Biochar for the Small Farm or Garden

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https://www.swiss-biochar.com/?lang=en

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THE NEXUS PROJECT

What is biochar?

Biochar starts with a feedstock, which can be virtually any dry biomass. It is heated to temperatures over 250 C (480 F) in a low or no oxygen environment. Much of the feedstock's mass is converted to a gas, which escapes. This leaves behind biochar!

Biochar is a highly porous, high carbon material. Much of its utility comes from these two qualities. In soil, the porosity helps retain a good balance of air, moisture, and nutrients, which can help build healthy soil and feed healthy plants. Because biochar is mostly carbon, it is gaining popularity as a carbon sequestration tactic, helping us store carbon in the Earth and fight climate change.

Biochar made from miscanthus grass

Biochar is generally characterized as a soil amendment, but has been used for many things, such as for water filtration, humidity regulation, and even as a toothpaste additive. It is *not* the same as charcoal. While they are both pyrogenic carbonaceous material, charcoal retains much of the material originally present in the feedstock, including lots of volatile matter, so it burns well and is used primarily for energy. Biochar burns but won't hold a flame. Unlike charcoal, it doesn't leave an oily residue on your hands.

To summarize, biochar provides a means of turning waste biomass into a useful medium for soil regeneration, agricultural yield increase, and carbon sequestration. When properly applied, biochar can help build healthy soil, which helps grow healthy plants. In some situations, yields can increase by four or five times due to the addition of biochar. Not all biochar is the same, however, and its use is not a one-size-fits-all approach. This document is aimed at familiarizing gardeners, farmers, foresters, and planet healers with the process of making biochar, preparing it for soil application, and applying it to soil for the best results. Hopefully, it will help you feel confident in making and using biochar!

Why is biochar interesting?

The Brazilian Amazon is not noted for high quality soil. Warm temperatures cause quick decomposition and constant rain leads to heavy leaching, so thick fertile soil does not build up. Isolated hotspots of highly fertile soil have been found throughout the Amazon. These dark patches of high-carbon soil coincides with signs of human settlement, such as pieces of pottery. These *Terra Pretas*, or "dark earths" are the result of centuries of biochar being produced and incorporated with organic matter. While the Amazon is noted for historical uses of biochar, sites around the world – in Germany, Russia, China, Japan, Australia, and more – exhibit highly fertile soil with high amounts of man-made pyrogenic carbon.

https://www.allotment-garden.org/composts-fertilisers/biochar-terra-preta/

Terra Preta shows us two things. First, adding biochar to soil can be highly beneficial to the accumulation of organic matter, to nutrient levels, and to fertility. Second, some of these soils were treated with biochar thousands of years ago and still have lots of biochar remaining, which demonstrates that biochar is highly persistent in soil. It doesn't decompose quickly like other organic forms of carbon, such as wood or leaves. It can last for thousands of years in soil! This makes biochar massively powerful as a means of transforming the health and fertility of soil for generations to come.

Sometimes when we find something new and powerful, we're quick to ascribe it with almost mystical powers. Used correctly, biochar can be immensely powerful in a wide variety of ways. It is not a panacea. No one tactic alone will heal the Earth. A vast array of practices, technologies, and relationships will be necessary to solve the many challenges we face as a people and a planet. Biochar will, however, be instrumental in regenerating healthy soil, which is the foundation for healthy ecosystems and productive agriculture. It will also be a powerful tactic for sequestering carbon, which fights climate change.

Effects of biochar

Effects of biochar on wheat

https://nwcasc.uw.edu/science/project/assessing-the-use-of-biochar-for-drought-resilience-and-crop-productivity/

Biochar has many effects on soil and is often misunderstood. This is partly because biochar can offer so many different things, but also because biochars can vary significantly depending on feedstock, production process, and post-production preparation.

Biochar is not quite a fertilizer. While it can offer significant nutrient value, it generally does not offer the nutrients that something like compost does. Biochar consists of mostly carbon, much of which is highly recalcitrant and won't break down. This means it isn't quite feeding the soil or feeding plants. Instead, it creates a foundation for the regeneration and growth of healthy soil.

Biochar is highly porous. This allows it to hold lots of water – easily up to 6 times its weight! This means it can keep soil from drying out, providing more water to plants with less need to water. Equally important, it provides a good balance between water and air. Biochar facilitates good drainage, which can be especially beneficial to soils with high clay contents. By opening up space, it allows water to infiltrate soil and move through the soil column.

Greater infiltration helps maximize the potential of rain and watering while minimizing runoff and erosion. Healthy soil acts as a sponge, sucking up as much water as possible. Biochar allows this to happen while preventing nutrient and soil loss from erosion. Additionally, biochar helps with stable soil aggregate formation, which further prevents erosion and intakes water.

