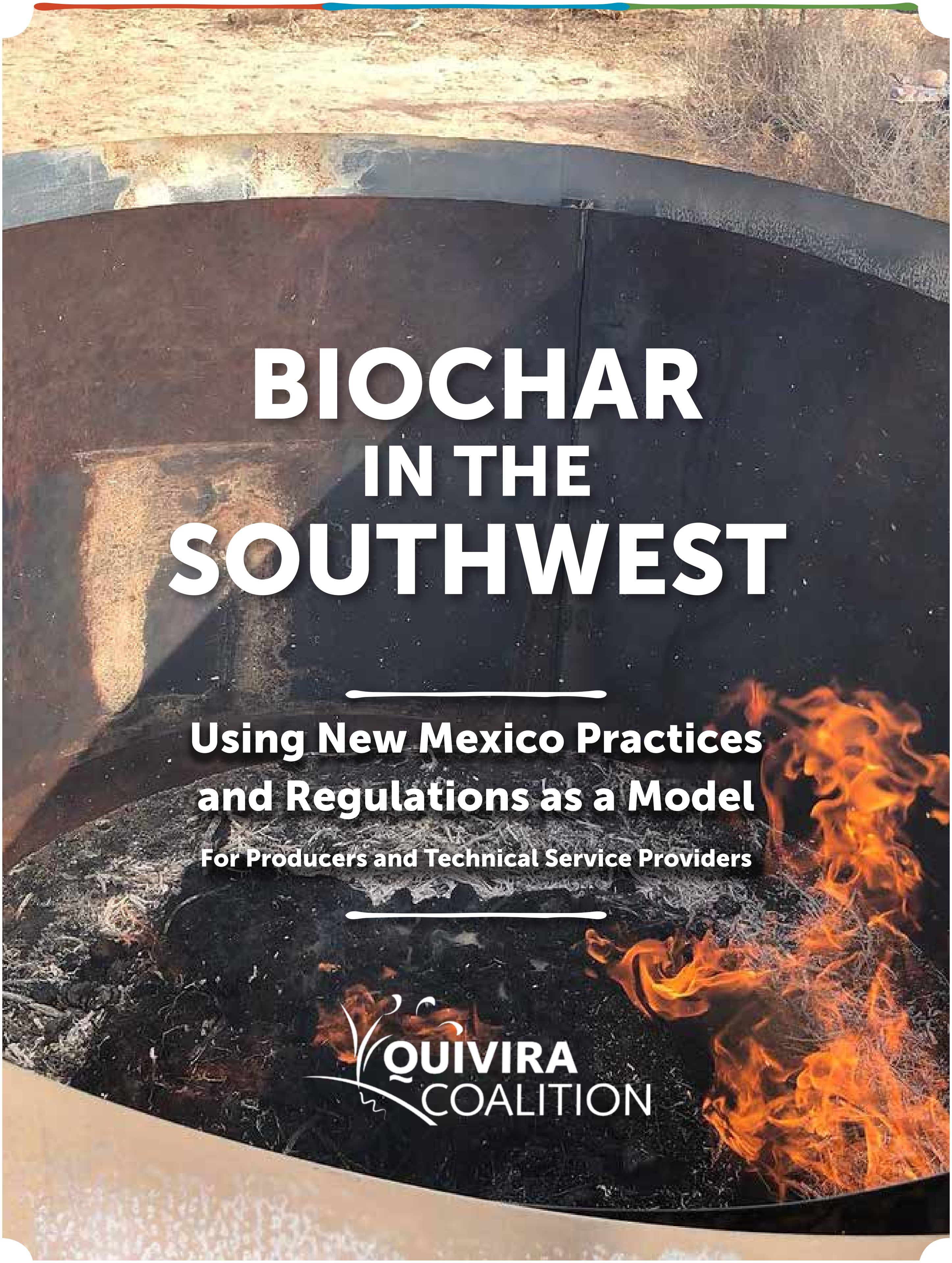

BIOCHAR IN THE SOUTHWEST

Using New Mexico Practices and Regulations as a Model

For Producers and Technical Service Providers

QUIVIRA COALITION

Workbook developed by

QUIVIRA COALITION

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Biochar production in a kiln by Eva Stricker

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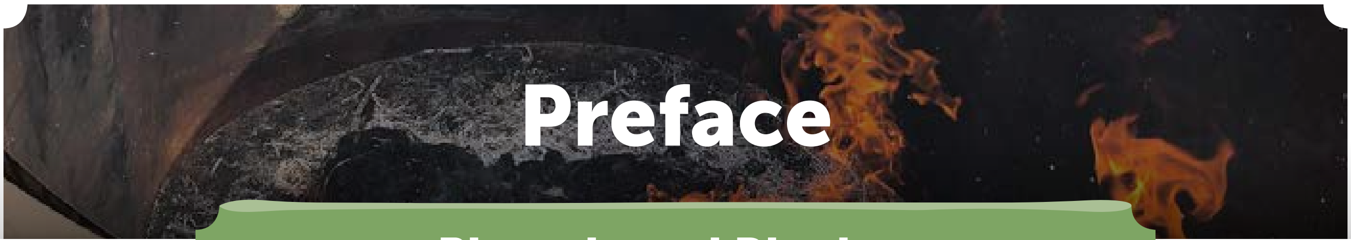
Key Terms

Biochar	charcoal made from organic material, or biomass, using various forms of controlled combustion that serve to limit oxygen and prevent the burning that turns charred wood to ash.
Biomass	organic matter, such as crop residue, wood waste, and manure, that can be converted into fuel
Broadcast burning	a form of prescribed burning that involves the controlled application of fire to fuels under specified environmental conditions that allow fire to be confined to a predetermined area and produce the fire behavior and fire characteristics required to meet forest health objectives identified in a burn plan (US Forest Service).
Burn supervisor	the person overseeing a burn who prepares the burn plan and is the key responsible person for the duration of the burn.
Carbonization	a process by which organic material is converted into carbon, usually by pyrolysis.
Charcoal	a solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment.
Combustion	fuel burning in the presence of oxygen. The phases of combustion are drying, devolatilization, pyrolysis, and char burning. The final product of complete combustion is mineral ash.
Conservation burn	a strategic burn pile that is constructed and managed for the purpose of maximizing production of biochar. Such piles must be quenched with water.
Devolatilization	the second phase of combustion, at which volatile matter is released as the result of heating.
Feedstock	the organic material that is being transformed into biochar.

Key Terms

Flame cap biochar kiln	a simple container used to produce biochar by flame carbonization.
Flame carbonization	combustion of carbonaceous material that is stopped before all of the char is burned to ash. Stopping complete combustion is accomplished by removing heat, oxygen, or both from the process.
Law of conservation of mass	mass can neither be created nor destroyed, although it may be rearranged in space, or the entities comprising it may be changed in form. For example, in chemical reactions, the mass of the chemical components before the reaction is equal to the mass of the components after the reaction.
Pile burning	a method of disposing of forest slash generated by logging for fuel reduction that involves piling logging debris and burning separate piles under safe conditions. Under New Mexico law, pile burning of forest slash is considered a form of prescribed burning.
Place-based biochar	biochar that is both produced and applied on a single site.
Prescribed burning	controlled application of fire to achieve specific natural resource management objectives.
Pyrolysis	thermochemical conversion of biomass in an oxygen-limited environment. Pyrolysis is the third phase of complete combustion, after drying and devolatilization, and before the combustion of char.
Quench	extinguish a burn.
Volatile gas	chemical products released by a biomass material as a gas or vapor, usually containing carbon, hydrogen, and oxygen. Unlike water vapor, volatile gases can burn in a flame.
Volatile matter	carbon compounds that remain in biochar after pyrolysis which are not chemically stable and can be consumed by microbes.



Preface

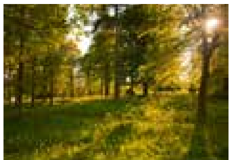
Place-based Biochar

The concept of place-based biochar is inspired by Indigenous land management practices that shaped the landscapes of the American West before the arrival of European colonizers. One hallmark of these practices was frequent burning that cleared the forest understory, in many cases leaving biochar as a byproduct. This practice created forest ecosystems that were more resistant to extreme wildfire and grasslands and savannas that supported the healthy cycling of water and nutrients. As we share modern versions of these vital practices, we want to acknowledge that colonizers devastated the traditional foodways and land management practices of Indigenous peoples, and that settlers and their descendants have appropriated Indigenous technologies without honoring or recognizing the Indigenous origins of those technologies. The authors of this workbook also want to express gratitude for the Indigenous people who have nonetheless carried their knowledge through to the present day; we are honored to be able to learn from their millenia-old land management strategies.

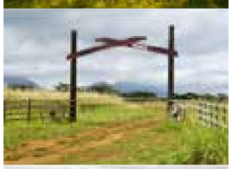
Place-based biochar refers to the process of producing biochar where the waste material is—in the field, forest, or on an agricultural operation. While there are some large-scale, woody biomass processing operations that make biochar for distribution, biochar can be made in place as long as there is a large enough area available that can be cleared of flammable material. Place-based biochar made with slash or other wood waste can serve as an important part of ongoing fuel reduction and vegetation management projects that are intended to reduce the risk of catastrophic fire and improve soil productivity. Foresters, orchardists, arborists, and other professionals already perform maintenance and restoration activities to maintain urban, forest, and agricultural landscapes; restore habitat; improve wildfire resistance; and provide a multitude of other benefits. Place-based biochar is another tool available to these and other land stewards. Biochar made in place and used to improve compost can help agricultural operations build circular systems where waste such as manure, stalks, bones, and other organic waste can be returned to the soil, providing nutrients and organic matter for food crops and livestock forage. The goal of place-based biochar practices is to convert materials that might otherwise end up as waste to a valuable resource—biochar. This process will ultimately allow a safe return to broader and more frequent use of fire as a land management tool that can improve habitat and increase the resilience of Southwest landscapes in a changing climate.

Producers of Place-based Biochar

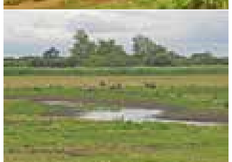
Producers of place-based biochar may include any of the following:



Woodland owners



Farmers and ranchers

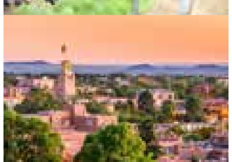


Land management organizations and agencies

Low tech (but innovative) backyard producers

Permaculturists and community educators

Forest, vineyard, and orchard operations



Urban foresters and arborists

Habitat restoration contractors

Wildland firefighters

Uneven-age forest management professionals

How to Use This Workbook

This workbook offers practices on lands in New Mexico as a model for conducting biochar burns in a relatively hot, dry, and windy environment, where legacies of past fire suppression make dire consequences from an escaped fire a real and present danger. One path towards reducing the risk over time is to dispose of nuisance wood, **but we can not overstate the necessity of adequate preparation before, awareness and focus during, and proper patrolling for sparks and smoldering residues after a burn to reduce (but never eliminate) the risk of wildfire.** It is also the case that laws, regulations, and liability governing burns will vary in different municipalities, counties, and states, and they may change over time. Thus, **it is essential that users contact relevant local authorities far in advance of a planned burn.**

This workbook is intended to accompany in-field or video training that will enable land stewards and technical service providers to safely produce biochar for use in their operations. Quivira Coalition aims to create a network of people and organizations who are willing to help and supervise burns. If you are interested in joining this community or assisting with the production of biochar, please contact Quivira's Carbon Ranch Initiative (quiviracoalition.org/carbon-ranch-initiative).

How to use your copy of the workbook:

- Write notes in it, get it dirty, keep it in your truck—make it useful!
- Review the safety (Chapter 3) and preparation (Chapter 5) chapters whenever you plan a burn.
- Use the burn plan template in Appendix 1 to write down and share your plan with relevant stakeholders.
- Use the data sheet in Appendix 2 to record the conditions and outcomes of your biochar burns. As you gain experience, you may learn what works best for you with your feedstocks, conditions, time, and resources.
- Use this book to help train volunteers or helpers on your burn—provide them with the link to a pdf version (quiviracoalition.org/techguides) in advance of your event, so that they have some background knowledge prior to attending.
- If you are out of kindling—rip out some pages; you can always print another copy!

The authors of this workbook encourage you to share your experiences with us. Data collection from many sources will allow us to share more specific information to people who are in your position in the future, giving them a better sense of how to proceed early on. Please feel free to send copies of your Burn Log (Appendix 2) to carbonranch@quiviracoalition.org.

What is Biochar and Why is it Important?

In this chapter, we introduce the relationship between fire and biochar. Fire is a natural part of most ecosystems, but changes to fire management have left many ecosystems vulnerable to catastrophic or extreme fire events. Across the western United States, communities have become familiar with the way that even relatively small wildfires can have hugely negative impacts on human infrastructure and local ecosystems, and thus have come to understand that mitigating fire risk is increasingly important. On a larger scale, fire also contributes to climate change by releasing large amounts of carbon dioxide from burning wood and other biomass into the atmosphere. Fortunately, there are solutions for dealing with the legacies of fire mismanagement and the effects of climate change that can also help build soil health. Biochar production and use is a promising strategy that is gaining support at local and national levels.

