wildfire would add biochar as charred material falls from burned trees on the soil surface.

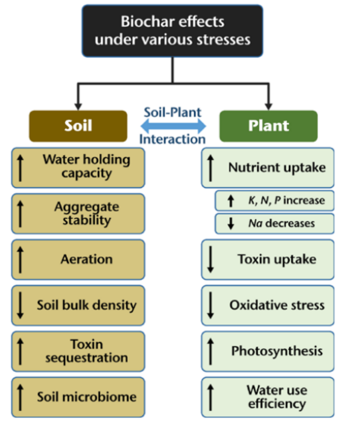

Figure 1. Model of how biochar affects soil, plants, and soil-plant interactions under stressed conditions (Source: Gang 2018 [39]).

Co-benefits

3.1. *Soil Health*: Biochar improves forest soil health in the following ways:

3.1.a.*Soil physical improvements:* Biochar can improve a range of soil physical properties, including soil porosity, pore-size distribution, bulk density, moisture holding capacity, infiltration, and hydraulic conductivity.[29,30] Biochar is highly porous and can hold an estimated twice its weight in water for several days after a rain event.[31] This short-term buffering effect helps blunt the impacts of large rains that lead to flooding. The additional water storage capacity of soil amended with biochar also serves to enhance plant productivity.

3.1.b. *Soil chemical improvements*: Although application of biochar may temporarily increase microbial respiration in soils, increasing CO2 emissions, cumulatively biochar has been shown to increase soil carbon stocks in forests by as much as 41%.[32] Just as pyrolysis of biomass releases some carbon into the air in the process of fixing the remaining carbon, so biochar application to soil often promotes increased microbial respiration. This is called priming and can occur from the addition of nutrients, pH changes, and the contribution of biochar stable carbon to the support of microbial life.[33] However, after biochar has aged in soil it begins to increase and protect soil carbon stocks through the formation of humus that adheres to biochar surfaces.[34] In addition, soil carbon emissions of CO2 and other GHG may start to decrease due to the increased metabolic efficiency of the microbial community as a whole in the presence of biochar.[35] This is called negative priming. In addition to carbon, biochar also increases nutrient availability,

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[28] Amonette, *Biomass to Biochar.*

[29] Atkinson, C. J., Fitzgerald, J. D. and Hipps, N. A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant and Soil, 337, pp. 1–18.

[30] Van Zwieten, L. V., Singh, B. P. and Cox, J. (2012). Biochar effects on soil properties. In: Cox, J. (ed.) Biochar in Horticulture: Prospects for the Use of Biochar in Australian Horticulture. New South Wales, Australia: Horticulture Australia, NSW Department of Primary Industries, Chapter 4.

[31] Amonette, *Biomass to Biochar,* 53-54.

[32] Sarauer, J. L., Page-Dumroese, D. S., & Coleman, M. D. (2019). Soil greenhouse gas, carbon content, and tree growth response to biochar amendment in western United States forests. *GCB Bioenergy*, *11*(5), 660–671. https://doi.org/10.1111/gcbb.12595

[33] Kuzyakova, Y., Friedelb, J. K., & Stahra, K. (2000). Review of mechanisms and quantification of priming effects. *Soil Biology & Biochemistry 32 (2000) 1485-1498.* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.709.6588&rep=rep1&type=pdf

[34] Zimmerman, A. R., Gao, B., & Ahn, M.-Y. (2011). Positive and negative carbon mineralization priming effects among a variety of biochar-amended soils. *Soil Biology and Biochemistry*, *43*(6), 1169–1179. https://doi.org/10.1016/j.soilbio.2011.02.005

[35] Ameloot, N., Graber, E. R., Verheijen, F. G. A., & De Neve, S. (2013). Interactions between biochar stability and soil organisms: Review and research needs. *European Journal of Soil Science*, *64*(4), 379–390. https://doi.org/10.1111/ejss.12064

including soil phosphorus, potassium, and nitrogen, and decreases nutrient loss from leaching.[36,37]

