Factsheets to Support Land, Water and Resource Management in Tŝilhqot'in Territory

Biochar as a Soil Amendment for Agricultural and Forestry Productivity

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UBC sustainability

Acknowledgements

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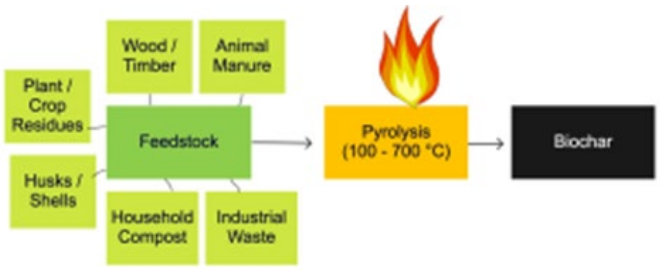
Overview

Biochar is a carbon rich charcoal product that is created through the burning of organic materials. The unique set of **physical** and **chemical** characteristics associated with biochar can make it a useful tool to alter soil **properties**.



HISTORY OF BIOCHAR

Biochar was created and utilized by communities in the Amazon basin more than 2,500 years ago. Burnt residues (wood, crop, and bones) from kitchen sites were incorporated into soils. These residues are still present in the fertile "**Terra Preta**" (dark earth) soils of the Amazon today.

HOW IS BIOCHAR MADE?

Biochar is usually produced through a process called **pyrolysis.** This process involves the burning of **organic matter** in a low oxygen or no oxygen environment. Pyrolysis temperature can range anywhere between 100-1000 °C and the temperature used will affect both the chemical and physical characteristics of the resulting biochar.

WHAT CAN BIOCHAR BE MADE FROM?

The organic matter used to produce biochar can come from a wide variety of sources with the most common sources of **feedstock** being: wood, plant/ crop residues, animal manure, household compost, industrial waste (e.g. paper mill by-products), husks and shells (e.g. corn husk, hazelnut shells).

WHAT ARE THE PROPERTIES OF BIOCHAR?

High **Cation Exchange Capacity** Can aid in soil nutrient and water retention.	High **Porosity +Surface Area** Can allow for improved aeration and aid in nutrient and water retention.	High **pH** Can alter the pH in acidic (low pH) soils.	Dominated by highly **Stable Carbon** Stable carbon is extremely slow to break down and can persist in soil for more than 1000 years.

WHAT CAN BIOCHAR BE USED FOR?

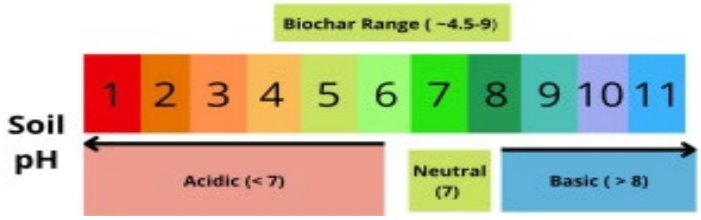
Improving Agricultural + Forest Soils Can help improve soils that struggle with water and/or nutrient retention, are compacted, or are acidic.	**Remediating Contaminated Water + Soils** Can absorb toxins such as heavy metals or organic pollinations.	**Manure Management + Animal Agriculture** Can reduce the loss of greenhouse gasses during manure storage. Can be utilized as animal bedding, decreasing the loss of nutrients from animal manure.	**Carbon Sequestration** Once the feedstock undergoes pyrolysis, the resulting biochar will be much slower to break down and will reduce the amount of CO^2 (a greenhouse gas) being release into the atmosphere.

References: **(1)** Hossain, M. Z., Bahar, M. M., Sarkar, B., Donne, S. W., Ok, Y. S., Palansooriya, K. N., ... & Bolan, N. (2020). Biochar and its importance on nutrient dynamics in soil and plant. Biochar, 2(4), 379-420. **(2)** International Biochar Initiative. (n.d.). Biochar Production and by-Products. Retrieved from https://biochar-international/the-biochar-opportunity/biochar-production-and-by-products **(3)** Ippolito JA, Spokas KA, Novak JM, Lentz RD, Cantrell KB. (2015). Biochar elemental composition and factors influencing nutrient retention. In: Lehmann J, Joseph S (eds) Biochar for environmental management: science, technology and implementation, 2nd ed. Routledge, New York, pp 137–161 **(4)** Joseph, S., Taylor, P., Rezende F., Draper, K., Cowie, A., (n.d.) The Properties of Fresh and Aged Biochar. Biochar International.

Biochar

Properties + Soil Interactions

Depending on the **feedstock** and **production method**, the properties of biochar will vary. However, there are some common characteristics among most biochars, and they effect soil in a similar way.