Learning Outcomes

By the end of this chapter, readers will be able to:

- Explain the role of overgrown forests in catastrophic wildfire
- Discuss how fire moves carbon from plants and other materials into the atmosphere and
describe the role of plants and soil in storing carbon
- Explain what biochar is
- Discuss the process of flame carbonization
- Describe the role of biochar in mitigating fire risk and greenhouse gas emissions

Fire in the Landscape

Wildfires can damage homes and livelihoods—they caused more than $12.9 billion in property damage in the US alone in 2018 (Badger and Foley 2019)—and their indirect effects on air and water quality may have much farther-reaching consequences. Catastrophic wildfires can lead to flooding and sediment loss and degraded water quality from ash and debris in waterways (USGS). They can also affect air quality and pose threats to public health, especially to people with preexisting conditions, such as asthma or cardiovascular issues (CDC).

Fortunately, reducing the density in overgrown forests can dramatically reduce the likelihood of catastrophic wildfire. Forest thinning as a restoration strategy has been shown to increase groundwater amount (reviewed in Schenk et al. 2020) and may help preserve biodiversity, sequester carbon, and reduce air pollution (reviewed in Stevens et al. 2020). Thinning and burning dry forests ensures that carbon stocks are less volatile and will persist for longer periods of time (Hurteau et al. 2019). Forest managers may use fire as a tool, first thinning forests and then following with pile and/or broadcast burning. These actions have been shown to make forests more resilient to wildfire, drought, and climate change.

While pile burning has been an essential step in the treatment of fuels in preparation for the return of naturally occurring fires, it has some downsides. Pile burning, as currently practiced, is focused on complete incineration of the material and getting the job done as quickly as possible. As a result, pile burning can leave burn scars on the land that destroy the soil's organic horizon and can take years or even decades to heal. As will be detailed further along in this workbook, new approaches to pile burning are being developed that avoid burn pile scars, reduce smoke emissions, and produce biochar. Biochar is becoming a valued solution for safely, efficiently, and productively dealing with wood waste in support of restoration thinning.

What is Fire?

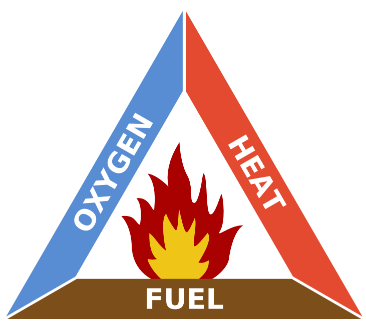
Fire is a chemical reaction that converts material into heat, light, and various reaction products. When you strike a match, you feel heat, see light, and smell sulfur, all resulting from the process of combustion.

A fire requires all three of these conditions:

Fuel

Oxygen

Heat



The fire triangle demonstrates what conditions are required for fire.

Fire can be controlled by humans who adjust these conditions. For example, using a fire extinguisher displaces oxygen from the vicinity, dousing a fire with water removes the heat, and firefighters can create a fire break around a wildland fire by removing the woody debris and other organic matter serving as fuel. If we can control the conditions of fire, we can manage fire at large and small scales to meet our goals, such as reducing the likelihood of catastrophic wildfire or creating biochar.

Biomass burns in three stages:

Drying — Heat from a flame penetrates a piece of wood or another organic material and drives off moisture by converting it to water vapor.

Devolatilization and burning of volatiles — As the wood or other organic material heats, volatile gases containing hydrogen and oxygen are released. These gases burn, producing a flame that provides heat to continue the process.

Pyrolysis – At this phase in the combustion process, heat transforms carbon compounds into a chemically stable form that is not easily decomposed. The final stage of combustion is when the vast majority of the volatiles are gone and there is no visible flame.

If allowed to continue, material burns to mineral ash.

We can control the production of ash, smoke, and biochar by controlling the conditions of the burn and halting the burning process at a specific time to meet desired needs.

What is Biochar?

Biochar is organic material that has been heated in the absence of oxygen or in low-oxygen environments to make a chemically stable form of carbon for use as a soil amendment and for carbon sequestration to mitigate climate change.

Biochar can also be defined as charcoal with certain properties. Charcoal refers to more than one substance because its properties can vary greatly depending on what it is made from and how it is produced. Biochar is charcoal that can be used in soil or for other beneficial purposes that do not return the carbon to the atmosphere. Charcoal used for fuel is not biochar because it does not preserve the carbon in solid form, sequestering the carbon from the atmosphere, but rather releases carbon into the air when burned for fuel.

Biochar is characterized by measuring the amount of organic carbon it contains, relative to the amount of mineral ash. In California, for instance, biochar is defined as containing at least 60% organic carbon. The stable carbon content of biochar is determined in a laboratory analysis that measures the amount of oxygen and hydrogen remaining in the char. Less oxygen and hydrogen means the char is more stable. Generally, biochar that is produced at higher temperatures contains more stable carbon.

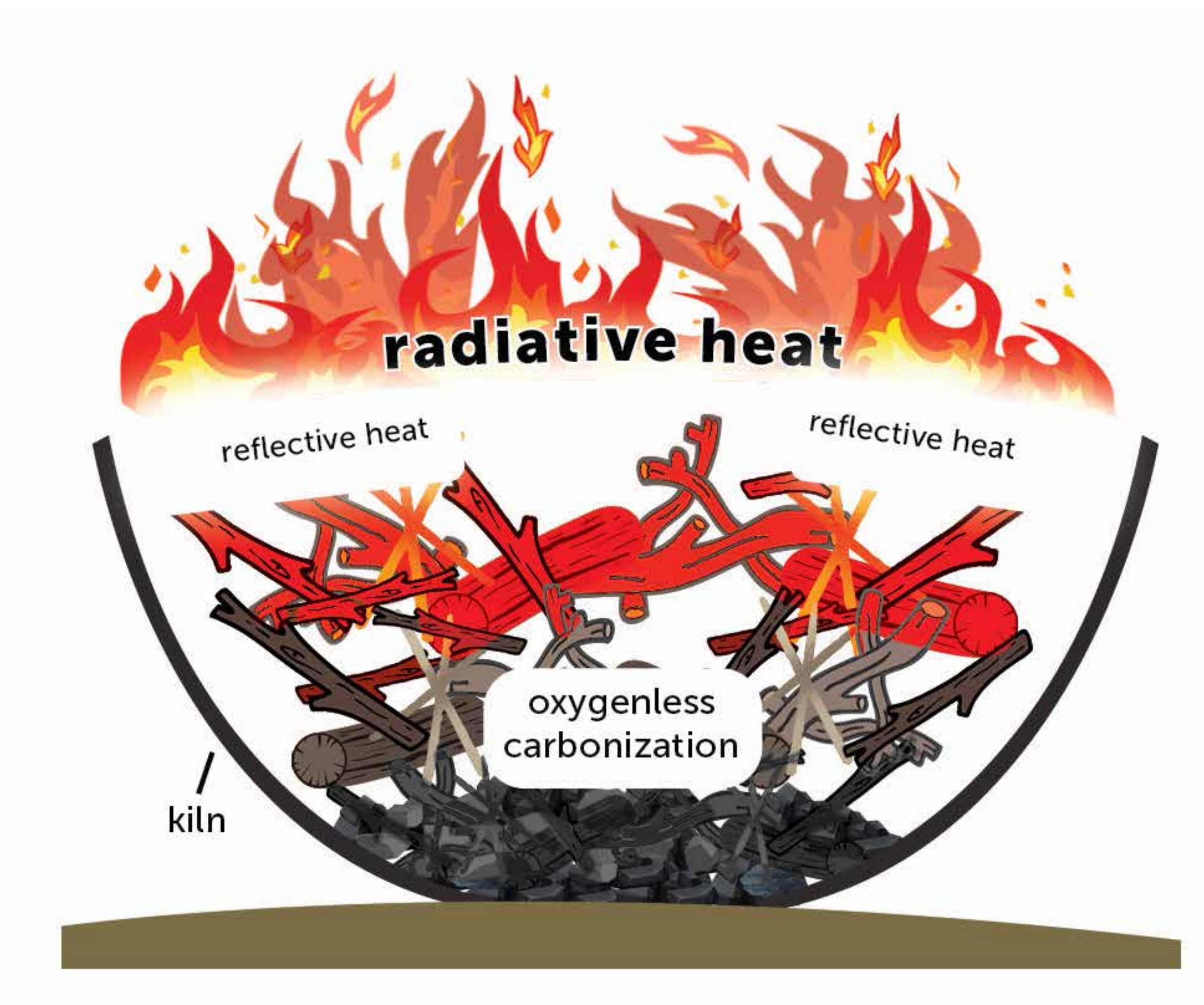
How is Biochar Produced?

There are many different ways to make biochar. The general term for the process is pyrolysis, from the Greek words for fire (pyro) and separation (lysis). Pyrolysis is separation by fire. Wood and other biomass is made of the elements carbon, hydrogen, and oxygen, with other trace minerals. Pyrolysis separates the carbon from the other elements by fire, producing the volatile gases containing hydrogen and oxygen and leaving behind solid carbon. In the process, the wood and other biomass is transformed into a carbon rich stable chemical state, known as biochar.

Traditional pyrolysis methods involve smoldering wood slowly at relatively low temperatures in a covered pit or mound. The process is very polluting and takes days to finish. This kind of char is not suitable for use in soil because it contains tars and oils.

Biochar can also be produced using a variety of modern technologies that transform organic matter into usable thermal energy for heat and electricity generation. Many new facilities now make biochar commercially as a co-product of energy generation. However, such facilities are expensive and must be located near strong biomass fuel supply chains. There are many places in the Southwest where these conditions do not exist or have not been developed. This is where, when executed with oversight and best practices, place-based biochar can fill a gap to provide biochar for soil benefit while managing excess biomass for ecological benefits.

Biochar can have widely varying properties, depending on feedstock, combustion temperature, and other factors. Production temperature is generally the main determining factor of biochar chemistry. The high-temperature biochar produced by flame carbonization generally contains more fixed, stable carbon and a smaller mass of volatile compounds than biochar made at lower temperatures. In contrast, charcoal produced at low temperatures is more suitably used as fuel for cooking on a grill than as a soil amendment.

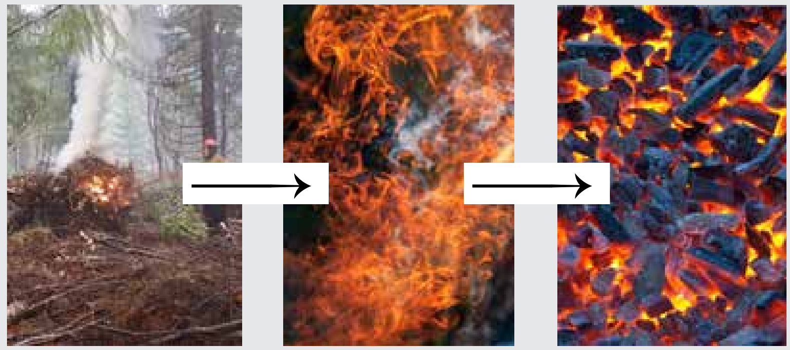


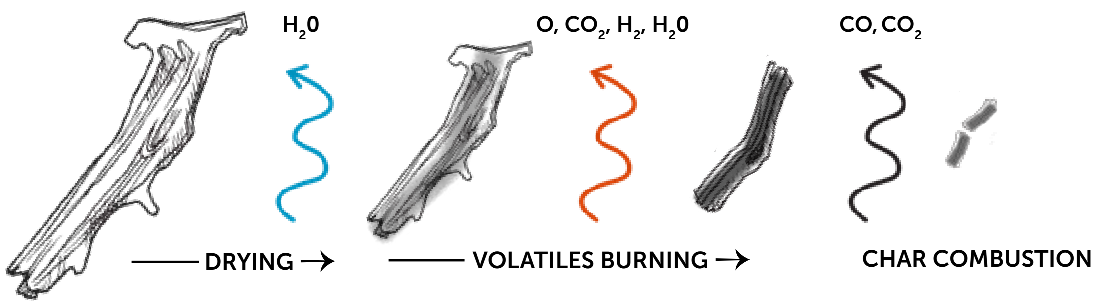
How a Flame Cap Kiln Produces Biochar.
Image concept by Kelpie Wilson, designed by Jessica Brothers.

Flame Carbonization

Making biochar in an open flame:

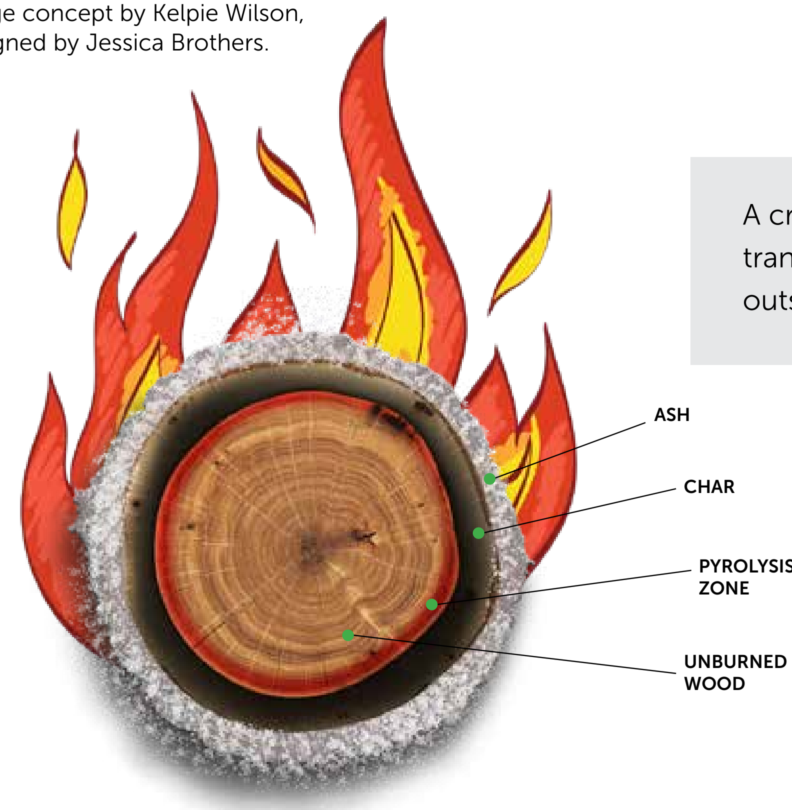
- Biomass burns in three stages (see page 13)
- To make char, stop the process before it goes to ash





Don't forget! To make char, the process **must be stopped** before ash.