Soil is alive! The ***soil food web*** is the community of microbes, mycelium, nematodes, earthworms, and more that fulfill the cycle of life. Without these tiny beings, soil would just be dirt – nothing would grow or decompose and all terrestrial life would be in severe trouble. The soil food web breaks down decaying organic matter, creating the potential for new life to sprout. The wide variety of pore sizes in biochar provides shelter and protection for many of these tiny creatures, simultaneously providing them with a good balance of air, water, and nutrition. Treating soil with biochar can stimulate the soil food web, resulting in greater nutrient cycling, better accumulation of organic matter, more plant nutrition, and ultimately the growth of healthy soil.

Cation exchange capacity reflects a soil's ability to hold cations. Cations are positively charged ions. Many important soil nutrients, such as potassium, calcium, ammonium, and magnesium, are cations. Soil particles, such as clay or organic material, are negatively charged and hold cations in the soil. A soil's cation exchange capacity defines how many parking spots it has for these important cations. Sandy soil, which has very little clay particles, has a very low cation exchange capacity, meaning it can hold far less cations than a more balanced soil. It would require more constant addition of compost to maintain fertility and good plant growth. When more cations are present than a soil can hold, they quickly leach away. Biochar has a high cation exchange capacity. When added to soil – especially sandy soil – it helps retain these important nutrients and prevent leaching, making any fertilizing or compost-adding you do go further. As biochar ages in soil, it oxidizes, further increasing its cation exchange capacity and ability to retain nutrients.

pH reflects how acidic or alkaline a soil is. Different plants like different ranges of pH and nutrients are most available to plants in a specific range of pH. Many farmers add lime to their soil each year to keep the pH up. Biochar can affect soil pH in two ways. First, biochar is generally alkaline but can also be acidic. This means it can be used to change the pH of soil, helping shift it into the most productive range for the plants grown in it. It can replace other pH-adjusting soil additives, such as lime or sulfur, which are often produced through extractive industry. Second, biochar helps buffer soil pH, which means it helps prevent the soil's pH from easily changing. This adds resilience to the soil and can lessen the need for lime or other additives.

Biochar also generally has a high ***electrical conductivity***. When added to soil, it helps with ion transfer, which increases nutrient cycling between microbes, mycelium, and plant roots.

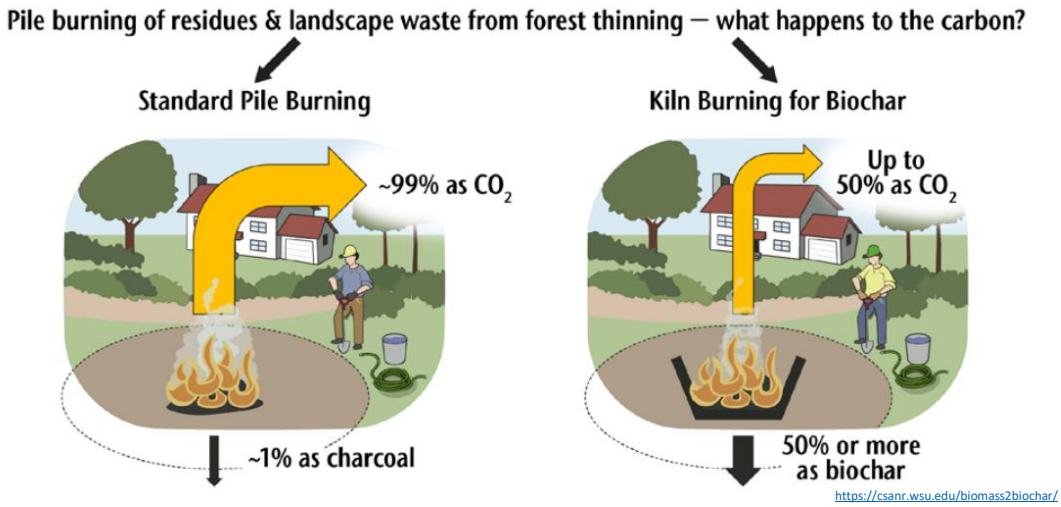
Biochar can also provide important ***nutrients***. Different feedstocks can offer a variety of nutrient levels, but biochar can offer N, P, K, Ca, Mg, and more. While these levels are generally not as high as compost or other organic forms of fertilizer, they can be an added benefit.