3.1.c. *Soil microbial improvements*: Biochar enhances microbial activity in forest soils, especially in the short term.[38,39] Microbial biomass is the major agent for energy transfer and nutrient cycling in the soil system.[40] In their meta-analysis, Blanco-Conqui (2020) noted that biochar can improve soil biological properties via the following mechanisms: provision of labile C and nutrients, nutrient retention by reducing losses (i.e., runoff, leaching, N_2O emissions), provision of microhabitats within its porous structure, adsorption of microbes, increased water retention and availability, reduction in soil acidity, and adsorption of toxic elements and compounds.[41,42,43] Though increased microbial activity may increase soil greenhouse gas (GHG) emissions in the short term (1-6 years) due to respiration, biochar does not appear to impact soil GHG emissions over a longer time horizon.[44]

3.2. *Plant Growth*: Most studies related to biochar and plant growth have focused on agricultural applications. Preliminary research on the impacts of biochar on forest growth suggest a negligible to moderately positive impact.[45,46] A recent meta-analysis found that when applied to soils, biochar amendments resulted in a 41% mean increase in woody biomass.[47] Although this analysis included both nursery tree and forest studies, the majority (75%) focused on nursery trees. Another study in Finland found that pine trees amended with biochar showed a 25% increase in diameter and a 12% increase in height during the first three years.[48] Biochar is especially impactful to sapling growth and thus helpful for reforestation efforts after logging.[49] However, these impacts appear to dwindle as tree age increases.[50] Additionally, conservation burns avoid the scarring and subsequent growth of invasive species common after wildfires or slash pile burns.[51] Sites with biochar additions have

[36] Borchard et al. (2019). Biochar, soil and land-use interactions that reduce nitrate leaching and N2O emissions: A meta-analysis. *Science of The Total Environment*, *651*, 2354–2364. https://doi.org/10.1016/j.scitotenv.2018.10.060

[37] Jindo et al. (2020). Role of biochar in promoting circular economy in the agriculture sector. Part 1: A review of the biochar roles in soil N, P and K cycles. *Chemical and Biological Technologies in Agriculture*, *7*(1), 15. https://doi.org/10.1186/s40538-020-00182-8

[38] Gujre et al. (2021). Sustainable improvement of soil health utilizing biochar and arbuscular mycorrhizal fungi: A review. *Environmental Pollution*, *268*, 115549. https://doi.org/10.1016/j.envpol.2020.115549

[39] Li et al. (2018). Effects of biochar application in forest ecosystems on soil properties and greenhouse gas emissions: A review. *Journal of Soils and Sediments*, *18*(2), 546–563. https://doi.org/10.1007/s11368-017-1906-y

[40] Bauhus, J., & Khanna, P. K. (1999). The significance of microbial biomass in forest soils. *Going underground-ecological studies in forest soils. Trivandrum, India: Research Signpost*, 77-110.

[41] Ameloot et al. (2013). Interactions between biochar stability and soil organisms: review and research needs. *European Journal of Soil Science*, 64, 379– 390.

[42] Gul et al. (2015). Physico-chemical properties and microbial responses in biochar-amended soils: Mechanisms and future directions. *Agriculture, Ecosystems & Environment*, 206, 46– 59.

[43] Lehmann et al. (2011). Biochar effects on soil biota – A review. *Soil Biology and Biochemistry*, 43, 1812– 1836.

[44] Sarauer, *Soil Greenhouse Gas.*

[45] McElligott, Biochar Amendments.

[46] Sarauer, *Soil Greenhouse Gas.*

[47] Thomas, S. C., & Gale, N. (2015). Biochar and forest restoration: A review and meta-analysis of tree growth responses. *New Forests*, *46*(5), 931–946. https://doi.org/10.1007/s11056-015-9491-7

[48] Palviainen et al. (2020). Biochar amendment increases tree growth in nutrient-poor, young Scots pine stands in Finland. *Forest Ecology and Management*, *474*, 118362. https://doi.org/10.1016/j.foreco.2020.118362

[49] Wilson, K. (2016). Biochar for Forest Restoration in the Western United States. Wilson Biochar Associates.

