Biochar's Dual Benefits for Agriculture and the Environment

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ABSTRACT

The carbon-rich substance known as biochar, which is created when organic matter is pyrolyzed, has advantages for both the environment and agriculture. By promoting beneficial microbial activity, raising soil pH, and enhancing nutrient retention, biochar improves soil fertility in agricultural applications. Increased agricultural yields and a decreased reliance on chemical fertilizers result from this. In terms of the environment, biochar functions as a carbon sink, absorbing CO_2 from the atmosphere and slowing down global warming. Its porous nature also helps retain water and lowers soil greenhouse gas emissions. Because of these complementary advantages, biochar can be used as a sustainable strategy to improve environmental health and agricultural output.

INTRODUCTION:

Black carbon produced by slowly pyrolyzing biomass in an oxygen-free or stressed atmosphere to prevent it from totally burning is referred to as "biochar." One excellent example of biochar made from woody biomass is charcoal. It is suggested that applying biochar to soil as an amendment will both improve soil production and mitigate the effects of climate change. These partly burned goods could serve as a significant long-term carbon sink. According to Glaser *et al.,* (2002), biochar has significant quantities of recalcitrant carbon, which allows it to sequester carbon for a long time. High levels of organic carbon in the form of char have been linked to the high fertility associated with

anthropogenic soils, or terra preta (Glaser *et al.,* 2001).



Agricultural biochar has long been used. For a long time, farmers have been utilizing it without realizing it to increase the yield of their crops. Slash and burn agriculture is one example of this, as it is still used in some areas of northeastern India. Biochar can be utilized to sequester carbon on centurial or even millennial time scales. When a plant's life cycle is complete, it breaks down quickly and releases carbon dioxide into the atmosphere, known as the natural carbon cycle. The natural cycle as a whole is carbon neutral. In contrast, if we produce biochar from the same biomass, at least 50% of the total carbon is permanently captured. After decomposition, 85–95% of plant biomass carbon returned to the atmosphere (Jha *et al.,* 2010).

As a result, biochar produces a carbon-negative process by removing circulating carbon dioxide from the atmosphere and storing it in essentially permanent soil carbon pools.
According to different estimates, 72–127 Mt of crop wastes are burned on Indian farms (Pathak *et al*., 2010).

Crop waste burning in open fields is thought to be an ancient method of increasing soil fertility in terms of P and K, although it frequently results in the loss of other nutrients (such as N and S), organic matter, and microbial activity needed to sustain greater soil fertility.

Burning these crop leftovers also releases black carbon, a tiny particulate substance that is created when combustion is incomplete. Air currents then move these particles from rural fields to surrounding urban areas.Thus, one practical way to increase soil's natural rates of carbon sequestration, decrease agricultural waste, and improve soil quality is to convert organic waste into biochar through the pyrolysis process (Srinivasarao *et al.,* 2013).

Feedstock selection in biochar production

The majority of biological sources are easily utilized to produce biochar; nevertheless, there are some restrictions on the kind of feedstock that can be utilized. According to Brinton (2000), pollutants should not make up more than 2% of the dry weight of the biochar that is generated. Biochar can be made from FYM, various manures, and municipal solid waste as long as there are no hazardous materials present. The manufacturer has to ensure that the raw materials used to make biochar are free of dangerous substances. In addition to other biological sources, 234.5 million tonnes of excess crop residues are available in India, where they are either burned or even fed to power plants (Moonmoon Hiloidhari *et al.,* 2014).

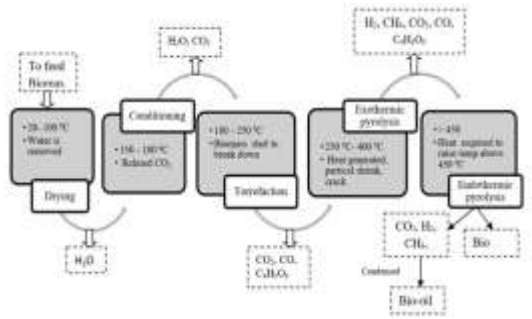
Biochar Types	Temperature	Country/Type of Experiment	Application Rate
Wheat Straw	300–500 °C	China/Greenhouse	3% w/w
Wheat Straw	300, 400 and 500 °C	China/Greenhouse	1% w/w
Rice Straw and Corn Stalk	450 °C	China/Field	1, 2 and 4 ton/ha
Miscanthus Giganteous Straw	500–750 °C	Norway/Field	8 and 25 ton/ha
Cow Manure	600 °C	Japan/Greenhouse	0, 10, 15 and 20 ton/ha
Rice Husks	450 °C	China/Greenhouse	0, 10, 25 and 50 tha^{-1}
Maize Stover	600 °C	USA/Field	0, 1, 3, 12 and 30 tha^{-1}
Woodchips	250 °C	Taiwan/Greenhouse	2% w/w
Woodchips	700 °C	USA/Field	5% w/w

(Ayaz *et al.*, 2021)

Biochar production process

To produce biochar from agricultural leftovers, biomass must first be fed into the combustion chamber without air. **Drying, conditioning, torrefaction, exothermic pyrolysis, and**

endothermic pyrolysis at various temperatures are the five basic steps in the production process. Carbon dioxide was released during the biomass conditioning process when the temperature reached 150–180 °C.At 180–250 °C, during the torrefaction phase, the breakdown of biomass begins, releasing carbon dioxide and carbon monoxide. An exothermic reaction generates a lot of heat as it starts, between 250 and 400 °C. As the temperature reaches 400 °C, the main products are condensable vapors such as tar, water, acetic acid, methanol, and so forth.It is possible to convert biomass to biochar at temperatures higher than 450 °C. This may be prevented from happening again by raising the temperature to 500 °C, which will finish the carbonization process (Panwar *et al.,* 2019).