Image concept by Kelpie Wilson, designed by Jessica Brothers.



A cross section of a piece of wood transformed into biochar from the outside in.

Image concept by Kelpie Wilson, designed by Jessica Brothers.

How does Biochar Relate to Climate Change?

To understand how biochar (and, more broadly, fire) relates to climate change, it is necessary to understand the carbon cycle—the process in which carbon moves from the atmosphere into and through plants and animals, into the soil, and back into the atmosphere.

Exercise #1

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#1: Where did most of the material that made the dry wood in the tree pictured here come from? Was it from soil, water, or air?

Write your thoughts below:

Bare Trees by McMac70

What did you answer?

If you answered soil: We know that soil is important for plant growth. It provides physical structure, allowing plants to grow upright, and it holds water and nutrients that the plant uses. But if plants took material from the soil to make wood, then a very large tree would use up all the soil around it, and there would be craters under every plant! *So no, most of the material that makes up wood does not come from the soil.*

If you answered water: Water is essential to plant growth because it dissolves nutrients and is needed to maintain plants' physiological activities. But again, *no, most of the material that makes up dry wood is not water.*

That leaves air: Specifically carbon dioxide, an invisible, tasteless, odorless gas that makes up a part of Earth's atmosphere. It is easy to forget that there is mass in the air because we humans cannot sense it directly. But chemical reactions in plants transform carbon dioxide molecules from the air into carbohydrate molecules (sugars) in a chemical process powered by the energy of the sun (photosynthesis). We can easily see, touch, and taste collections of carbohydrate molecules as they make up into myriad plant structures, from the largest trees to the smallest duckweed.

Animals eat the plants as food, and microbes in the soil decompose dead plants and animals. Most of that material originates from the large pool of carbon that exists in the form of carbon dioxide in the atmosphere. Next, we will see one way that carbon cycles back to the atmosphere.

Exercise #2

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#2: Where did the walls of this house go?

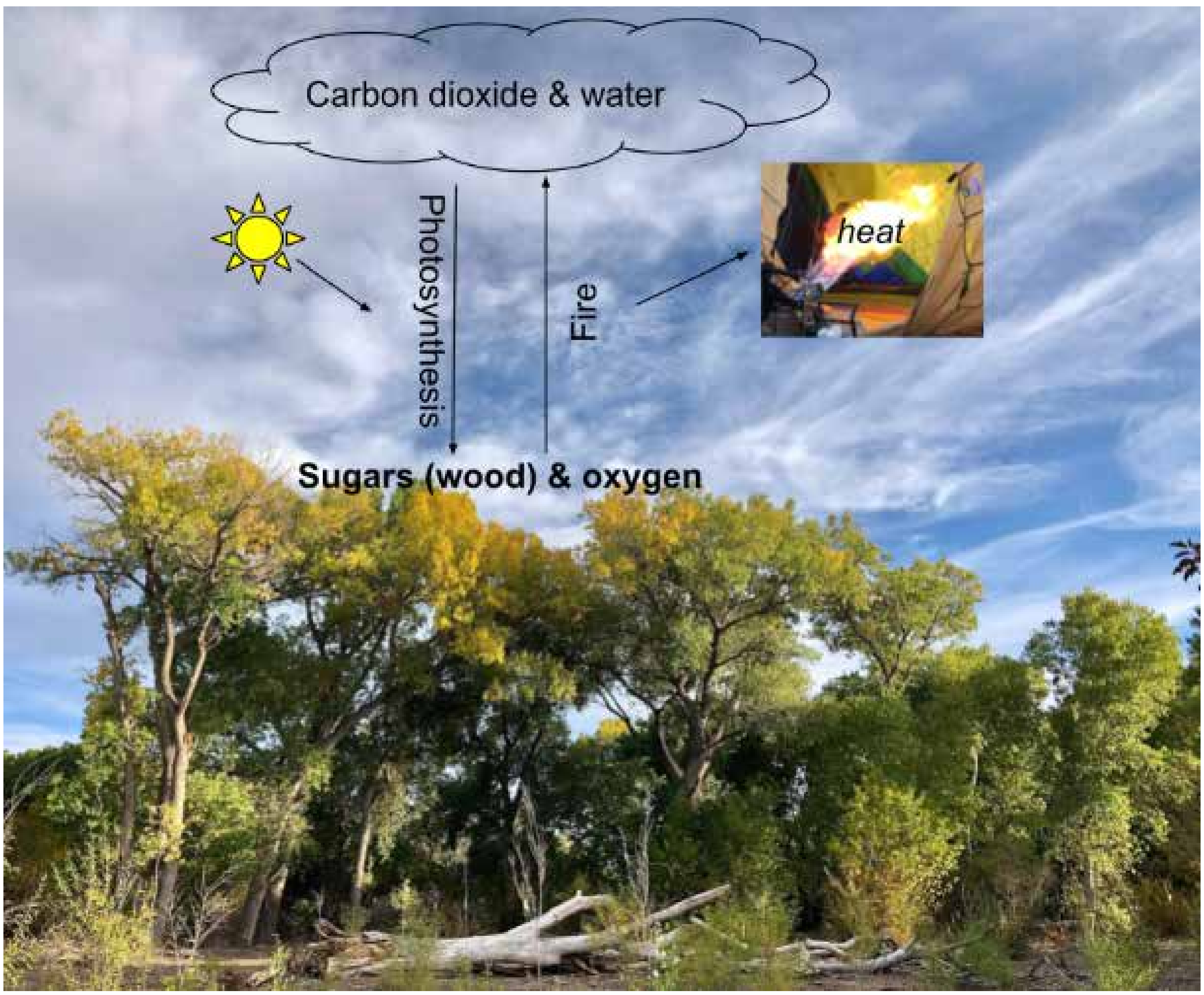
Write your thoughts below:

"burned house skeleton" by ChrisReilly

Our Response

The material that once made up the walls of the house are now invisible, odorless, and tasteless (at least to humans). The mass that formerly made up the wooden walls has returned to the atmosphere as carbon dioxide. This, too, is the carbon cycle in action.

The carbon cycle comprises all the processes by which carbon moves through the environment, cycling through soil, oceans, plants, animals, and air. The movement occurs through processes including photosynthesis; the respiration of animals, plants, and microbes; the decomposition of animals, plants, and microbes after their death; and fire.



Simplified diagram of how fire and photosynthesis relate to the pools of carbon in the atmosphere and in vegetation. Photo by Eva Stricker, courtesy of Quivira Coalition.

Exercise #3

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#2: Has wildfire affected you or your community? How has wildland fire changed in your lifetime? Write your reflections below:

Fire is an important and natural disturbance in healthy landscapes, but there are two important ways that human behavior has changed conditions in forests, grasslands, and shrublands. First, for most of the twentieth century, fear of fire led the US Forest Service to suppress natural wildfires, which resulted in a dangerous overabundance of fuels in the form of duff and dead wood. Secondly, climate change as a result of fossil fuel usage has led to overall warmer temperatures and more extreme weather patterns. In the arid Southwest, one way this has manifested is in prolonged periods of drought.

These conditions together (climate change and fire suppression) have caused natural wildfires to become increasingly catastrophic. Healthy forests, shrublands, and grasslands store carbon in woody plant material and in soil; wildfire releases carbon stored in trees and other plants into the atmosphere. Increased availability of woody material for wildfires means the fires burn at higher temperatures, for longer periods, and over greater landscapes. This accelerates greenhouse gas accumulation in the atmosphere and leaves behind areas of bare soil that, over time, will also release carbon into the atmosphere. The massive 2020 wildfires in California emitted more carbon dioxide than annual emissions in 2018 from countries like Chile and Greece- roughly 90 million metric tons (Grandoni 2020).

Converting wood waste and other organic waste material into biochar means that the material is less likely to return to the atmosphere as carbon dioxide and other gases over long time scales. In the wake of so many destructive fires, public policy has shifted, and private landowners who make biochar can now contribute to wildfire fuels reduction while benefiting the environment in multiple additional ways.

Adding carbon dioxide to the atmosphere is like adding a warm blanket to a bed—it holds heat close to Earth rather than allowing the energy to radiate out into space. Thus, fire relates to climate change by contributing to greenhouse gas accumulation. In turn, the resulting hotter, drier conditions can weaken vegetation and make large fires more likely to occur. The results of this process produce generally negative outcomes for humans and the environment.

Converting wood waste to biochar:

- Can be less expensive than chipping and landfilling (where a potent greenhouse gas, methane, is produced)
- Limits the release of polluting particulates into the air by inefficient burning
- Makes it possible to return carbon to soil in a pure, stable form (as a soil amendment)

The use of biochar in soils can enhance plant growth and function. More plants with more leaf surface area with which to photosynthesize means more removal of carbon dioxide from the atmosphere. The results of this process produce generally positive outcomes for humans and the environment.

2. Biochar for Soil Health

Characteristics and Best Practices

There are two compelling reasons to produce biochar on Southwestern working lands: waste management and soil health improvement. This chapter provides an explanation of the overall benefits of biochar application with an emphasis on its use in agricultural systems.

Biochar Workshop
Photo courtesy of Quivira Coalition

Learning Outcomes

By the end of this chapter, readers will be able to:

- Describe the ways biochar can contribute to general soil health
- Differentiate between physical, chemical, and biological impacts of biochar
- Discuss current evidence of biochar amendment use in the Southwest
- Relate biochar use to the Healthy Soil Principles
- Apply an understanding of the soil health benefits of biochar to agricultural systems in the Southwest

Biochar for Improving Soil Health

Biochar can be beneficial for agricultural soil health because it adds carbon to the soil, altering the soil's physical, chemical, and biological characteristics as outlined below. Best practices suggest that biochar must be inoculated with nutrients and microbial life before adding it to soil.

Physical Characteristics

The application of biochar as a soil amendment has many positive potential benefits; most notably, it increases water retention. One recent study showed increases in soil water content at field capacity by up to 51 percent (Razzaghi et al. 2020), which supported increased plant productivity. Increased capacity for water retention is particularly significant in arid Southwestern climates, as it provides more opportunities to take advantage of increasingly infrequent precipitation.

In addition, biochar has been shown to relieve salt stress in droughty soils. It can work synergistically with amendments like vermicompost to mitigate salinity stress and improve water use efficiency and plant growth (Hafez et al, 2021).

Biochar's high surface area at the microscopic level, due in part to the porous nature of its structure, also makes it useful for improving air flow in soils. Adding biochar to soils decreases the bulk density of soils, helping to mitigate the damage caused by previous compaction (Burrell et al, 2016).

Indirectly, biochar can contribute to improved soil aggregate stability by increasing plant rooting and fungal growth (Mukherjee and Lal 2013). This property can reduce the risk of wind and water erosion.

Four Winds Farm biochar soil rows. Photo courtesy of biocharproject.org

Chemical Characteristics

Biochar has been shown to impact the chemical properties of soil, including cation exchange capacity and pH, but these effects are dependent on soil type. A 2022 meta-analysis of fifty-nine studies conducted on biochar between 2012 and 2021 found that coarse and fine soils (those with high sand and high clay percentages, such as soils found throughout the Southwest) showed the greatest tendency toward improvement in cation exchange capacity and pH increase when amended with biochar (Singh et al, 2022). It is possible however, that the high pH soils found throughout the Southwest may not experience the benefits of increased cation exchange capacity, as the high pH can make nutrients such as phosphorus less available to plant uptake, so these effects may cancel each other out. More research is needed on the use of biochar in the Southwest to more fully understand its impacts.

Biological Characteristics

Biochar's proportionately large surface area provides a home for microbes. In Southwestern soils, which are low in the organic material that microbes inhabit, this protective microhabitat can allow for increased microbial biomass (Lehmann et al. 2011) and biodiversity.

biochar soil
Photo by Rob Goodier

Physical Characteristics

improve aggregate stability, infiltration, water storage, bulk density, soil temperature moderation

Chemical Characteristics

improves nutrient storage, soil pH, reduces nutrient leaching

Biological Characteristics

improves habitat for microbes, mycorrhizal colonization, microbial activity

Best Practices for Amending Soil with Biochar

More often than not, biochar needs to be inoculated in some way before it can be applied to soil. Biochar applied alone at high rates can attract nitrogen and other nutrients from the soil instead of leaving them available to plants in the short term. Biochar can be cultured with inoculants such as silage additives, bokashi, or compost tea. Composting biochar charges it with nutrients and inoculates it with beneficial soil microbes. (To learn about composting in the Southwest, see https://quiviracoalition.org/rural-dryland-composting/.). Paired with compost, biochar has been shown to increase the water and nutrient holding capacity of soils on working lands in multiple contexts (Agegnehu et al. 2017).

Adding biochar to manure or plant waste improves the composting process by:

- **Retaining air and water in the compost pile**
- **Neutralizing the pH overall (Nguyen et al, 2022)**
- **Allowing microbes to digest volatile matter remaining in biochar**
- **Charging biochar with nutrients and microbial life**

One exception exists for the need for inoculation: when planting a legume crop, it can be beneficial to mix unamended biochar into the soil. Legumes fix their own nitrogen and biochar helps promote the nitrogen fixing bacteria that live on legume roots (Farhagi-Abriz et al., 2022).