So what does this mean for ***crop yields***? In general, even a random application of biochar is likely to increase your yield. With proper biochar production and charging, you are likely to see at least some increase in yield. Sometimes that's only 20-30% and sometimes it's greater than a 400% increase in yield! Your soil conditions are a major factor here – the more degraded and unhealthy your soil is, the greater the increase in yield could be. But even healthy, well managed soil can see greater yields due to biochar!

Making biochar

When considering making biochar, there are a few important considerations:

- *Soil needs:* What is your soil like? Soil testing is either cheap or free depending on the season. You can visit your local Cooperative Extension office to pick up boxes for soil samples. The extension agents can also help you decipher your soil tests. Soil testing will tell you about your soil pH, nutrient levels and deficiencies, cation exchange capacity, and more. This will help you define what deficiencies, if any, you want to address with biochar. Additionally, issues like leaching, poor drainage, and poor water infiltration can be addressed with biochar
- *Quantity:* Are you planning to make a little biochar for use in your garden or a few tons for your farm?
- *Feedstock type and availability:* The type of feedstock you want to use can dictate the method of biochar production that fits you best. What feedstock will make the best biochar for your soil? What feedstock do you have the most access to? What sort of waste feedstocks could you remove from the waste stream?
- *Space, money, and time:* You will need a good amount of open space to make biochar safely. Some methods would work fine in a small backyard, while others are better suited to a larger open area. Making biochar can be very inexpensive, but budget is an important consideration. Time is also important. Do you want to do a few large burns a year or a few small batches a month?



The graphic above gives a good comparison between a biochar burn and a campfire or a burning slash pile. With the slash pile on the left, most of the carbon initially present in the

feedstock is transformed to gaseous form and escapes, leaving very little biochar and lots of ash – and funneling harmful emissions into the atmosphere. Simply surrounding the burning feedstock, such as with the kiln in the image on the right, restricts airflow. This creates the conditions necessary to produce biochar.

When a feedstock is heated, it first dries out completely. Second, *pyrolysis* occurs as organic molecules decompose into smaller gaseous molecules, leaving the solid material. Many of these molecules are flammable and can burn, helping create the heat to continue the process. If the process were allowed to continue without being quenched, the char would burn, but it needs oxygen to do this. During the pyrolysis process, the char doesn't burn because the escaping gases are using most of the oxygen up as they combust. Towards the end of the process, as less and less gas escapes, the char can begin to burn. It is important to stop the process before this happens to maximize the biochar produced and minimize emissions. This is done by cutting off air. Water is generally the easiest method of quenching a biochar reactor. It also washes away ash and opens up pores in the biochar. We'll explore a few other methods, such as using soil and a metal top.

Safety first! When making biochar, it's important to have water close by. Temperatures can get extremely high and material can easily fall out of the reactor. It is a good idea to pour a little water around the reactor to prevent anything from catching fire. Never leave a reactor unattended, as fire can spread very quickly. Fire ecology is important, but making and dispersing biochar replicates much of that process, so you don't need to start any forest fires.

Let's look at a few simple, low-budget biochar reactors.

Open pit

https://ubetbiochar.blogspot.com/2017/06/biochar-for-arborists-and-tree-service.html

The **open pit, kon-tiki kiln,** or **flame-cap kiln** is the simplest biochar reactor. It is basically a slightly tapered fire pit. Feedstock is loaded and lit. As it burns down, it reduces in volume and more feedstock can be added. Because of its size, the open pit can get quite hot and quickly reduce a large brush pile into biochar.

At the end of the process, it must be quenched. Generally, this is done with water. Buckets of water seem slightly more effective than a hose, but either can work.

If water access is limited, a little can be poured on to reduce the heat before a metal plate is added to cover the majority of the top. Around the seams, soil can be packed to fully cover it, preventing any air from getting in. Quenching with water can be done in a few minutes, but covering the fire can take a day or more to put the fire completely out and cool down.

There are many different adaptations of the open pit. The simplest is a hole dug in the ground, which is easily covered with dirt to quench. Pits such as those pictured above can be welded and will last many years. A drain plug in the bottom is very useful in draining water after quenching a burn.

The main advantage of the open pit is its simplicity. It is easy to operate and can take a wide variety of feedstocks. It can reduce large volumes of waste biomass relatively quickly, especially because it can be continuously loaded. It is not the most efficient method of biochar production and a conversion efficiency of around 5-15% should be expected (dry biochar/dry feedstock).

There are a few important considerations when building a fire on the ground. First, fire kills soil life, which will regenerate but is good to avoid if possible. Second, when the soil is dry, fire can travel underground through roots and surface other places. This necessitates care and attention to prevent unwanted fire and ensure water is handy.