Biochar: A catalyst for soil regeneration and improved crop performance

- It has been demonstrated that adding biochar to soil can reduce nutrient leaching, boost yield, and enhance nutrient usage efficiency (Kalus *et al.,* 2019).
- Over time, biochar effectively stores enormous amounts of carbon in the soil, boosting crop yield and soil fertility while reducing global warming (Singh *et al.,* 2018).
- It increased stomatal conductance, moisture retention, pore ratio, decreased bulk density, and fertility. Additionally, biochar makes the soil more capable of retaining water.
- Biochar on paddy fields reduced CH_4 generation and demonstrated increased CH_4 consumption. Biochar significantly decreased yield-scaled greenhouse gas intensity by 29% (Spokas, 2010).
- Biochar's high magnesium and calcium concentration causes it to lower exchangeable acidity and raise soil pH.
- Soil quality is mostly dependent on cation exchange capacity (CEC), which is increased by adding biochar to the soil. A soil's capacity to fix nitrogen is indicated by its CEC, and this is important for plant growth (He *et al.,* 2021)
- The effects of biochar on soil bacteria that promote growth have been confirmed. It was investigated that by adding biochar at a rate of 5 t/ha between 10–20 cm of soil depth enhanced microbial biomass. According to studies on the effects of adding 1 and 2 percent biochar to wheat and miscanthus straw on soil enzymatic activity and microbe count, 1% biochar raised the number of fungus and bacteria by 26% and 380%, respectively (James Wong *et al.,* 2019).

Biochar Feedstock	Impact on soil properties
Bamboo	Soil moisture and microbial population mass were increased.
Wood	Increasing soil organic carbon content and soil pH.
Hardwood	Increasing available potassium and soil organic carbon content by 300% and 37%, respectively.
Maize straw	Increasing fungi/bacteria ratios and soil organic carbon. Decreasing bulk density and enhancing plant available water and soil aggregate stability.
Rice straw	Increasing soil pH.
Rice husk	Enhanced macro and micro aggregates.
Woody biomass	Biochar increased soil cation exchange capacity.

Biochar Feedstock	Crop	Impact on Crop productivity
Hardwood 500°C	Cocoyam	Increase yield 8.1, 7.8, and 5.5 %, respectively
Willow wood pyrolysis, 6000°C	Papaya Banana	Reduced banana yield by 18-24% and neutral for papaya
Rice straw BC (RBC) 550°C	Rice	Grain yield increases by 8.5 to 10.7%
Acacia biochar 400–500°C	Maize	Increased yields in 1st year by 20% and after 2nd year by 12.5%.
Rice Straw and Corn Stalk	Corn, peanut and sweet potato	Use 1 to 2 t/ha of biochar to increase yield by 5–15%. 20% yield increased with 4 t/ha.
Rice Husks 450°C	Rice and wheat	Biomass yield by 233-322%

(Jagnade*et al.,* 2023)

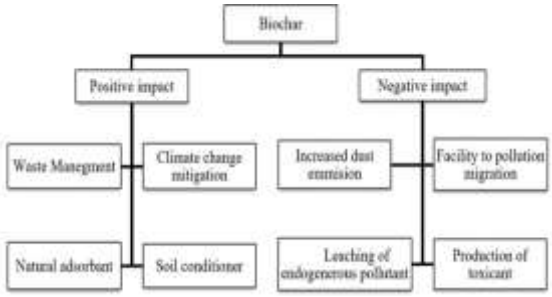


Without Biochar **With Biochar**



Biochar's impact on the environment

The impact of biochar on the environment includes eliminating harmful pollutants from agricultural lands, soil remediation, natural adsorbent, material waste management, and climate change mitigation.A case study proved that 920 kg of CO2e (CO2-equivalent) is sequestered by biochar soil storage and biofuel use by converting 1 tonne of crop residues into biochar. Biochar decreases annual national carbon emissions by about 4.5 percent **(Sigmund *et al.*, 2017).** Applying biochar with a high water content and avoiding windy days are two ways to limit dust emission which is harmful to human health.



CONCLUSION

Biochar maintains sustainability in soil health to improve agriculture output and also improve environmental resilience. As a soil amendment, it improves soil structure and nutrient retention, enhancing crop productivity and resilience to drought. Simultaneously, biochar sequesters carbon in soils, mitigating greenhouse gas emissions and aiding in climate change adaptation. Because it lessens the bioavailability of pollutants, its application also shows promise in soil cleanup operations. However, effective use of biochar requires careful consideration of feedstock sources, production methods, and specific soil conditions to maximize its benefits while minimizing potential drawbacks. Ongoing research is essential to optimize biochar's contributions to sustainable agriculture and environmental health.

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