Biochar can also be inoculated directly with nutrients if composting is not an option. Mixing biochar directly with a nitrogen source like urea can prevent biochar amendments from absorbing plant-available nutrients in the soil, but this combination does not provide the addition of microbial diversity.

Annual soil testing is recommended for land stewards who want to measure the impact of any and all management practices, including the application of biochar. Soil monitoring is particularly important with biochar use because different feedstocks and production conditions may lead to different chemical characteristics. In general, it is a good idea to assess soil before and for some time after using an amendment such as biochar. A laboratory soil test generally costs around $35 and provides information about soil pH, cation exchange capacity, and nutrient status. For guidance on sampling, refer to the Quivira Soil Health Workbook at https://quiviracoalition.org/soil-health-workbook/.

Biochar and the Healthy Soil Principles

Biochar amendments are aligned with the Healthy Soil Principles as described by the Natural Resources Conservation Service (NRCS). These include:

- Minimize disturbance
- Maximize biodiversity, including livestock
- Maintain a living root
- Keep the soil covered

Management aligned with any one (or more) of these principles increases the likelihood of improved soil health, primarily by building and maintaining soil organic material—the carbon-rich compounds produced by the slow decomposition of plants and soil microbes. (Quivira Coalition's Soil Health Workbook provides for more information: www.quiviracoalition.org/techguides.)

Using biochar as an organic amendment aligns with at least two of these principles: covering the soil (which also slows the release of carbon into the atmosphere) and maximizing biodiversity by housing diverse microbes. The results of inoculating biochar with microbial communities may depend on inoculant quality and type, as well as soil characteristics, and for this reason local knowledge or trial and error are important before deploying inoculated biochar over large areas.

Biochar in Range Systems

Only a small percentage of biochar amendment research has been conducted in the Southwest, but findings in similar areas elsewhere suggest that there may be positive impacts in Southwest agricultural systems. The results of two separate studies in the sagebrush-steppe ecosystems of central Oregon (characterized by heavy western juniper growth) indicate that while biochar may not make any improvements to dry rangeland soils on its own (Phillips et al., 2020), it can have significant positive impacts when combined with a rotational grazing system (Gao and DeLuca 2022). The Quivira Coalition is in the process of conducting field trials on the impact of organic amendments on rangeland, including compost and biochar, and a report of these findings will be available by 2024 on the Quivira Coalition website.

Biochar in Orchard, Crop, and Vineyard Systems

More often than on rangeland, biochar is studied in orchards and crop systems. There has not been extensive research conducted in the Southwest as of this writing, but based on related research in other regions, it appears that the general soil health improvements biochar can provide would translate to the Southwest.

Tree crop and horticultural benefits can include:

- Disease control — Biochar has been shown to induce resistance to a variety of pathogens and to encourage strong root growth in many different horticultural crops (Elad et al, 2012).
- Water management — Biochar's water-holding capacity is significant in addressing issues with fungal-borne diseases and the interruptions in nutrient cycling that result from patterns of flooding and drying. Maintaining consistency in soil moisture can also prevent the problems with calcium uptake that cause diseases such as apple bitter pit and blossom end rot in fruit crops. In new orchards, higher water retention in soils can make all the difference for the survival of young trees.
- Nutrient retention — Biochar has been shown to decrease nutrient leaching in irrigated orchards and croplands. Biochar application thus allows for less fertilizer use and in turn decreases the accumulation of fertilizer salts in the soil. This is particularly important in the Southwest, where soils tend to have high salinity.

Biochar Application on Large Areas

While it is rarely economically or logistically feasible to treat entire operations with organic amendments, emerging research supports the idea of nucleation of treatments that can create seeds and spores, which then spread out to adjacent areas (Michaels et al. 2020). Thus, applying biochar to key areas in watersheds or production systems may have disproportionately positive effects on soil health, water quality, habitat, and productivity in the surrounding area.

Some methods of distributing biochar can be built into activities that are already part of a farm or ranch operation. Biochar can be mixed into holes where perennials will be planted for hedgerows or buffers around water sources. It can also be shoveled out of the back of a truck on the way out to complete another task, like fixing a pasture fence. Biochar can be spread with a manure spreader, but be sure to protect workers from inhaling the fine particles. Some research indicates that if livestock are fed biochar, they will distribute the biochar along with their manure, and the biochar would not have to be mixed with compost first (Joseph et al, 2015).

Organic amendments such as biochar may support soil health by increasing soil carbon and can help make ranches and farms more resilient to environmental changes, such as floods or droughts. This has a ripple effect: on land that withstands such impacts, soil health continues to improve, and the healthy soils on working lands support increased soil health across whole landscapes. If biochar is produced at a regional scale, whole regions can avoid inefficient burning or sending biomass to landfills; thus, biochar production has the potential to yield compounded benefits to air, water, and habitat quality. However, we are in the early stages of understanding the specific mechanisms and contexts where biochar is most effective. Please consider sharing what you learn through your own experience!

Exercise #4

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#4: What are some areas in lands that you are familiar with that may benefit from biochar? Write your reflections below:

3. Making Biochar Safely

The process for making biochar in the field is very similar to the practice of pile burning that many land managers are already familiar with. However, that is no reason to take a casual approach. It is essential to learn, understand, and apply all safety measures when dealing with any fire, and it is worth emphasizing that even experienced producers should never take shortcuts. It is also important to realize that the dangers involved with fire do not need to be completely prohibitive. If producers learn what seasonal and weather conditions allow for safer burning and develop relationships with their local fire authorities, they will know when to use fire in their operations and when not to.

Safety is so important that we provide baseline safety considerations in this chapter, prior to introducing the exact procedures for making biochar in Chapter 4, and then revisit safety in Chapter 5 by guiding readers through creating a burn plan.

Managing fire requires knowledge and experience, but conducting safe burns is something anyone can do by following local and regional regulations in addition to these guidelines.

Learning Outcomes

By the end of this chapter, readers will be able to:

- Identify proper safety measures specific to biochar.
- Identify general human-centered safety practices.
- Discuss characteristics that contribute to safer or more dangerous burn conditions, especially in relation to scheduling a burn.

Before a burn, it is important to write a biochar burn plan as described in Chapter 5. When a site host or burn supervisor writes out the safety measures, this time and intention can clarify important steps for all participants. It also allows them to share the plan with the local fire department. Always familiarize yourself with a space, make calls, and use common sense to ensure that you have planned for extreme or unusual events in addition to the more routine concerns.

Participant Expectations

Share information from this section with anyone who will be attending a burn event.

All participants in the burn event should be healthy enough to lift tools, step around fallen branches or mud, and withstand heat and potential weather conditions that can occur during a burn. They should be briefed in advance on likely conditions so that they can make informed decisions about whether the state of their health will put them or others at risk on the day of the burn. Everyone attending the event and/or participating in the burning should be alert to prevailing weather conditions and aware that these may change without warning.

First Aid

It is highly recommended that someone with first aid training attend each burn event. If needed, this person can provide emergency aid on site or en route to the nearest available medical treatment. First aid training is offered through multiple entities and ranges in cost and time required. Always let participants at a burn event know who has first aid training.

While it is essential to work with someone trained in first aid or medicine, the following items may be useful in a first aid kit. If chainsaws will be in use, two or more commercial tourniquets can be included in the first aid kit along with gauze to address blood loss. Regardless of chainsaw use, materials to clean and protect burn wounds or cuts, materials to stabilize a joint or bone, pain relieving medication, and electrolyte mix are useful items to have on hand

Hydration and Nutrition

Being exposed to heat for long periods is exhausting. Doing physical labor outdoors during the heat of the day can drain a body's fluids and utilize more calories than usual. Overheating can lead to heat stroke. Make sure to bring or have available ample water for each person per day.

Remind participants at the burn event to:

- Stay well hydrated by drinking water at regular intervals.
- Eat a nutritious breakfast and continue to eat throughout the day.
- Work at a moderate pace and take frequent breaks, communicating with the team and supervisor to ensure that someone is covering assigned tasks before stepping away.

Outdoor Protection

Wear sunscreen and reapply as needed. Insect repellent may reduce distractions from the burn task at hand.

Clothing and Footwear

All participants must have non-flammable attire that is appropriate for the work and weather conditions.

Recommended clothing items for a burn event:

- Leather (or another nonflammable material) hiking or work boots with good ankle and/or toe protection.
- Long sleeves and long pants made from nonflammable fabrics washed without fabric softener (which is flammable); cotton and wool are best. This is not the day to wear your favorite fringed vest.
- Good leather gloves to help prevent blisters, splinters, and burns.
- A nonflammable hat to protect from the sun and keep hair safe from flames and embers. Long hair should also be secured. This is not the day to use a lot of hair spray or other flammable products.
- A hard hat and other necessary personal protective equipment, depending on what loading and other preparation participants will be assigned. For example, if a skid steer is used for loading, or if large branches or trunks are being moved and cut with a chainsaw, all participants should wear hard hats, and anyone operating equipment should have proper safety gear.
- An optional face shield to help protect against heat and smoke.

Behavior

Awareness of other participants is critical. Participants should pay attention to where other team members are at all times. Remind them to be cautious around anyone using tools such as axes with over-the-shoulder action. The heads of tools, including axes and shovels, can come loose and become deadly projectiles. Observe and make sure that all participants are lifting, carrying, and using tools, equipment, and supplies safely (e.g., no one should carry tools over or across their shoulder). Remember that how the host and burn supervisors behave can directly affect the safety of all participants. It is a good idea to set guidelines at the beginning of the day (or each day) and remind everyone to be aware of and considerate toward all other participants at all times.

Building Rapport

It is very important that the burn supervisor spend time with the burn team prior to the event so that everyone can get to know each other, go over each role, and make sure each person understands their responsibilities. When the Quivira Coalition conducts burns, we always have name tags with large writing. We intentionally build in an hour of introductions and small-group discussion, using prompts such as: What is your interest in biochar? What is your background/expertise? How did you hear about this event? This gives people a way to get to know each other’s names and backgrounds and provides them with general awareness of who they are sharing space with. If all participants know their own and other peoples' roles and are looking out for one another, they may be less likely to make mistakes.

Review the burn plan (see Chapter 5) immediately prior to the burn. Allow enough time to complete this essential communication before beginning to burn.

Self-Assessment Before and During the Burn

Participants may be asked to sign a waiver including a statement such as "I understand and accept the risks and expectations of the burn and I am physically and mentally fit to participate." Participants should be directed to stop tending a pile or adding new material to a kiln when they are tired even if there are more feedstocks. It is better to stop before burning all of the material and save the rest for another day than to risk injury or mistake because participants are tired.

If the burn supervisor suspects that a participant is impaired by drugs or alcohol, they should ask them to watch from a safe distance (at least twenty feet) or get a ride home.

At Quivira, we like to practice "opt in" for both starting and continuing a burn. The burn supervisor asks for verbal or thumbs-up confirmation from everyone participating at each stage of initiating or continuing a burn (such as before adding more feedstocks to the kiln or pile). If anyone does not wish to continue because their own capacity has been reached, they should step away from the burn. If there are no longer sufficient people to manage the burn or if someone is uncomfortable with the wind conditions or the safety of the team, the burn should be quenched with water.

Work Areas

Work areas should be kept neat and well organized. Trash must always be placed in receptacles, and tools and materials (rakes, McLeods, propane tank) must be put away when not in use. It is important never to leave tools lying around.

A good site for setting up a kiln or burn pile will have the following characteristics:

- A level location for placing the kiln or burn pile, free of objects or holes that can become tripping hazards.
- Adequate surrounding space. Regulations vary between municipalities, but a kiln or pile should never be placed within twenty feet of trees or structures.
- Well-cleared surrounding space. Clear flammable debris for a few feet beyond the kiln or pile perimeter. Use rakes and shovels to clear the area, or conduct the burn on snow. If working on a lawn or turf, all the grass will not need to be removed, but wet the area down with a hose and keep it wetted down for the duration of the burn.
- Adequate overhead space. Select a site that is free of overhanging items. In particular, the burn area should be at least twenty feet from tree branches or other overhanging vegetation.
- A safe distance from feedstock. Site a burn at least twenty feet from the feedstock, allowing ample room to manage and stage it.
- Within reach of water. The best option is a good hose connected to a water source with reliable pressure. The hose should reach all the way around the kiln or pile. **Secure and test your water source before you light the kiln or pile.**

  A good source of water is needed for safety and for quenching the biochar at the end of the burn. Small burn piles can be quenched with about five gallons of water, but larger flame cap kilns may need 150 gallons or more to quench completely.

  Always have more than enough water on hand for emergencies.
- Supplied with essential tools. Have available enough long handled tools, such as shovels, rakes, and McLeods, for participants to help control flames from escaped embers. Caution participants to be aware at all times of the potential for embers to be transported out of the kiln or burn pile and into nearby flammable material.

Photo by Gregg Young, Environmental Director, Potter Valley Tribe, CA.

Exercise #5

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#5:Write down how these images might relate to planning a safe burn. We'll discuss each topic further below.

Scheduling a Safe Burn

Season and Temperature

Season affects temperature and moisture conditions that in turn affect plant and fuel characteristics and therefore fire behavior, but local conditions may mean burns are not advisable even on winter days. High air temperatures favor high fire temperatures and affect the amount of heat needed to ignite fuel. Cooler average temperatures and snow cover in the winter result in more frequent fire-safe days.

Plants that are physiologically inactive are more resistant to fire, making an escaped fire slower to take off and easier to control in winter than in summer.