TLUD

The **TLUD,** or top-lit updraft gasifier, is another relatively simple reactor. It consists of one and a half 55-gallon steel drums, angle iron, and HVAC ducting. The bottom of the bottom

drum is covered in holes. These can be drilled, cut with a plasma cutter, or made with an angle grinder. The bottom drum is loaded with feedstock and lit on top. As it burns down, it pyrolyzes much of the feedstock similar to the open pit.

The top, which fits into the bottom drum, consists of half of a steel drum with a chimney made of HVAC ducting. The chimney helps create a draft, pulling air through the holes in the bottom of the larger bottom drum. The purpose of the second half-drum is to reduce emissions. Within the reactor, there is not enough oxygen to fully combust all of the gases that are escaping the feedstock. Many of these gases – methane, carbon monoxide, etc. - are far more harmful to the climate than carbon dioxide. The holes in the half-drum allow air to come in and, when mixed with heat and these gases, allow a full combustion. When the TLUD gets going, you'll see thick smoke within the half-drum, but mostly clear smoke coming out of the chimney. These harmful gases are combusted, converting mainly to carbon dioxide and water.

The TLUD is an effective method for converting logs, brush, and wood chips to biochar. It is important that it is packed tightly, but if it is too tightly packed the airflow will be so limited that it cannot burn well. Sometimes mixing feedstock – wood chips and branches, for example – can help attain a good amount of airflow.

Depending on feedstock, the TLUD will run for 30 to 90 minutes. It should be sitting on bricks, allowing airflow in the bottom. When you see that the feedstock in the bottom of the drum is glowing red, generally wait around 5 or 10 minutes and then remove the top drum and quench it. The TLUD can be quenched with about five 5-gallon buckets of water. Buckets work better than a hose at ensuring all pockets of fire are doused.

The TLUD increases efficiency to around 10-30%, which is an improvement over the open pit. It also addresses emissions. It is a little less versatile in feedstock. Grasses do not char well in the TLUD. It is also a batch system, so it isn't as quick to make large amounts of biochar or reduce large amounts of brush.

TLUD with retort

TLUD with top removed to show retort inside

Slits cut in the bottom of the retort allow gas to escape, preventing explosion

A simple modification to the TLUD is to add a **retort**. A retort is basically a closed but vented chamber that feedstock is loaded into. It is heated externally. In this case, the retort is made from a smaller 35-gallon drum, which is closed but has holes drilled on the bottom for gas to escape. This retort fits into the TLUD and is surrounded by firewood. The firewood is lit and burns down, providing the heat to pyrolize the feedstock within the retort.

The main advantage of the retort is that it has a much higher conversion efficiency – generally 30% or greater and often over 50% of the feedstock within the retort being converted to biochar. This would be a reasonable method for a higher value feedstock or one that doesn't burn well, such as bone. It also doesn't require quenching, so if it's in a safe area, it can be lit and left.

It is very important to ensure the retort has holes in the bottom for gas to escape. If the gas has nowhere to go, the retort could burst and create an explosion. The escaping gas is also fed into the fire, which adds to the heat.

Closed kiln

The **closed kiln** also involves a retort, which is placed within a kiln above a fire. The kiln is well sealed and heat builds, pyrolyzing the feedstock within the retort.

Many farms use wood stoves similar to this to heat greenhouses. A fire is built, which heats a heat exchanger and ultimately the greenhouse. This is essentially an adaptation of a wood stove with the added benefit of biochar production.

Because it takes a considerable amount of firewood to fully pyrolize a full 35-gallon drum of feedstock, this is not a very efficient method of biochar production. It also results in high emissions because the kiln is rather oxygen-deprived and full combustion cannot occur. Many greenhouse-heating wood stoves can be fitted with a barrel for biochar production.

Feedstocks

Virtually any dry biomass can be converted into biochar. Some common feedstocks include wood, grasses, agricultural wastes, manure, and bone. Different feedstocks result in different qualities in biochar, so selection of feedstock is important. The effects of feedstock on biochar qualities are explored in greater detail later in the "designer biochar" section.

A good moisture content is around 20% or less. You can estimate this with a wood moisture meter if it's a larger feedstock. If it isn't dry enough, it won't burn hot enough and might not burn at all.

Feedstocks can be dried in a solar dryer, which is essentially a mini greenhouse that traps heat and allows enough ventilation to rid itself of moisture. In summer months, when greenhouses are in less intensive use, they can provide a good place for drying feedstock without worrying about rain.

Wood is the most common feedstock, especially in a heavily forested region, and is easy to make into biochar. Wood chips can often be sourced for free from landfills or from landscapers (Google "chip drop" to find local sources of free wood chips).