[50] Sarauer, *Soil Greenhouse Gas.*

[51] Amonette, *Biomass to Biochar,* 63.

shown improved native vegetation success and increases in pollinator plants and insects due to the enhanced soil health.[52]

Maximizing Net Carbon Capture

In-stand surface application of biochar would reduce emissions in the sourcing, production, and application stages. Conservation piles are smaller and more distributed, requiring less movement of biomass. There are no additional scope one, two, or three emissions associated with conservation burns because no energy is required to operate, move, or build a kiln. Likewise, the biochar will not have to be transported or processed at an external location, which will also reduce emissions in the application stage. In addition to the carbon sequestration and resulting climate benefits of surface application, in-situ application will significantly reduce operation costs and emissions.[53]

Wildfire Mitigation and Recovery

In fire adapted forests, post-fire charcoal has long been an important source of soil organic carbon.[54] Studies have found that soil profiles from older forests show significant amounts of char, while soil profiles from younger forests that have undergone decades of fire suppression are severely lacking char.[55] Pre-colonial Indigenous communities in the American West performed frequent landscape burns that cleared forest understory and produced biochar.[56] This stewardship practice created exceptional wildlife habitat and a forest ecosystem that was more resistant to catastrophic fire. Short of revitalizing these practices through the return of Indigenous stewardship of the land, place-based biochar production can support the restoration of forests to a condition where prescribed and cultural burning is once again possible. Place-based biochar production is a temporary intervention and harm-reduction tool as we recover from decades of fire suppression. “The best thing we could do with the char would be to leave it in the forest soils.”[57]

As more organizations look to prescribed burning as an essential fire risk reduction tool, there is growing potential for integration with biochar production. Converting forest slash from necessary wildfire thinning projects into biochar turns a costly and highly polluting waste disposal process (burning or chipping), into an economically viable and ecologically valuable solution. Leaving biochar on site to enrich forest soils should help forests become more resilient to the environmental stresses of climate

[52] Neukirch, *Biochar Basics*.

[53] Puettmann, M., Wilson, K., Oneil, E. (March, 2018). Life Cycle Assessment of Biochar from Post-Harvest Forest Residues. Waste to Wisdom: Subtask 4.7. Consortium for Research on Renewable Industrial Materials. https://img1.wsimg.com/blobby/go/55a2e356-17ba-48af-b8c3-a76d3f66be29/downloads/w2w-biochar-lca-final-report.pdf?ver=1663358352629

[54] Wilson, Forest Restoration.

[55] DeLuca, T. H., & Aplet, G. H. (2008). Charcoal and carbon storage in forest soils of the Rocky Mountain West. *Frontiers in Ecology and the Environment*, *6*(1), 18–24. https://doi.org/10.1890/070070

[56] Amonette, *Biomass to Biochar,* 59.

[57] Wilson, *Biochar in the Woods, 5:58.*

change.[58] Though more research is needed, biochar may also aid in post fire soil recovery. One study found that biochar reduced soil erosion by 50% - 64% compared to unamended post-fire plots.[59]

Importantly, the climate mitigation potential of place-based biochar is not limited to the soil carbon sequestration achieved by adding biochar. “If biochar can be returned to forest soils at a large enough scale to improve soil and plant resiliency, it could be the difference between forests sequestering carbon or contributing carbon to the atmosphere through forest fires.”[60]

Section 4: Parameters for Use in Future Projects

We propose the following considerations for use of this appendix in future projects:

4.1. Surface application of biochar as a unique soil amendment is only permissible in forestlands in which the removal and conversion of biomass is consistent with the best management practices appropriate to the forest type.

4.2. The following site-selection criteria should be considered to minimize biochar loss due to wind or water:

- 4.2.a. Biochar should not be added to slopes greater than 35 degrees. Biochar may only be added to areas containing adequate organic soil horizons that can “catch” biochar should any pieces be moved in water runoff.
- 4.2.b. Project application sites should include adequate windbreaks.

4.3. Additional precautions shall be undertaken to minimize biochar loss due to wind or water transport including, but not limited to:

- 4.3.a. Biochar shall be appropriately quenched to reduce ash formation.
- 4.3.b. If needed, additional water should be added to thoroughly wet biochar immediately after application to the soil surface.
- 4.3.c. Biochar pieces should not be ground or otherwise processed to reduce their size. This will minimize the amount of biochar “dust” that is created.

4.4. All efforts to maintain soil structure shall be employed, including, but not limited to:

- 4.4.a. No tilling or digging.
- 4.4.b. The use of heavy machinery on intact forest soils should be minimized to avoid soil compaction. If machinery such as a high-capacity biochar spreader is needed, it can be mounted on a log forwarder and used on skid trails or log landings.

4.5. All other measurement, monitoring, and verification requirements applicable to forestry applications under the *Methodology for Biochar Utilization in Soil and Non-Soil Applications* and site specific work plans should be followed.