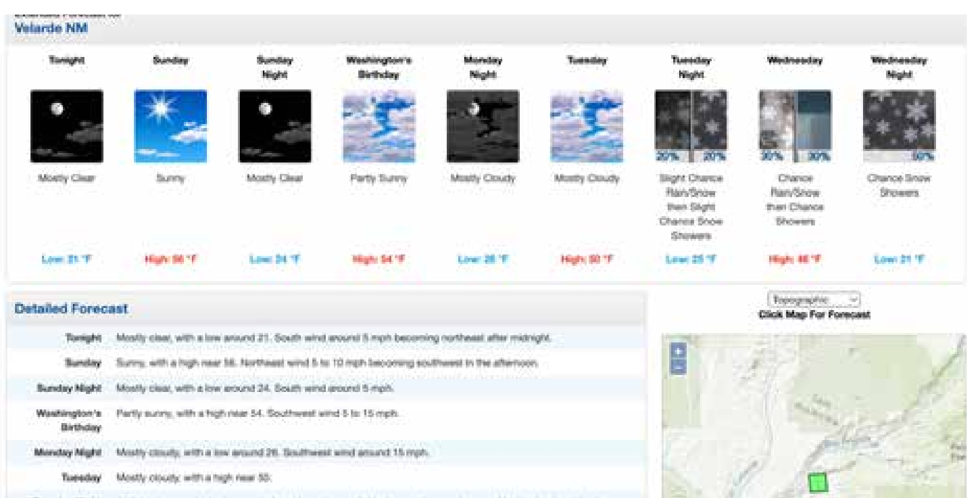
Consider timing of burns based on pets, livestock, and neighboring wildlife. Small animals and young ones that are not mobile enough to move away can be injured by heat, embers, or smoke, even from a contained kiln or pile burn. Take some time to learn about the nesting and life cycle patterns of birds and other small wildlife that live in the area, and consider timing the burns to avoid potentially harming their young.

Humidity

Relative humidity affects fuel moisture content and the amount of heat needed for fuel ignition. Higher relative humidity is safer for burning.

Time of Day

In general, mornings are cooler, more humid, and less windy than afternoons and evenings. As the day progresses, relative humidity declines, air temperature increases, and wind speed and direction become variable. Many counties and municipalities require that burns be conducted only in the morning and early afternoon, and most fire districts restrict burning to daylight hours.



Wind

Wind is the most treacherous environmental variable because it can change more quickly than any other. A simple shift in wind direction can change an easily controlled, cool fire into an uncontrollable, hot fire that can cause great damage. Wind speed should be between zero and thirteen miles per hour and should never exceed twenty miles per hour during a burn. Be aware that this may differ in specific jurisdictions. For example, in Santa Fe County, ten miles per hour is the maximum wind speed allowed on the day of a burn. Estimating wind speed is a difficult task, and the following scale is meant only as a guide. You should always follow local fire regulations.

In the Beaufort Wind Estimation Scale below, which is a modified version of the Significant Weather Observation Program Wind Scale (www.weather.gov/ilx/swopwindscale), yellow highlighting indicates higher risk; red indicates conditions in which all burning is prohibited.

Being familiar with these specifications can make participants aware of changing conditions in real time. If conditions are calm at the start of the burn but signs indicate that conditions are shifting towards moderate, the burn supervisor can make changes to the plan or halt activities so that the burn is not active in dangerous winds. Be aware at all times of fluctuations in wind, and do not override the recommendation of the local fire station—**if they say not to burn, do not burn** (even if there is little observable wind!). Always keep in mind that the lower the relative humidity and greater the air temperature and wind speed, the faster a fire will spread and the more intensely it will burn.

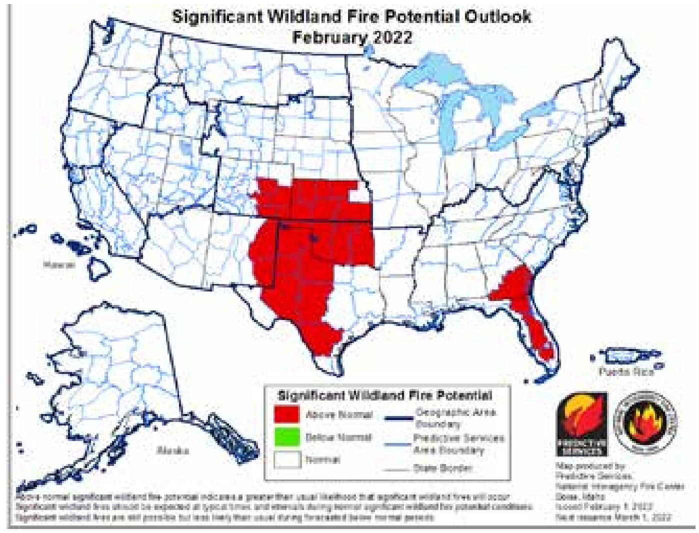
Beaufort Wind Estimation Scale		
MPH	**Description**	**Specification**
<1	Calm	Smoke rises vertically
1-3	Light Air	Direction of wind shown by smoke drift but not by wind vanes
4-7	Light Breeze	Wind felt on face; Leaves rustle; Wind vanes moved by wind
8-12	Gentle Breeze	Leaves and small twigs in constant motion; Wind extends light flag
13-18	Moderate	Raises dust, loose paper; Small branches moved
19+	Fresh	Small trees begin to sway; Crested wavelets form on inland waters

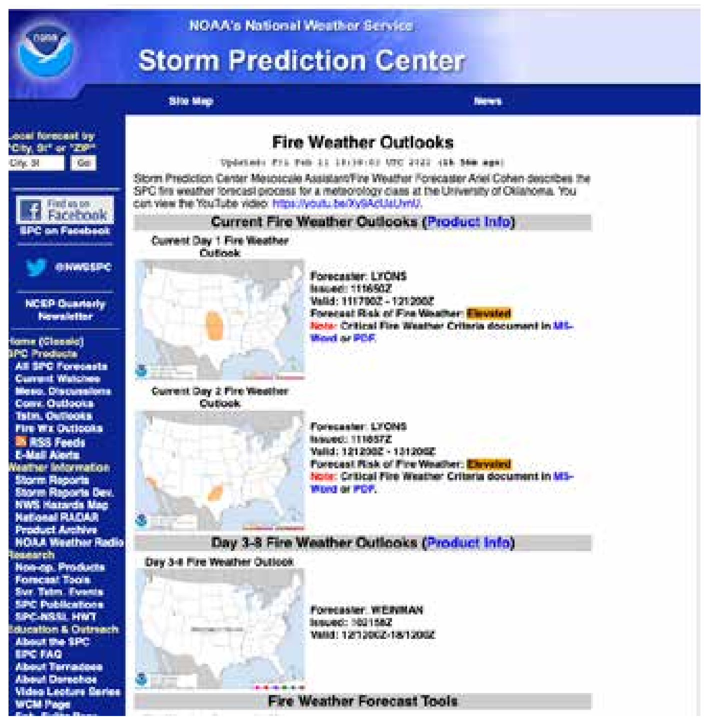
Weather and Fire Risk Forecasting

Paying attention to the weather can help predict potential fire behavior, but only for people who know what to look for. If you are interested in learning about wildland firefighting, including predicting potential fire behavior, the National Wildfire Coordinating Group offers introductory training online and free of charge at www.nwcg.gov. These training sessions can increase your understanding of how fire tends to behave so that you can be aware of risks, but remember that it is still up to the local fire station to give permission to burn on a given day.

Use the National Weather Service map (www.weather.gov/fire) to see fire-related forecasts. Click on the map to see the forecast for different regions.

At the online New Mexico Fire Information site, www.nmfireinfo.com/fire-restrictions, there is a map of New Mexico and Arizona fire restrictions along with other information about fire restrictions, organized by the agencies that manage various localities. Even in winter there can be burn bans, and landowners are responsible for acquiring proper permission and following fire regulations in any season.





Exercise #6

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#6: While we have provided general guidelines to planning for and conducting a relatively low-risk burn, you will be the expert of your individual situation.

What else can you do before, during, and after a burn event to keep yourself, your community, and the lands safe?

Please spend time thinking deeply about how you can minimize risk and then be sure to add those considerations to your burn plan and follow the planning up with appropriate action.

4. Making Place-Based Biochar: Two Methods

This chapter provides basic instructions for two ways to manage the flame carbonization process: a flame cap kiln and a conservation burn. Each burn host will need to determine which method to use based on their resources. Both methods follow a basic three-step process: ignite, feed, extinguish. The flame cap kiln may lead to more efficient burning, while the conservation burn requires less equipment. With skillful management, either method transforms nuisance wood or agricultural waste into valuable biochar.

As described in Chapter 1, biomass burns in three stages. To make biochar, these stages are managed to optimize the outcome. We stop the process as soon as the fuel has reached the glowing coal stage and is no longer producing a flame. The lack of flame indicates that the first two stages of combustion are complete. To save the char and prevent its oxidation to ash, we stop the combustion by removing heat, air, or both. Quenching with water is the best way to accomplish this.

Learning Outcomes

By the end of this chapter, readers will be able to:

- Compare biochar production methods
- Identify the types of kilns available for biochar production
- Identify the steps and describe the process of making biochar
- Prepare material for a kiln or pile burn
- With additional video training, field experience, or on-site guidance, conduct a kiln or pile burn

Note: Biochar can be made in furnaces, stoves, and gasifiers that provide heat energy as well as biochar. These are called combined heat and biochar or CHAB technologies. Though we will not discuss them in this workbook, readers can gather more information at the US Biochar Initiative website (www.biochar-us.org).

Preparation

We recommend that you read through this entire chapter even if you plan to use only one method. The principles and procedures all reinforce each other and can help you have a holistic understanding of the process.

Tools and Supplies

Most of the tools and supplies needed to make biochar are ones that many land stewards already have on hand, but frequent burn participants may want to acquire one or more specialty tools to help with efficient production. Also note that additional supplies are needed for safety, such as leather gloves and fire-retardant clothing. (See Chapter 3 for more safety instructions and supplies.)

Here is a list of valuable supplies:

- Shovels and rakes
- A hand saw or small electric chainsaw
- Water buckets, hoses, nozzles
- A propane torch
- A McLeod fire rake
- A wood moisture meter (optional)

Photos from top to bottom: Weeding tool by photo farmer, a firefighter in Wayne National Forest by Wayne National Forest. Moisture meter by Kelpie Wilson, Credits in references list.

Feedstocks

Most woody materials make good feedstocks for biochar produced using either the kiln or pile methods. Woody feedstocks can consist of brush, branches, small logs, old lumber, mill ends, or any clean biomass material that will not pack down. Be aware that feedstocks with leaves attached can create flames high in the air that may cause embers to be transported out of the kiln or pile burn. Certain agricultural wastes, such as corn stover and hemp stalks, also work well with both methods. Other organic wastes, such as manure, straw, or nutshells would be difficult to burn in a kiln. Different biochar characteristics result from the feedstocks used as well as the burn conditions, so it is useful to keep track of the results; there is a table for this purpose in Appendix 2.

Wood chips will not work well because they pack down and exclude the air needed for combustion.

When selecting feedstocks, there are two primary conditions to manage for:

Moisture: Use dry feedstocks. Ideally, the moisture content of the bulk of the material should be between ten and twenty five percent. While a moisture meter is not the most common piece of equipment, at around thirty dollars it is a worthwhile investment for anyone planning to make biochar. Wood and feedstocks that are too dry (around five percent or less) can create large amounts of black, sooty smoke because they burn too quickly. Use extra caution if your feedstocks are very dry, as flame lengths will be longer than when using wetter feedstocks. Wet wood with thirty percent moisture or more should not be used because too much feedstock will have to burn to create the heat needed for the water to evaporate from the feedstock, making the process less efficient. Allow wet woody feedstocks to dry before burning, following these guidelines:

- Up to two inches in diameter: dry thirty days
- Two to six inches in diameter: dry sixty days

Depending on how wet the wood is, these timelines should allow the wood to fall within ten and thirty percent moisture for making char. The moisture meter will give you a better sense of what different moisture levels feel like in the wood you use when used to measure the feedstocks before and after drying. Fuel moisture is the main factor that will affect the time to char material. Allow plenty of time to complete your burn if you must start with damp feedstocks.

Size: The ideal size of woody feedstocks is between one and four inches thick. If the feedstocks are very dry, pieces up to eight inches thick can be successfully charred in a large kiln. Small brush and branches should be separated from large logs and processed separately. If you mix feedstock sizes, the small material will be wasted because it will burn completely to ash before the bigger material has finished charring.

Critical Feedstock Safety Notes Checklist:

- [ ] Do not burn treated wood or wood with paint.
- [ ] Know the characteristics of the feedstocks! There are woods that release deadly chemicals when burned (oleander, for example).
- [ ] Reach out to poison control or other experts if the host wants to burn woody material that has been killed with herbicide or other chemicals to understand the risks.
- [ ] Keep feedstock piles at least twenty feet from the kiln or pile burn, ideally upwind. Remember to ensure that someone is patrolling to make sure that no embers have landed on the feedstock pile

Exercise #7

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#7: Consider local conditions or considerations and add additional items to remember here that will help you prepare for a relatively low-risk and useful burn.

Biochar Methods

There are several similarities between the flame cap kiln and conservation burn methods. Use the table below to compare the methods so you can make a decision about which method is right for you. See "The Three Step Method" on page 60 for a checklist for burning with each method.