Grasses such as miscanthus, arundo donax, or bamboo can be easily charred as well. Miscanthus and arundo donax are often grown as *energy crops* because they quickly produce lots of biomass. They dry quickly and light easily. A little bit of miscanthus is a great firestarter for other feedstocks in the TLUD or open pit.

Agricultural wastes are also a good source of feedstock. Burning them can reduce pest or disease risk while producing value in biochar. Corn stover, rice husks, nut shells, bagasse, and hemp stalks are commonly used for biochar.

Manure and ***bone*** can make more nutrient-dense chars and can often be sourced for low-cost or free.

Miscanthus, a common energy crop and biochar feedstock

When sourcing feedstocks, it is important to consider the source. Plants on the side of roads can accumulate heavy metals from car exhaust. These contaminants remain in the biochar and can pose a risk to your soil and your health, so it is best to avoid roadside trimmings. Treated woods, such as from some pallets or construction waste, are also best to avoid when making biochar. There is an abundance of potential feedstock, so when in doubt,

Crushing biochar

A handful of crushed wood chip biochar

It is important to crush biochar before applying it to soil. This increases the surface area, which helps it adsorb more water and nutrients, and allows for a better mixture of soil, organic matter, and biochar. In general, a texture that's coarser than sand but finer than pea gravel is desired. It can be surprisingly difficult to crush biochar in bulk.

Dry biochar crushes easiest, but this can cause it to make a lot of dust. Be careful of dust! Biochar doesn't decompose, so it'll stick around in your lungs like coal dust, which is not something desirable. Wear a respirator if you're exposed to biochar dust.

Here are some methods for biochar crushing:

- *Crush inside bag with stick, feet, car tyres*
- *Roto-tiller:* with a roto-tiller, you can incorporate biochar into soil while crushing it
- *Dispose-all:* a sink garbage dispose-all can be used for biochar crushing, but this is best done outdoors!
- *Hammer mill*
- *Tumbler*: much like a rock tumbler, biochar can be loaded along with rocks and turned until it is crushed
- *Coffee grinder:* larger, industrial coffee grinders grind biochar to a nice consistency
- *Lawn roller*
- *Leaf vacuum*

Charging biochar

Biochar is like a battery for holding extra nutrients in soil, but it doesn't come fully charged. When applied to soil in its raw form, biochar can adsorb nutrients and keep them from plants in the first season or two after application. While addition of uncharged biochar doesn't always decrease plant growth, biochar is definitely more immediately useful to soil and to plants when it is charged.

Charging biochar packs it with organic material and nutrition, maximizing its potential to benefit plants. To charge biochar, it is mixed with some form of organic material, often compost, manure, compost tea, urine, or anaerobic digester effluent. Residence times and ultimate nutritional value vary depending on which organic amendment is used to charge biochar.

Charging biochar with compost

Compost is one of the most common and most synergistic charging methods for biochar. Generally, biochar is mixed with mature compost anywhere between 20% and 50% by volume and allowed to sit for at least two weeks. (It is far more accurate to measure biochar by volume than mass because biochar mass can vary greatly depending on water content). Similar processes would be used for other solid amendments, such as manure. While biochar is high in carbon, it should not be counted as carbon in the compost pile because it is mostly recalcitrant carbon that will not break down. Calculating ratios of C:N should be done only on the other organic material added.

Biochar and mature compost before mixing

For many of the same reasons biochar is so beneficial in soil, biochar can be greatly beneficial to the composting process. *Co-composting* involves mixing biochar with compost at the beginning of the composting process. This results in much higher composting temperatures, which leads to faster composting. It also helps create higher quality compost. Biochar reduces the emissions of a compost pile by reducing the amount of bacteria that create methane. While co-composting is not the quickest form of charging, it is definitely one of the most synergistic.