BIOCHAR PROPERTIES	SOIL PROPERTIES	BIOCHAR EFFECT ON SOIL PROPERTIES
STABLE FORM OF CARBON	• The soil is an important **carbon sink**. When carbon is stored in or remains in soil, there is a direct reduction in the amount of CO2 (a greenhouse gas) being release into the atmosphere. • Carbon serves as a food source for soil microbes, high additions of which can stimulate **microbial activity**.	• Biochar is a very stable form of carbon, and can persist in soil for millennia, making it a meaningful way to **sequester carbon**. • Biochar additions to soil can stimulate microbial activity, causing an increased decomposition of **soil organic matter** and a flush of nutrients.
HIGH CATION EXCHANGE CAPACITY (CEC)	• The CEC describes how strongly **cations** (positively charged atoms and molecules) will be held and exchanged in the soil. Many nutrients essential for plant growth (ammonium, calcium, magnesium, and potassium) are cations. The higher the CEC, the greater ability to retain and exchange nutrients.	• The **negative charge** on the surface of biochar particles will hold onto positively charged atoms or molecules (cations). • Biochar additions to soil will raise the CEC of the soil, holding onto nutrients, and reducing the amount of nutrients lost through **leaching**.
HIGH PH	• The pH of soil has a direct effect on **nutrient** availability. The ideal soil pH for plant growth is ~7, and soils are considered acidic when they are below 7. Acid soils will cause nutrients important for plant growth to become unavailable for plant uptake.	• The pH of most (but not all) biochar is above 7 and will have a **liming effect** on acidic soils. This means that biochar can also raise the pH of soils that fall below 7. As temperature of biochar increases, pH of biochar also generally increases.
HIGH POROSITY	• The porosity of soil is the amount of space between and within soil particles. When soils are **compacted** (high bulk density) they have decreased porosity.	•Biochar is highly porous and can increase the porosity of soil, decreasing **bulk density** • This provides more **pore space** for oxygen infiltration into soil, greater retention of water and nutrients, and habitat for soil microbes

References: **(1)** Hossain, M. Z., Bahar, M. M., Sarkar, B., Donne, S. W., Ok, Y. S., Palansooriya, K. N., ... & Bolan, N. (2020). Biochar and its importance on nutrient dynamics in soil and plant. Biochar, 2(4), 379-420. **(2)** International Biochar Initiative. (n.d.). Biochar Production and by-Products. Retrieved from https://biochar-international/the-biochar-opportunity/biochar-production-and-by-products **(3)** Ippolito JA, Spokas KA, Novak JM, Lentz RD, Cantrell KB. (2015). Biochar elemental composition and factors influencing nutrient retention. In: Lehmann J, Joseph S (eds) Biochar for environmental management: science, technology and implementation, 2nd ed. Routledge, New York, pp 137–161 **(4)** Joseph, S., Taylor, P., Rezende F., Draper, K., Cowie, A., (n.d.) The Properties of Fresh and Aged Biochar. Biochar International.

Biochar

Production

Biochar's properties will be directly influenced by both feedstock selection and method of production. Biochar can be produced at small scale for home use utilizing garden/forest debris and simple methods of production, or at large scale using forestry/industry waste and more effective methods of production.

WHAT CAN BIOCHAR BE USED FOR?

- Liming - Raising pH of acidic soil
- Increasing Soil + Compost Aeration
- Increasing Nutrient Retention
- Increasing Water Retention or Infiltration
- Carbon Sequestration

Biochar is most effective in **acidic** (pH < 7), coarse textured (**sandy**) soils, or soils with low levels of **organic**

FEEDSTOCK SOURCES

INFLUENCE

Biochar can be made from a wide variety of organic matter referred to as "feedstock". The selected feedstock will have a distinct impact on the properties of the resulting biochar. **Woody feedstock** will generally have a greater impact on soil physical properties (eg: porosity) and sequester more carbon. **Manure** and **crop residues** will generally have a greater impact on soil chemical properties (cation exchange capacity, pH, and nutrient additions).

SOURCES

Sources can be broadly grouped into six categories:

- **Wood**: logging residues, slash piles, pine beetle or wildfire effected trees, pruning waste, sawdust
- **Plant residues**: crop residues, pruning of annual plants, grass clippings, straw, seaweed
- **Manure and sludges**: cow manure, chicken manure
- **Municipal solid waste**: household compost
- **Industrial waste**: papermill residues

METHODS OF PRODUCTION

INFLUENCE

Just as with feedstock, there is a variety of methods that can be used for biochar production. Each method and the corresponding length and temperature of production will have an impact on biochar properties. Biochar produced at **higher temperatures** will generally have higher porosity, higher stable carbon, higher pH, and lower yield than those produced at **lower temperatures**.