4.6. Care should be taken to time production and application with appropriate seasonal weather patterns.

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[58] Amonette, *Biomass to Biochar,* 73.

[59] Jien, S.-H., & Wang, C.-S. (2013). Effects of biochar on soil properties and erosion potential in a highly weathered soil. *CATENA*, *110*, 225–233. https://doi.org/10.1016/j.catena.2013.06.021

[60] Amonette, *Biomass to Biochar,* 73.

4.6.a. For example, in the Pacific Northwest, biochar should be applied during the fall when precipitation increases but flood potential is still minimal. This will also ensure that the biomass has been thoroughly dried during the summer to create optimal biochar.

Section 5: Summary

We propose an appendix to the current application requirements under the *Methodology for Biochar Utilization in Soil and Non-Soil Applications,* specifically to allow for in-forest surface application of biochar as a unique soil amendment. In contrast to the current methodology that limits unamended biochar to subsurface soil application, we propose a project design that reduces soil disturbance, decreases prohibitive economic barriers, and maintains the high standards of measurement, monitoring, and verification necessary to support the integrity of carbon markets consistent with the purposes of the methodology. Surface application of biochar in forests, when managed appropriately to reduce the risks of wind and water loss, solves the economic and ecological problems associated with digging or mixing biochar with additional compost or manure substrates.

Section 6: Resources

Ameloot, N., Graber, E. R., Verheijen, F. G. A., & Neve, D. (2013). Interactions between biochar stability and soil organisms: review and research needs. *European Journal of Soil Science*, 64, 379– 390.

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Section 7: Exhibits

Exhibit A. Email Correspondence.

1.

From: [redacted]@verra.org>
Date: Thursday, June 16, 2022 at 1:29 PM
To: Steve Hollenhorst <hollens@wwu.edu>, Kulshan Carbon Trust <info@kulshancarbontrust.org>
Cc: Sarah Parker <sarah@peaksustainability.com>
Subject: RE: Introductions and Methodology Questions

You don't often get email from [redacted]

Hi Steve,

For soil surface application, the methodology requires that the biochar be mixed with other substrates such as compost or manure, or digestate from anaerobic digestion. This is to minimize the risk that the biochar is washed or blown away outside of the project boundary, where its fate could not be determined. For subsurface application, the biochar can be applied either as a unique soil amendment or mixed with other substrates.

Let me know if this answers your question!

Best,
[redacted]

VERRA Standards for a Sustainable Future

[redacted]
www.verra.org

2.

From: [redacted]
Sent: Wednesday, June 29, 2022, 12:17 PM
To: Steve Hollenhorst <hollens@wwu.edu>
Subject: RE: [External Email]Carbon credit creation from place-based biochar production

Hi Steve – great to hear you are making biochar! Thanks for the awesome work on getting the slash pile work into the carbon credit arena.

I've attached a nice review on ecosystem services from biochar. There aren't any pubs (that I know of) specific to PNW forests (or even forests), but this one generally tracks with data I've seen from forest sites. You can also check out this science you can use bulletin on biochar: https://www.fs.usda.gov/rmrs/documents-and-media/biochar-basics-z-guide-biochar-production-use-and-benefits.

I will have two CharBosses working in OR sometime this fall. One will be on the Siuslaw NF where skid trails will be rehabbed with biochar made from slash piles. The other one will be working primarily on BLM lands near Eugene (salvage logging near the Holiday Farm Fire area) and near Medford (Siskyou-Cascade National Monument ponderosa pine thinning). Once those projects wrap up, we'll head to the Willamette NF. If you haven't seen the CharBoss working you can check out this short YouTube video (https://www.youtube.com/watch?v=lqiQPYhbmXk).

In general on forested sites, we have not seen biochar eroding – even from ~35% slopes IF there is an intact forest floor. The organic horizons catch the biochar so it stays on-site.

Holler if you need anything else
[redacted]

[redacted]
Senior Scientist & Research Soil Scientist
Forest Service
Rocky Mountain Research Station

Exhibit B. Site Pictures.

Figure 1. Biochar Pilot Project forest site location. Note the relatively small piles that are distributed throughout the project area. Also note the proximity to intact stands and the presence of foliage and other organic anchors to prevent biochar loss due to water. (Photo credit: Sarah Parker, Kulshan Carbon Trust).