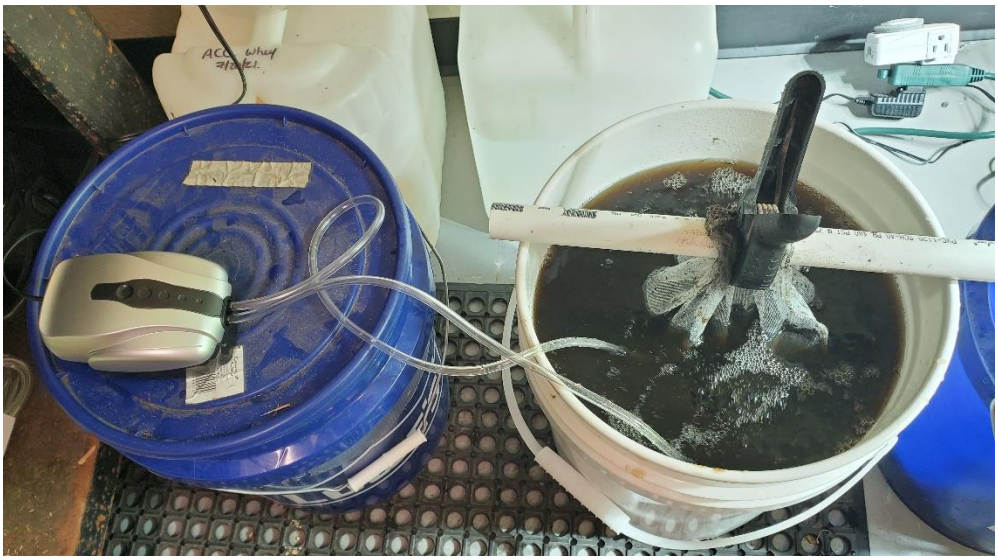
Biochar co-composted in windrows

https://artemisthai.com/organic-farming-in-greenhouses/

Charging biochar with liquid amendments

While they generally don't offer the nutritional density of a solid amendment like compost, liquid amendments can greatly reduce the charge time for biochar. They also benefit greatly from biochar because, without solid matter to anchor them in the soil, they are highly prone to leaching. Let's look at *aerobic compost tea* and *anaerobic digester effluent*, two common liquid amendments that provide effective means of charging biochar. We'll also consider urine, which biochar can help in returning to the soil and closing the loop.

Aerobic compost tea is a powerful soil inoculant and a dilute fertilizer. It brings important microbial life and diversity to the soil, helping build a healthy soil food web. You can download Elaine Ingham's *Compost Tea Brewing Manual* for free here. Charging with biochar only adds a few extra steps to the process. After brewing your compost tea for about 72 hours, when you would normally apply it to your soil, the compost tea bag is removed and biochar is added. The biochar is steeped for two hours with aeration and then both the compost tea and the biochar can be immediately applied to soil. It is important this happens quickly so that the microbial population doesn't begin to die off.



Brewing aerobic compost tea: the aquarium pump on the left provides aeration while compost is suspended in a paint strainer bag in the solution

Anaerobic digester effluent provides another quick means of biochar charging. An anaerobic digester is essentially a big stomach. It is primed with manure and uses similar a similar bacterial community to the stomach of a cow to digest food waste. It produces methane, which can be used to cook, as well as effluent, which is like a liquid form of compost. It is more nutrient dense than compost tea and provides a reasonable alternative to a compost pile. Charging biochar with effluent is simple. The two are mixed and allowed to sit for about 72 hours, after which they can be applied to soil.

Biochar charging in anaerobic digester effluent

Urine is a very nutrient-dense substance. There is certainly uneasiness in many people about returning it to the garden, but it is an important consideration in closing the loop and attaining sustainable nutrient cycling. Urine contains lots of nitrogen, phosphorus, and potassium (N, P, and K), which are three of the most important nutrients for plants. Rather than losing these valuable nutrients, they can be reclaimed and pumped back into the soil. Charging biochar with urine can be as simple as peeing in a bucket of biochar and adding it to your soil. Alternatively, you could add it to your compost pile as a high nitrogen ingredient. Biochar will cut down significantly on odor, which also makes it an appealing addition to a composting toilet.

Applying biochar to soil

When biochar is crushed and fully charged, it's ready to go into the soil! Biochar application rates can vary significantly depending on availability, budget, and soil needs. Rates between 1 and 50+ metric tons/hectare (0.5-22 tons/acre) are common. A general goal of 10-20 metric tons/hectare (5-9 tons/acre) is a good goal, although this depends on soil needs and results. The table below shows common application rates.

It is best to start small and gauge effects. Test your soil and pay attention to cation exchange capacity, pH, and how nutrient levels are changing. Observe the way water flows and how it interacts with the soil. If you've had issues with erosion, lack of infiltration, or poor drainage, look at how these things change. While it is unlikely that a well-informed application of biochar will be detrimental to soil, subsequent applications could be adjusted to maximize

effectiveness. We'll look at some of these tactics later in the "designer biochar" section. Biochar also oxidizes as it ages, increasing in its ability to retain nutrients. This means that, over time, its impact in soil grows.

A power harrow incorporates biochar into soil

When a forest fire occurs, biochar is created and falls only on the surface of soil. Over time, animal footsteps, worms, accumulating organic matter, and water flow help incorporate it into the soil column. To maximize immediate effectiveness, it's best to incorporate biochar in soil. This also prevents it from being carried away by the wind. No-till methods for incorporating biochar into soil include a broadfork or power harrow. Biochar is generally mixed into the top 4-6" of soil.