	Flame Cap Kiln Method	Conservation Burn Method
Feedstock size	Woody material or feedstocks one to four inches in diameter; larger diameter feedstocks can be burned if dry or using a larger kiln.	Woody material or feedstocks one to four inches in diameter; larger diameter feedstocks can be burned if pile is built to handle larger wood.
Feedstock quantity	Burns material more efficiently so more feedstocks can be burned in a given amount of time.	Burns material less efficiently so less can be burned in a given amount of time for a given pile.
Number of people to assist with burn	At least two, but three are recommended. More are needed for managing multiple kilns.	One person can build and manage one pile but we recommend two people for safety. More people are needed for managing multiple piles.
Cost of equipment	Varies considerably by size, portability, and materials.	No specialized equipment needed.

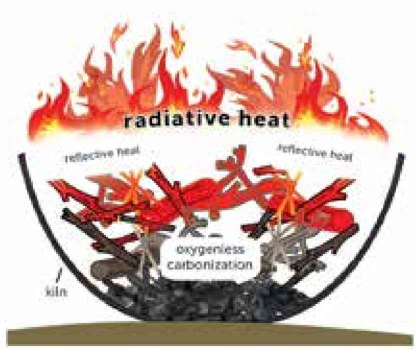
For both methods:

- Make a burn plan (Chapter 5), get a burn permit, and make sure it is not too windy to burn. Follow all other safety considerations from Chapter 3.
- Separate sizes of feedstocks: Make separate piles of items less than four inches in diameter and greater than four inches in diameter.
- Load feedstocks loosely, with kindling-sized materials on top.

Flame Cap Kiln Method

Flame cap biochar kilns produce biochar in an open flame. The flame cap kiln method uses a container made from bricks, ceramics, or metal, or an earthen pit or trench, to exclude air from the bottom and sides of a pile of burning biomass. It differs from a conservation burn pile mainly in that it excludes air from the bottom of the pile to preserve biochar formed in the combustion process and prevent biomass carbon from oxidizing. In combination, the enclosed bottom and the open flame on top preserve the biochar until it can be quenched and saved. See the Three Step Method on page 60.

The basic principle of operation is that of counter-flow combustion (see image below). Air enters the kiln only from above. The air feeds a flame that is maintained by constantly feeding in new fuel. As each new layer of fuel bursts into flame, the heat transfers by radiation into the partly charred material underneath; that material continues to char, releasing gases for the flame. (Recall the process of burning biomass as explained in Chapter 1) The flame consumes all of the available air, so no air is available to burn the biochar that forms beneath the flame. The counter-flow combustion air keeps flame lengths low and minimizes the emission of embers or sparks. The flame also burns most of the smoke, reducing particulate emissions. When new feedstock is loaded into the kiln, it temporarily interrupts the flame cap, but the flame cap is quickly reformed. When the kiln is full of biochar, it is quenched with water, raked into a thin layer to lose heat, or snuffed with a lid. Water is the fastest and easiest way to cool burning coals, so best practice is to use at least some water to help stop the burn and cool the biochar. The next few sections use examples of different flame cap kilns to illustrate the Flame Cap Kiln Method.



How a Flame Cap Kiln Produces Biochar. Image concept by Kelpie Wilson, designed by Jessica Brothers.

Flame tips curl downward in a flame cap kiln, showing how all the air comes from above in a counter-current flow. Photo by Kelpie Wilson.

The Oregon Kiln: A Small Bin Kiln

Flame Cap Kiln

Method #1

The Oregon kiln is a small bin kiln. Free plans available at WilsonBiochar.com

Preparation:

Load dry feedstock loosely in the kiln.

Step One:

Ignite. Make sure there is dry, kindling-sized material on the top. Light evenly across the top.

Throughout the burn...

Keep a flame cap across the top in order to burn up most of the smoke.

Step Two:

Feed. Once the first pile has burned down, start adding more material.

Once the kiln is very hot, bigger material can be added.

Throughout the burn…

Monitor. If pieces move too close together, air is cut off. Pull them apart with a rake.

Step Three:

Extinguish. When all the flame is gone and ash starts to form, it is time to quench.

Use plenty of water. Too little water may result in total evaporation and re-ignition of the biochar.

Panel Kiln with a Heat Shield

Flame Cap Kiln

Method #2

This type of kiln works efficiently for two reasons:

1. The heat shield holds more heat inside the kiln than a kiln without a heat shield

2. The heat shield acts to preheat combustion air, improving combustion efficiency and reducing particulate emissions.

Note: Ring of Fire Biochar Kiln: Available for purchase at www.WilsonBiochar.com

Preparation:

1. **Unload** kiln components- they are lightweight and portable.
2. **Set up** the inner ring and seal the bottom with dirt.
3. **Attach** the heat shield pieces to the inner ring.

Preparation:

Load. Load the initial feedstock, keeping it loosely packed.

Step One:

Ignite. Light the feedstocks on top

Step Two:

Feed. Load more feedstocks once the first pile has burned down.

Step Three:

Extinguish. Cool kiln with water. Spray the joints until cool enough to touch. Remove the bolts; move the heat shield and panels away from the char to enable efficient spraying and raking.

Spray and rake to fully quench the burn.

Big Box Kiln, a large bin kiln

Flame Cap Kiln
Method #3

For those who have access to heavy equipment, it is possible to make biochar in larger kilns. These are often re-purposed tanks or steel containers. Utah State University Forestry Extension has designed and built their own large bin kiln called the Big Box Kiln.

Preparation:

All the procedures and preparation for operating small kilns apply, except that machinery can be used to mobilize, load, and dump kilns.

(See page 46)

Biochar produced in large kilns using heavy equipment. Photos by Darren McAvoy.

Step One:

Ignite. Make sure there is dry, kindling-sized material on the top. Light evenly across the top.

Keep a flame cap across the top in order to burn up most of the smoke.

Step Two:

Feed. Once the first pile has burned down, start adding more material.

Now that the kiln is very hot, bigger material can be added.

Throughout the burn...

Monitor. If pieces move too close together, air is cut off. Pull them apart with a rake.

Step Three:

Extinguish. When all the flame is gone and ash starts to form, it is time to quench.

Use plenty of water. Too little water may result in total evaporation and re-ignition of the biochar.

Flame Cap Kiln Comparison Chart

	Small Bin Kiln (e.g., Oregon Kiln)	Panel Kiln (e.g., Ring of Fire Kiln)	Large Bin Kiln (e.g., Utah Big Box Kiln)
Mobility	ATV, Hand crew	Hand crew	Road based
Feedstock diameter	Up to four inches	Up to four inches	Up to eight inches
Feed method	Hand fed	Hand fed	Machine or hand fed
Extinguish method	Flood	Spray and rake	Flood

Additional Kiln Considerations

Kilns can have any shape, including cylinders, cones, troughs, pyramids, rectangles, or polygons. They should have an aspect ratio of height to width that is one to one or less. A kiln that is too tall will have trouble getting enough air to maintain combustion. Some examples are shown below.

Photo: Montana by Rasmus

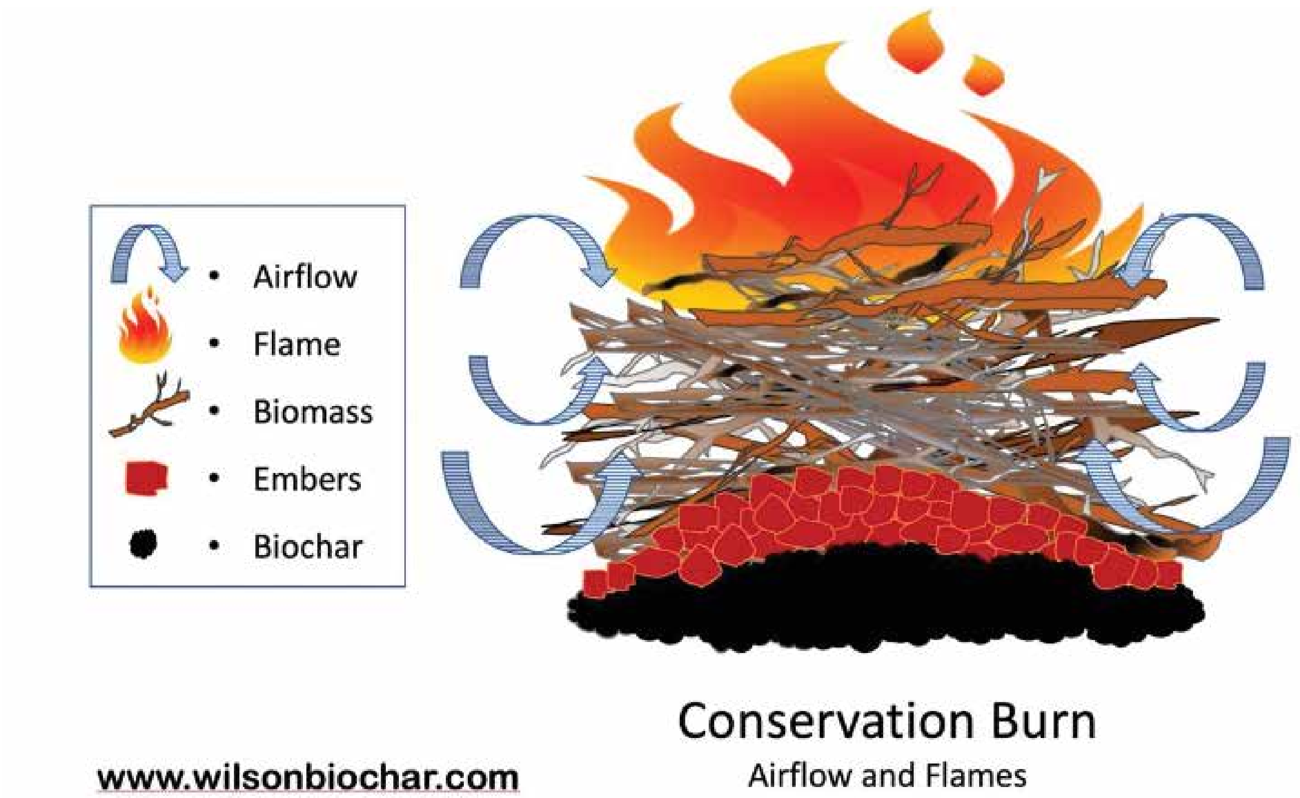
Photo: Kon Tiki kiln by biochar4ss

Other examples of kilns include:

- Stock tank kiln. A description can be found at www.forestry.usu.edu/files/utah-forest-facts/hazardous-fuels-reduction-using-flame-cap-biochar-kilns.pdf
- Trough kiln. https://warmheartworldwide.org/flame-cap-trough/

Conservation Burn Method

The conservation burn is a specialized burn pile that is built and tended in such a way that it produces biochar. This method requires less equipment than a kiln burn, but will also be less efficient; it takes more time and produces less biochar per feedstock. As with a kiln burn, the flames will burn up much of the smoke; both kiln and conservation burns are cleaner than open-air methods and less likely to annoy neighbors with smoke. If you have been managing burn piles on your land and would like to try making biochar, this method allows you to adapt the practices you are used to without a big investment. See "The Three Step Method" on page 60.



One benefit to the conservation burn method is that this procedure can work with larger material than a kiln. Even hard-to-burn material, like old lumber and logs larger than eight inches in diameter can be charred with a conservation burn pile. See images below for how to char small brush, bigger logs, mixed sizes, and old lumber.

Small brush can produce a lot of biochar very quickly. The key is to consolidate it as it burns and put it out at the right moment. Photos by Kelpie Wilson.

To char bigger logs (those pictured are between three and six inches), make sure there is space for air between the pieces, the material is dry, and there is no dirt in the pile. Light the pile on top, and put it out with water. Note: All the smoke in the third picture is coming from one branch that is sticking up out of the hot zone. Keep everything in the hot part of the fire and you will not see smoke. Photos by Kelpie Wilson.



Mixed-size piles are made by stacking smaller branches in the middle of the pile and then placing the larger logs in a cone formation around the pile. The larger logs will not completely char, but they will be very effective in holding in heat and controlling air flow, so the smaller material in the middle will char quickly and efficiently. After quenching, the partly charred logs can be scattered on the surrounding land for ecological benefits. Photos by Kelpie Wilson.


To burn old boards, stack them in a rack with space for air between each board and light them on top. Boards stacked in this manner will burn cleanly and quickly and yield a nice pile of biochar. Photos by Kelpie Wilson.

The Three Step Method

Flame Cap Kilns

Prepare: Build an initial pile of medium-size material (one to two inches thick is ideal) that is open and loose on the bottom to facilitate airflow. Fill the kiln up to the kiln rim. On top of the pile of medium-size material, place a densely-packed pile of small, very dry brush for kindling. This can be about twelve inches high.

1. Ignite

Always top light the center first, then the outer parts of the pile, so that there is an even burn across the entire surface. Keep a strong flame on top to burn the smoke and provide heat to the charring feedstocks underneath. A propane torch is useful but not necessary if starting with dry fuel. Lighter fluid and matches can also be used to light the top.

2. Feed

Prepare to load additional feedstock: During the first phase of operation, air is drawn from the top down to the bottom of the kiln while the initial load mostly burns down to a layer of coals. The first load must produce a good bed of coals before you add more material.

Continue to feed: Once the first load produces a good bed of coals, begin to add more material. When the second layer begins to show a film of white ash, add another layer of feedstock. Try to add wood of the same diameter to each layer so that charring is even. Add the biggest material in the middle stages of the burn so that it has time to char completely.