METHODS

There are four main methods for biochar production:

- **Pyrolysis**: usually involves the direct burning of feedstock at temperatures between ~300-~1000 + °C
- **Torrefaction**: a mild form of pyrolysis that involves burning of feedstock between ~200- ~350 °C
- **Gasification**: an indirect form of biochar production where it is a byproduct of syngas production
- **Hydrothermal carbonization**: Specifically involves the heating of wet feedstock (e.g. fresh

SMALL SCALE PRODUCTION

BURN PILES

The simplest method of producing biochar is to dig a **trench** or **hole** and fill with dry feedstock. Once this is ignited, covering the feedstock with wet plant matter or soil to restrict the flow of oxygen. This method requires low financial investment but will produce a **lower relative yield**.

BURN BINS + KILNS

Containers such as burn bins and kilns can **increase efficiency**, create a more controlled environment and "burn cleaner". Simple burn bins can be created from bricks or repurposed metal drums. Open-source plans can be found online for the Ring-of-Fire or Kon-Tiki kiln.

References: **(1)** Hossain, M. Z., Bahar, M. M., Sarkar, B., Donne, S. W., Ok, Y. S., Palansooriya, K. N., ... & Bolan, N. (2020). Biochar and its importance on nutrient dynamics in soil and plant. Biochar, 2(4), 379-420. **(2)** Jeguirim, M., & Khiari, B. (2022). Thermochemical conversion of tomato wastes. In Tomato Processing by-Products (pp. 285-332). Academic Press **(3)** Joseph, S., Taylor, P., Rezende F., Draper, K., Cowie, A., (n.d.) The Properties of Fresh and Aged Biochar. **(4)** Sivaprasad,S., Manandhar, A., Shah, A. (2021). Hydrothermal Carbonization: Upgrading Waste Biomass to Char. Ohio State University Extension. **(5)** Yaashikaa, P. R., Kumar, P. S., Varjani, S., & Saravanan, A. (2020). A critical review on the biochar production techniques, characterization, stability and applications for circular bioeconomy. Biotechnology Reports, 28, e00570.

Biochar

Activation, Application, and Concerns

Due to the wide variety of uses for biochar, activation and application methods will vary depending on available nutrient sources, and the sites selected for application. With all biochar application there can be both human health and ecological concerns that can be identified and mitigated.

ACTIVATING BIOCHAR

PURPOSE

Biochar can act as a "sponge" with minerals and nutrients. If applied to soil "unactivated", plant available nutrients can sometimes become temporarily unavailable. However, as the biochar ages in soil the effect decrease. In order for biochar to be effective more quickly, biochar can be loaded or "activated" with nutrients prior to application.

NUTRIENT SOURCES

Creating contact between biochar and a nutrient rich source with moisture content can "load" biochar with nutrients prior to application.

- **Compost**: mix biochar into compost piles; the compost will also benefit through increased aeration and decomposition
- **Animal manure**: mix biochar directly into manure piles or use as animal bedding or in animal runs
- **Yard trimmings**: mix biochar with fresh plant matter, such as grass clippings; contact must be maintained between the biochar and the plant matter.

APPLICATION METHODS

In order to be effective and minimize wind losses, biochar should be integrated into the top 10-20 cm of the soil. When applied to **agricultural land**, depending on scale, incorporation can be done through shovelling, hand raking, tillage, or banding. Application to **forestry sites** is more complicated due to roots, rocks, and existing stands of trees. Incorporation in forestry sites can be done during site remediation, directly into planting holes when tree planting, or occasionally biochar is left on soil surface and is very slowly integrated into soil during rain or snowfall.

APPLICATION RATES

Application rates vary (anywhere between ~1-100 t/ha) and should reflect how much feedstock is available. Greater application rates do not always reflect greater benefits. An application rate of 10 tons/hectare is considered "standard".

Standard average application rate of 10 tons/hectare = 1 kilogram/square metre

CONCERNS + MITIGATION

INHALATION OF BIOCHAR DUST

Due to abundant small sized particulate matter, respirator and eye protection must be worn during application.

HYDROPHOBICITY

Biochar may initially be water repellent and may create this condition in soil. Aging or activating biochar can decrease hydrophobicity.

RETENTION OF CONTAMINANTS

Biochar's ability to absorb contaminants can decrease their bioavailability, but can also decrease their movement through soil and increase their concentration.

POLYAROMATIC HYDROCARBONS

These carcinogens are formed during biochar production. However, exposure is generally low if application is below 20 ton/ hectare.

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