Biochar can also be applied just around a plant's roots for more efficient use. When transplanting a start into soil, place charged biochar along with compost or soil around the roots of the plant.

Application rate	Metric tons/hectare	Tons/acre	5 gallon buckets/ 100 sq. ft.	Compost
Light	1 - 5	0.5 - 2.5	1/4 – 1 1/3	1.5-2.5 5 gal buckets
Average	10 - 20	4.5 - 10	2.5 - 5.5	10-15 5 gal buckets
Heavy	30 - 50	14 - 23	8 – 13.5	½ - 1 cu. yd.

Designer biochar

Biochars produced with different feedstocks, pyrolization techniques, and post-production preparation can be very different and can offer different benefits to soil. It is important to know about these differences in order to avoid unwanted soil changes and to maximize soil's potential. Designer biochar is biochar that is specifically tailored to a specific

soil's needs and deficiencies. While much research on biochar has been performed, this is one of the frontiers and there is still a lot to learn about how different biochar affects different soil conditions. You can help the biochar community by learning about different biochar characteristics, amending soil with designer biochar, and recording data and observations.

We'll look at two main factors – feedstock and temperature – and how they affect biochar characteristics and quality.

Feedstock

Wood biochar is a good general purpose biochar, which is convenient because of how plentiful wood waste is. It generally has a fairly neutral pH of around 7.5-8, a high cation exchange capacity, high porosity, and high density. It doesn't offer a lot of fertilizing value, but does offer a good balance of nutrients.

Grass biochar is not a general purpose biochar. It is more alkaline than wood biochar with a pH generally around 8.5-9.5, making it a good choice for soil that needs liming due to low pH. It is one of the most porous biochars, making it very important to charge well. This helps it hold on to water and nutrients very effectively. It has a low density, a high electrical conductivity, and a high cation exchange capacity.

Manure biochar is also a more targeted biochar. With a pH in the range of 8.5-10, it can also be used to increase soil pH. It has high levels of N, P, K, S, and Ca, making it more valuable as a fertilizer than other biochars. It has a lower cation exchange capacity and lower porosity than other biochars, making it less useful for adsorbing and holding nutrients in the soil

Temperature

High temperature biochar generally has a higher pH, higher electrical conductivity, higher porosity, and higher nutrient values. For soils that suffer from poor water retention, such as sandy soils, high temperature biochar can offer the greatest porosity and greatest water holding capacity.

Low temperature biochar generally has a higher cation exchange capacity and a lower pH, which can often even be acidic.

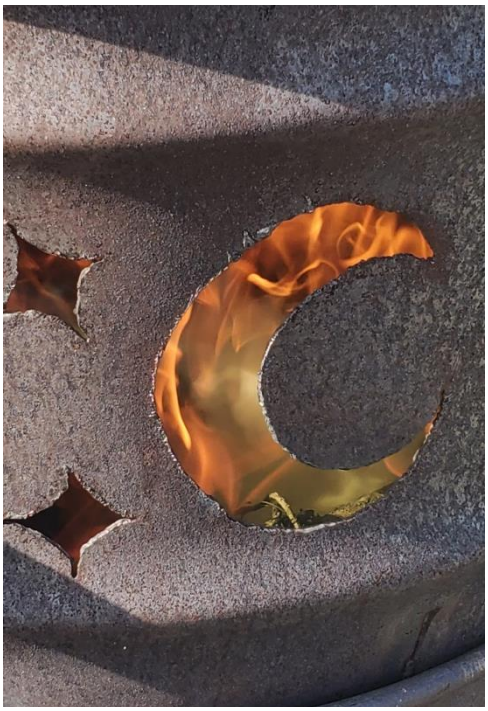
Other factors

There are many other tactics for tailoring biochar to soil needs. Quenching a burn late can result in high ash content, which can be useful in soil that needs liming (alternatively, a high pH biochar such as from grass or manure could be used). For soils that struggle with water infiltration and drainage, such as soils with high clay contents, biochar that is crushed more coarsely can help open up space for air and water in the soil, increasing infiltration and reducing heavy water flow and erosion.

Emissions

Emissions can vary greatly when producing biochar. The same feedstock can produce far more harmful emissions depending on the way the burn progresses. Full combustion produces mainly carbon dioxide and water. While this is not a positive addition to the atmosphere, it is far less harmful than the products of partial combustion, which produces larger hydrocarbons, such as methane, along with other harmful pollutants. Not only do these pollutants create a higher global warming risk, but they also are more harmful to human health.