Monitor the flame: Let the flame be the guide for adding new material. A good strong flame should be maintained on top because that is the heat source for making char. If you load too much too fast, you will smother the flame. If that happens, the burn team must pause and wait for the flame to come back up. If you do not load enough material, the flame will die down and the char will start to burn to ash. If that starts to happen, add more material to keep the flame going or extinguish the flame. As the kiln fills with red hot glowing coals, make the last few layers of feedstock you add medium-size material to allow any larger pieces to finish charring. The charring is complete when there are no longer any flames.

3. Extinguish

Quench the flame: Quenching the flame removes heat by adding water, or removes air through snuffing.

Flood quench: When using a bin kiln with a drain plug, it is possible to flood quench. Once all the flames are gone, begin adding water in a gentle spray to the top of the kiln. Take care not to use a strong spray because it can drive air into the kiln and force a cloud of black particulates into the steam. Make sure that there is plenty of water; with too little, the water may evaporate, and the biochar can re-ignite. To conserve water, take the time to stir the biochar in the water until it is all cool. Alternatively, dump the wet biochar on the ground and spread it thin so that it loses heat.

Spray and rake: When using a panel kiln, there is no option to flood quench. Once all the flames are gone, spray a bit of water to cool the kiln enough that you can remove one panel. Continue to spray water as you rake out the coals and spread them thin to remove heat.

Note: If the hot char will be raked out for cooling and quenching at the end of the burn, make sure that you have cleared a large enough area free of flammable material at the site for that purpose.

Snuff: An airtight lid in a bin kiln can work to quench biochar. Place a thin sheet of steel directly on top of the biochar layer inside the kiln and seal the edges with dirt or clay. Alternatively, shovel hot coals out of the bin and into a metal drum with an airtight lid. Allow the char to cool for at least twelve hours. Use caution when reopening the drum or bin: if oxygen is reintroduced while the material is still smoldering, the fire may reignite.

Note: After quenching, the material should be cool enough to put your hand in it.

Conservation Burns

Prepare: Make a small pile (or multiple piles) of medium-size material that are loose enough to provide good airflow and contain no dirt. A good pile size is four to six feet in diameter and four to six feet tall. On top of each pile of medium-size material, place a densely packed pile of small, very dry brush for kindling. This layer can be about twelve inches high.

Tip: Consider building many piles to burn all at once; this is useful across a rugged landscape where it would be difficult to deploy kilns.

1. Ignite

Light the pile(s) on the top as with a kiln. Always light the center first, then the outer parts of the pile, so that there is an even burn across the entire surface. A propane torch is useful but not necessary if starting with dry fuel. Lighter fluid and matches can also be used to light the top.

2. Feed

- Prepare to load additional feedstock: The pile will burn slowly at first, but soon the entire pile will be blazing. The top-down method of burning is much faster than other pile burning methods.
- Monitor the burn piles: As with a kiln, add material to the pile just as ash is beginning to appear.
- Monitor the flame: Once all feedstock has been added (or other circumstances indicate that it is time to finish up), look for flames dying down to indicate that it is time to use a rake to push unburned material to the center of the pile.

3. Extinguish

Quench the pile by spraying and raking.

When the pile has collapsed into a bed of glowing coals, use the spray and rake method to put it out. Spray water to cool the coals enough so that the team can rake them out thin to remove heat

Note: If the hot char will be raked out for cooling and quenching at the end of the burn, make sure that you have cleared a large enough area free of flammable material at the site for that purpose.

5. Compiling A Burn Plan

Answering "Where? Why? What? Who? When?" will help a burn team keep track of all the considerations to ensure a low-risk burn and put together a thorough burn plan. The answers to these questions should be communicated multiple times, both within the burn team and with other stakeholders. At the Quivira Coalition, our plans include a site visit prior to the burn with all team members, the local fire chief, and neighbors; phone calls (in addition to emails) in the days before a planned burn to keep all stakeholders updated on weather conditions and considerations such as road work that might impede emergency personnel; and a day-of briefing to review the plan. An example burn plan template in Appendix 1 can be modified to meet your needs

Learning Outcomes

By the end of this chapter, readers will be able to:

- Identify the components of a burn plan
- Write a sample burn plan using the template provided
- Discuss the importance of a burn plan as it relates to safety

Sample Communication Schedule

At least a month in advance	Ten days before the burn	One week before the burn	Daily, approaching the burn	One day before the burn	Burn Day!
Get burn permit	Contact burn team, local fire chief, and neighbors to alert of planned burn	Site visit to burn location; write burn plan. Distribute burn plan and this safety chapter to all participants	Check weather forecast	Finalize burn plan; share finalized plan with burn team, local fire chief, and neighbors	Call local fire dispatch, assess immediate conditions, on-board participants.

On the day of the burn, do not assume that everyone has read the advance communications. It is always worth slowing down and ensuring that everyone's questions are answered.

Why - Objective of the Burn

Writing down the objective is an important part of the burn plan. This objective is a key communication to the burn team and external stakeholders. Consider and answer the questions: What do you hope to accomplish through this burn? How will this benefit you and the landscape?

Who — The Biochar Burn Team

The minimum size for a biochar burn team is two or three people: a landowner/land steward, a supervisor, and at least one additional person to help. The burn supervisor can be the landowner, but if the landowner does not have any experience using fire as a management tool, it is best to solicit someone with experience to be the burn supervisor.

On the day of the burn event, use a sign-in sheet to account for all people attending. Have each person list or confirm both their own names and telephone number(s) and the names and telephone number(s) of their emergency contacts. In an emergency, it is essential to have an accurate count of people. Anyone arriving at or leaving the event should notify the person in charge of the list, who must keep the list updated throughout the event. In the event of an emergency, an accurate participant list allows emergency personnel to save time not looking for people who have already left or failing to search for someone whose arrival was not noted.

Roles and Responsibilities

The burn supervisor is responsible for making the burn plan, getting it approved, and assigning roles at the burn event. This person should have experience with fire management and knowledge of fire behavior in order to make on-the-spot safety calls. They should also be familiar with the terminology introduced in this manual in order to ensure clear communication with local fire emergency and agency personnel. The burn supervisor will manage and direct loading, burning, and quenching to ensure safety and efficiency.

Additional people will be responsible for managing water and patrolling the burn area for sparks or embers. The person patrolling will need a tool such as a shovel or McLeod, or a fire extinguisher or water, to quickly extinguish ignitions. For larger groups, two or more people are assigned to each task.

No matter who is doing what, it is essential to assign clear roles and responsibilities to each participant and ensure that they know who the supervisor is. Who is responsible for the hose? Who is responsible for feeding new material into the kiln or onto the conservation pile? Who is responsible for patrolling for embers near and far from the burn?

Neighbors

Neighbors near the burn site may be inconvenienced or even alarmed by smoke and noise. The burn supervisor and/or the property owner should contact neighbors at least a week before the burn and explain that burning for biochar is a low risk, well-contained process and usually produces very little smoke. Neighbors who are interested can be invited to the event, and all should be added to the list of people to be updated as the event approaches. In addition to supporting general safety, open communication gives anyone with respiratory problems plenty of notice to avoid potential (though unlikely) smoky air.

When — Timing

Time of year, time of day, and weather are all factors in determining when to burn. Chapter 3 includes the factors that will affect the timing of a burn, and the local fire department will have detailed information about whether a given day is relatively safe for a burn. When conditions are conducive to low-risk outdoor pile burning of forestry or agricultural waste, making biochar in a kiln or pile is also low-risk. In contrast, Red Flag Warnings are issued when weather conditions have the potential to allow wildland fires to grow rapidly in size and intensity before first responders can contain them. The National Weather Service provides a forecast for burn conditions online with an up-to-date Hazard Map.

Important safety concerns regarding timing a burn:

- Burn only on legal burn days and under safe conditions as determined by the local fire department. Never burn on Red Flag Days.
- Check with the local fire department. The local fire station will likely have regulations about times of day and days of the week that are acceptable and unacceptable for burning. Be sure the burn plan aligns with these regulations.
- Remember to call your local fire station well in advance of your burn and on the morning of your planned burn to ensure that conditions are safe.

Where - Context

Location is about more than identifying the area where the team will make the biochar. When developing the burn plan, the burn supervisor should have a map of the site and make a visit to assess the space for fire safety and prepare the ground in the specific location where the kiln or burn pile will be.

- **Orient participants.** The address and directions to the burn property should be clearly stated on the first page of the burn plan, along with telephone numbers for the local fire department and ambulance service, so that every participant at the event can easily find them in case of emergency and communicate the location correctly. Do not rely on only the landowner or burn supervisor to have this information. Also, do not rely on digital map apps; include a map in the burn plan showing local roads and how they connect to major arterials. This information may be important for participants if they need to get off the property quickly. It could also help them guide emergency services to the location.
- **Arrange for a safe meeting place**, one protected by fire breaks or with ample water nearby, and with easy access to vehicles, where all participants should gather in the event of an emergency. Use the sign-in sheet to identify anyone who is missing and possibly at risk; this is essential information for emergency service personnel.
- **Map the burn property** at both large and small scales, noting characteristics of its topography, vegetation, water, and roads. Is the property in a valley or near mountains? Wind can move up and down slope in predictable patterns at particular times of day, but it can also behave unpredictably when there are topographic features, such as hills and swales, nearby. Topography can affect fire behavior: Vegetation upslope can be preheated by flames below and can thus catch fire more rapidly. Winds can spread embers great distances. Making a note of where you are on the landscape and considering what would happen in the worst-case fire scenario will help you plan a low-risk burn.
- **Make an inventory of the types of vegetation on the property** (grasses, shrubs, trees) and their phenological stage (well-watered, living leaves and stems or crispy dry leaves and dead branches). Is there ladder fuel (undergrowth that could easily allow a fire to transition from the ground up into the tops of trees)? Is there continuous vegetation, or is vegetation patchy with lots of bare ground, water, or snow in between?
- **Map the sources of water on the property**. Where is the hose bib and what is the water pressure? Has the hose been unkinked? Is there a source of water that can be mobile, such as a five gallon bucket or a portable pump? These

should be stationed downwind of the burn so that if an ember escapes, they can be easily deployed to extinguish it. It is a good idea to spray down the area directly around the biochar kiln or pile, both before the burn and periodically as it progresses.

- **Identify and map both natural and constructed fire breaks**, such as streams and roads, or even a well-watered lawn on a neighbor's property.

For mapping, the burn supervisor can use a satellite image, like these examples below taken from Google Maps; a printed road or topographic map; or a hand-drawn or traced map of the property.

A map showing some of the **local** features of a planned kiln burn.

A map showing some of the **regional** features of a planned kiln burn.

What — Tools and Supplies to Have on Hand

Depending on the size of the burn event and the tasks required, the burn team will want to have a variety of tools, supplies, and safety equipment on hand. These may range from hand tools and a first aid box to power tools and earth-moving equipment to five gallon buckets of water and a portable pump. The burn supervisor should make a checklist before the event so that the team can have everything they need on-site and operational on the day(s) of the burn event.

The following supplies are essential to any burn event:

- Copies of the burn plan for each participant
- Sign-in sheet and contact information for all participants
- Safety gear (check Chapter 3 for a checklist), including:
  - A fire extinguisher if burning will take place near structures (wooden fences, buildings, vehicles, etc.)
  - A first aid kit
  - Cell phone, radio, or landline to call the local fire department on the morning of the burn and for emergencies
  - Extra supplies of water, snacks, sunscreen, gloves, and fire resistant clothing in the event that participants run low or forget
- Production gear (check chapter 4 for a complete checklist), including:
  - A kiln with all required parts (if using)
  - Shovels, rakes, and a McLeod fire rake
  - Water buckets, hoses, and nozzles

If one or more participants is unfamiliar with the proper and safe use of particular tools, the burn supervisor should ensure that there is time for adequate training or assign these people to tasks that do not require use of those tools.

A note regarding power tools, machinery, and other large equipment: This workbook is meant to introduce readers to biochar and the process of making it, with the goal that they can do it on their own. However, this book is not able to cover all safety measures (such as first aid or chainsaw training) that will be useful to the reader intent on making biochar.

photo by Karolina Grabowska

6. Best Practices: Making Biochar & Regulations

If you are planning to burn frequently, get to know the fire officials in the local area. Call ahead, invite them to attend burns, and follow up if they have questions. Though this is not a legal requirement, it will absolutely help burn managers plan, prepare, and respond in the event of an emergency.

Learning Outcomes

By the end of this chapter, readers will be able to:

- Identify who they need to alert about the planned burn in order to comply with local and state regulations, given their location and ownership structure
- Discuss the importance of liability in prescribed burning and other agricultural burning
- Explain the impact of the New Mexico Prescribed Burning Act

Local Regulations

Anyone who is going to be burning materials outdoors first needs to call their local fire station well in advance. The county or municipality may require a permit to burn materials outdoors. Some counties allow residents to apply for permits online, but in many cases the applicant needs to call in order to acquire the proper permits. Many counties have restrictions on the day of the week that people may burn; it may even be the case that there are only specific hours during which people may burn. As soon as you decide you want to start burning on your land, call your local fire department. This is the first step and will guide the rest of your process.

Additionally, it is important to let local emergency responders and fire dispatch know that a burn will occur by calling first thing in the morning the day of the burn; this allows them to safely track reports of smoke or flames and to be prepared if reports start to register as potentially dangerous. Fire dispatch will let burn teams know if conditions are unsafe to burn that day.

State Regulations

In addition to local burn permits, land managers must familiarize themselves with laws concerning the use of fire in their state. The following paragraphs describe the legal landscape in New Mexico; other states will have different regulations. This section introduces the types of state regulations to look for and become familiar with when planning a burn.

Since the practice of making biochar is not very widespread in New Mexico, there is not yet a clear answer as to which state laws should regulate that practice. Land managers should be aware of the Prescribed Burning Act, passed in 2021. A copy of the act itself, as well as information about it, can be found on the Energy, Minerals, and Natural Resources Department website: www.emnrd.nm.gov/sfd/prescribed-burning/. The act expands the use of prescribed burning on private lands, which the state sees as a benefit to the public to reduce the risk of extreme wildfire events. However, the most conservative assessment at this time is that if biochar is made in a kiln or pile, that practice does not fall under the Prescribed Burning Act protections. For now, biochar production should be considered to fall under general agricultural burning.

Agricultural burning is regulated within the New Mexico Environment Department (NMED) because of its potential impact on air quality. NMED issues air quality permits based on tons of emissions per year and pounds of emissions per hour, much more than one fire can emit. If the burn team is going to burn over a vast landscape, the burn supervisor must be aware of the point at which they will need an air quality permit and be sure to record the calculations of emissions. Reach out to NMED to learn about guidelines for specific areas.

> Note: Laws often change. It is always a good idea to research the most up-to-date regulations and implications.

Some additional information:

- Anyone who leases land from the Bureau of Land Management, United States Forest Service, or New Mexico State Land Office should contact the person who manages their lease if they are interested in creating a burn plan for producing biochar on their leased area.
- If someone is interested in using fire as a land management tool or simply wants to better understand fire and fire fighting, the National Wildfire Coordinating Group (NWCG) has an online learning portal with introductory courses that can be accessed free of charge at www.nwcg.gov.

Exercise #8

Write your answers down or discuss the following question with your family, friends, or neighbors before moving to the next page.

#8:What is your plan for determining regulations in your area?

Who will you call and when?

Feel free to write the phone numbers down below for quick reference.

Quick Reference Contacts

Name/Contact	Phone Number

Appendix 1. Burn Plan Template

Write a plan in advance and review it with all participants prior to burning, as well as participant expectations (p32-34). Note that some of the burn plan can be completed days to weeks in advance, while some things must be completed the night before or the morning of the burn. If you make changes to your plan, be sure to update anyone you've shared it with, including local authorities and participants. Best practice is to share plans both digitally and in print.

Why

Objective: What do you hope to accomplish through this burn? How will this benefit you and the landscape?

Who

List names and cell phone numbers for the land owner, burn supervisor, and anyone assisting with the burn, along with the names and phone numbers of each participant's emergency contact. Also list anyone else you may need to contact, such as neighbors. Ask each person to sign/initial by their name when they check in to ensure you have an accurate list of participants.

Role	Name	Phone	Emergency contact	Emergency contact phone	Initials
Site host					
Burn supervisor					
First aid certified participant(s)					
Participant(s)					

Additional Contacts:

Name/Contact	**Phone Number**	**Role or Relationship to Burn**	**Initials**

Define roles and responsibilities of participants.

Who will:

Participant Initials:

1. Load material into kiln or pile

2. Manage hose

3. Patrol for embers during and after the burn

4. Observe (anyone without proper safety attire should stay back at least twenty feet from burn)

5. Communication (including who will be in charge of maintaining the participant list and who is available to make or receive calls with either a landline or a cell phone with service in the area)

Create a communication log.

1. Write down the date of advanced notice to the local fire department or relevant entity and the contact information for that person/entity.

2. Write down the date of advanced notice to neighbors and add the contact information of those people/entities.

3. Write down the date and time of day-of notice to the local fire department or relevant entity and the contact information for that person or entity. ***If they do not approve a burn on that day, do not burn.***

4. Write down the date when an up-to-date burn plan was shared with the local fire department and the contact information for that person or entity.

5. Write down when and how you conducted safety training and burn plan briefing for attendees.

When

1. Write down dates, times, and descriptions of activities in preparation for the burn, such as site visits, feedstock preparation, and clearing obstacles and vegetation from the local burn area.

2. Date of burn*:

3.

Activity	Planned agenda of day	Actual agenda of day
• Participant arrival:	______________	______________
• Safety briefing:	______________	______________
• Start time of burn:	______________	______________
• End time of burn:	______________	______________
• Time for final patrol on foot for embers:	______________	______________
•	______________	______________
•	______________	______________
•	______________	______________
•	______________	______________
•	______________	______________
•	______________	______________

*** If they do not approve a burn on that day, do not burn.**

4. What is the ignition plan and procedure? What tools will you use to ignite the kiln or pile?

5. How will you decide when to continue feeding the kiln or pile and when to quench?

6. What is the quenching plan and procedure? What tools will you use to quench the kiln or pile?

Document the weather forecast.

Attach a screenshot showing that there is no red flag warning:

Attach a screenshot of the forecast the day before the burn for local temperature, precipitation, and wind conditions:

Describe what criteria you will use to stop a burn:

Always stop the burn if local fire authorities instruct you to stop.

Wind:

Temperature:

Personnel:

Other:

Notes:

Dated signature of burn supervisor and other relevant stakeholders:

____

Where

State the address and driving directions in case any participant needs to call for emergency help:

Driving Directions:

Describe your site:

Vegetation composition (grasses, shrubs, trees, etc.):

Phenology (dry and dead, well-watered and active):

Describe your site, continued

Soil moisture (snow on the ground, recently flood irrigated, etc.):

Distance of burn site from structures, trees, and power lines:

Distance to water source(s), rate of flow of water, and total amount available:

Natural/constructed fire breaks, if any:

Escape route and emergency meeting point for all participants:

Map #1

Attach a map of the burn site and immediate area, including location of safety equipment, landline or other designated communication tool(s), and water sources. Indicate where participants should park, leaving areas clear for emergency equipment to maneuver.

Map #2

Attach a map of the region highlighting escape routes and the emergency meeting point, and indicating natural fire breaks.

What

Describe the feedstocks that you plan to burn (orchard trimmings, old lumber, mechanically treated shrubs, etc.):

____

____

____

Describe your equipment:

What tools and safety equipment will be on hand and their condition:

#______ Hoses/buckets/tanks of water
Condition:

#______ Extinguisher
Condition:

#______ First aid kit
Condition:

#______ Rakes/shovels/McLeods
Condition:

Other:

#______ ____________________
Condition:

#______ ____________________
Condition:

#______ ____________________
Condition:

#______ ____________________
Condition:

Describe available or required Personal Protective Equipment:

#______ Eye protection
Condition:

#______ Leather Gloves
Condition:

#______ Leather Shoes
Condition:

#______ Non-flammable clothing
Condition:

#______ Hair ties or other means to tie long hair back
Notes:

#______ Plenty of drinking water and snacks available
Notes:

Other:

#______ ____________________
Condition:

#______ ____________________
Condition:

Additional Notes

Appendix 2.
Biochar Burn Log Template

Daily Biochar Production Log for Flame Cap Kilns and Conservation Burns	
Record your results to evaluate what factors affect your resulting biochar so you can learn as you go! Tracking what you do and how you do it will allow you to make accurate, useful adjustments to your process and improve over time.	
Name of burn supervisor:	
Date:	
Weather (temperature, sunny, cloudy, rain, wind speed, etc.):	
Location and site notes (physical address and description—forest, field, steep slope, flat, etc.):	
Number and type of kilns or piles:	
Feedstock types and approximate amounts of each (e.g., fifty percent Doug fir, thirty percent pine, twenty percent oak):	
Feedstock moisture (record several moisture measurements from middle of logs, not ends):	

Feedstock diameters and approximate amounts of each (e.g., seventy percent under two inches, twenty percent between two and four inches, ten percent greater than four inches):	
Feedstock amount (number of piles, approximate dimensions or size of piles, e.g., cubic yards or cords):	
Maximum hauling distance feedstock to kiln or pile:	
Start time (when kilns or piles are lit):	
Quench time and amount (when water is applied and how much):	
Approximate yield of biochar in cubic yards, cubic feet, five gallon buckets, or fifty five gallon barrels:	
Workers (names, hours worked):	
Notes:	

Appendix 3. Resources

1. Innovations in Biochar: New CSP enhancement helps forest owners convert tree debris to soil-friendly, carbon-storing biochar

   https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/stories/?cid=nrcseprd1499267

2. Biochar Basics: An A-to-Z Guide to Biochar Production, Use, and Benefits

   https://www.fs.usda.gov/rmrs/documents-and-media/biochar-basics-z-guide-biochar-production-use-and-benefits

3. US Biochar Initiative - has a searchable database on biochar production and use

   http://biochar-us.org/

4. Pacific Northwest Biochar Atlas - developed for a different region, but has widely applicable guidelines for matching biochar to soil types

   http://www.pnwbiochar.org/

5. Biochar: Prepping it for Soil, by David Yarrow

   https://www.ecofarmingdaily.com/build-soil/soil-inputs/minerals-nutrients/biochar-prepping-soil/#:~:text=Author%20David%20Yarrow%20helps%20install,once%20in%20a%20single%20event.

6. Wilson Biochar Associates – hosts biochar practice guidelines developed for NRCS, sells Ring of Fire Kiln

   http://wilsonbiochar.com/

7. Biochar in the Woods Webinar and Field Days - presentation files and recordings

   https://biochar-us.org/presentations-biochar-woods-webinar-and-field-days-jan-feb-2022

8. Biochar in the Woods Discussion Forum - join to learn from peers who are developing biochar practices

   https://biochar.groups.io/g/Biocharinthewoods

9. International Biochar Initiative

   http://www.biochar-international.org/

10. The Biochar Journal

    https://www.biochar-journal.org/

Appendix 4. Funding Resources

Making biochar is a practice supported by the Natural Resources Conservation Service (NRCS), an agency of the US Department of Agriculture, so there may be cost-sharing support available for land stewards who want to incorporate it into their land stewardship activities.

To cost-share with the NRCS, call the local office and ask about developing a Conservation Plan, which will include the conservation practices relevant to the operation. Find the local NRCS office here: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/contact/local/

There are several NRCS-aligned conservation practices associated with this workbook.

- Woody Residue Treatment Conservation Practice 384. This practice enables ranchers and farmers to reduce or otherwise address "the management of woody plant residues created during forestry, agroforestry or horticultural activities, or resulting from natural disasters" (NRCS).
- Conservation Enhancement Activity E384135Z. This activity enables landowners to produce biochar that can be used on-site to build soil health which is an enhancement of Woody Residue Treatment Conservation Practice 384. This practice enables ranchers and farmers to reduce or otherwise address "the management of woody plant residues created during forestry, agroforestry or horticultural activities, or resulting from natural disasters" (NRCS).
- Conservation Practice Standard Code 336. This practice concerns the application of carbon-based amendments (including biochar) to improve or maintain soil organic matter, sequester carbon and enhance soil carbon stocks, improve soil aggregate stability, and improve habitat for soil organisms.

Note: Each operation will need a Farm Service Agency Tract Number prior to any contract with NRCS. This can be a time consuming process, so be sure to get started well before you plan to apply for cost-share funding.

Technical support may also be available through the local Extension Service, a collaboration between the USDA, land grant universities, and state and local governments. They will have deep knowledge of management practices specific to the local soil, production systems, and climate.

Local nonprofits such as the Quivira Coalition may help connect land stewards and operations to other resources or funding sources, such as educational opportunities, tool and equipment lending libraries, grant writing support, and networking. Please stay in touch!

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Pg 13: Fire Triangle https://en.wikipedia.org/wiki/Fire_triangle#/media/File:Fire_triangle.svg

Pg 16: Charcoal series, All photos downloaded from canva.com with non-exclusive use license

Pg 17: "bare trees" by McMac70 https://wordpress.org/openverse/image/5d52d91a-8f20-4306-b457-5c99ae818404

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Pg 23: 'Biochar Workshop', courtesy of Quivira Coalition

Pg 36: Images used for Exercise #5:

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Pg 37: "Time of Day" screenshot of Valarde, NM daily forecast by www.nws.noaa.gov/

Pg 39: Forecast screenshots

- "Wildfire Outlook,"Screenshot taken Feb 2022.https://www.predictiveservices.nifc.gov/outlooks/outlooks.htm
- "Storm prediction" screenshot, NOAA/NWS Storm Prediction Center. https://www.spc.noaa.gov/
- "red flag warning", screenshot taken Feb 2022. National Weather Service https://www.weather.gov

Pg 42: Tools and Supplies:

- Weeding tool by photo farmer, https://openverse.org/image/3cc185ff-ac59-4464-adbd-646563d1c8f4/
- a firefighter in Wayne National Forest by Wayne National Forest, https://upload.wikimedia.org/wikipedia/commons/2/24/Wayne_National_Forest_%283620426058%29.jpg
- Moisture meter by Kelpie Wilson

Pg 52: Additional Kiln Considerations:

- Montana by Rasmus https://wiki.opensourceecology.org/wiki/Earth_Pit_Kiln.
- Kon Tiki kiln by biochar4ss https://wordpress.org/openverse/image/ef660443-f58c-45bf-8b47-073f1a46a02e

Pg 64: Chainsaw work, photo by Karolina Grabowska via Pexel and downloaded from canva.com with non-exclusive use license.

The Quivira Coalition fosters resilience on arid working lands. To create a culture of land stewardship that integrates ecological, economic, and social health, we work in coalition with ranchers, landowners and land stewards, public agencies, conservationists, educators, students, and the general public. We believe this culture is rooted in three areas of practice: education, innovation, and collaboration at the *radical center,* a way of working together that champions coalition building and results over compromise.

At the foundation of all of Quivira's work is the concept that effective and adaptive stewardship of working lands is one of the most powerful and immediately viable paths to remedy the imminent impacts of climate change.

Our efforts are dedicated to communities and working lands in arid regions of the western United States and to connecting these to land-based communities around the world.

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