To achieve full combustion, high heat and plenty oxygen is needed. Contrary to what you might think, a large fire burning dry feedstock produces limited emissions because the area above the feedstock has a high amount of heat and plenty of oxygen for full combustion. In the TLUD, air is pulled into the top drum, mixing with high heat to fully burn any harmful gases.



Yellow smoke within the TLUD indicates methane and other harmful gases

When making biochar, a dry feedstock is crucial. Without sufficient dryness, the temperature of the burn won't get hot enough to fully combust many of these harmful gases and could also affect the quality of the char. A good fire on a dry feedstock creates a large flame, lots of heat, and mostly clear smoke. White smoke is an indicator of moisture in the feedstock. Blue smoke is an indicator of volatile gases, while yellow smoke indicates methane and other harmful gases. In the photo on the left, you can see yellow smoke within the top drum of the TLUD. These holes suck in air, fully burning these harmful gases and resulting in clear smoke coming from the chimney.

Apart from building high heat on a dry feedstock, quenching the biochar quickly when finished is important. A fire's greatest emissions are when it is building heat and going out, so it's important to build heat quickly and quickly quench it to limit this.

Other uses of biochar

Biochar has countless uses apart from soil amending. It would be impossible to list them all, so here are a few common uses that can increase its value and potentially be used prior to incorporation in soil.

- *Seed starting mix:* rather than using vermiculite, adding biochar to a seed start mix can help hold on to water and get seedlings off to a good start
- *Poultry bedding:* biochar can provide a great bedding for poultry, cutting down on odor and adsorbing nutrients from chicken manure for later application to soil. It can improve health conditions in a chicken coop for the chickens by reducing ammonia in the air as well.
- *Feed additive for cows and pigs:* Biochar can be added as a free choice additive to food for cows and pigs. It improves digestive functioning and charges while being digested.
- *Odor reduction:* Because of its high adsorptivity, biochar can be a great odor reducer. This could be useful for composting toilets, compost piles, or reducing animal odors. Oftentimes it can be charged while being used as an odor reducer.
- *Dessicant/humidity regulation:* Biochar can adsorb lots of moisture, making it a useful dessicant, and one that's more renewable than silica gel. In addition to adsorbing moisture, it can filter toxins from the air, resulting in higher air quality. Biochar has been mixed with earthen plasters to help regulate indoor humidity and offer dark pigmentation.
- *Water filtration:* Biochar can filter sediment and toxins such as heavy metals from water. Activated carbon, which is commonly used for water filtration, is essentially just highly oxidized biochar. You can learn about using biochar for water treatment here.

Biochar added to cattle feed

https://static.wixstatic.com/media/cc21d6_552e7217fac5401993f92b2a67a6e386~mv2_d_2238_1258_s_2.jpg/v1/fill/w_1000,h_562,al_c,q_90,usm_0.66_1.00_0.01/cc21d6_552e7217fac5401993f92b2a67a6e386~mv2_d_2238_1258_s_2.jpg

Biochar and planet healing

https://www.amazon.com/Biochar-Application-Essential-Microbial-Ecology/dp/0128034335

More than ever before, our generations are called to be planet healers. Rampant topsoil loss threatens agricultural production and the health and resilience of many terrestrial ecosystems. Forest, agricultural, and urban ecosystems are in peril, including the ecosystems within the soil. Climate change threatens every ecosystem and community on Earth. There is certainly hope, and ecosystem restoration, regenerative agriculture, and climate mitigation and major sources of hope for a brighter future. These are fields that our generations are called towards. We can rebuild a resilient and sustainable food system, provide for biodiversity to flourish, and redefine our connections with the Earth and with our own communities.

There are countless tactics to achieving success in these endeavors and no one thing will lead to success. Biochar does provide a powerful method of rebuilding healthy soil, which can prevent aridification and increase plant growth. Healthy soil is the foundation of a healthy ecosystem and a healthy farm. Biochar is also a great carbon sequestration tactic, storing carbon in the ground for millennia to come. Apart from the carbon sequestered within biochar, the addition of biochar to soil can help build more soil carbon in the form of the soil food web and, in turn, in the form of bigger and more healthy plants. And it all starts with redirecting waste material!

Questions?

If you have any questions about biochar or are interested in buying a biochar reactor or hosting a workshop, please contact me! I'd love to help you start making and using biochar.

Alex Gray

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Resources

Biochar basics

Terra Preta

Composting with biochar

Living Web Farms blog

Ways of making terra preta

Choosing a biochar reactor

Properties of fresh and aged biochar

55 uses of biochar

Biochar and water treatment

International Biochar Initiative

US Biochar Initiative

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