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An overview of biochar application for CO_2 sequestration

Among various CO_2 sorptive materials, biochar has gained considerable attention. Biochar is generated from the thermolysis of biomass. By converting biomass into biochar, a long-term sink of atmospheric CO_2 could be realized and contribute to carbon neutral energy production. The process releases energy and converts a portion of an easily degradable carbon (biomass) into a form that is more stable and resistant to biodegradation. Biochar is possibly lasted for several millennia, which offers a strategic way for CO_2 capture and sequestration.

Biochar, with its strong affinity for nonpolar substances and high surface area, can be a potential material to capture and store CO_2 by adsorption in its pores. Biochar can also act as a soil conditioner enhancing plant growth by supplying and, more importantly, retaining nutrients and by providing other services such as improving soil physical and biological properties.

Biochar productions

Slow pyrolysis of biomass primarily produces solid biochar. Pyrolysis is a thermochemical process where biomass is heated in the absence of oxygen (or partially combusted in the presence of a limited oxygen supply). Heating temperature, heating rate and holding time for slow pyrolysis, are 300–800 °C, 5–7 °C min−1, and > 1 h, respectively. In general, pyrolysis of biomass at temperatures ≥ 450 °C in the oxygen-free conditions (N2 or Ar) results in carbon-rich and porous biochar due to the thermally induced vaporization of volatile matters in the biomass. Compared to conventional combustion, under the current practice of complete burning, more than 90% of the C in an organic material is oxidized to form CO_2, whereas under the various systems of biochar production only 45–48% of the organic C is oxidized to CO_2.

The application of biochar in soil and CO_2 sequestration

Land application of biochar is not a new concept. Certain dark earths in the Amazon Basin (so-called Amazonian Dark Earths or “terra preta”) have received large amounts of charred materials, the residues from biomass burning. These applications were most likely a result of both habitation activities and deliberate soil application by Amerindian populations before the arrival of Europeans. Large amounts of biochar derived C stocks remain in these soils today, hundreds and thousands of years after they were abandoned.

The application of biochar to soil is proposed as a novel approach to establish a significant, long-term, sink for atmospheric carbon dioxide in terrestrial ecosystems. Apart from positive effects in both reducing emissions and increasing the sequestration of greenhouse gases, the production of biochar and its application to soil will deliver immediate benefits through improved soil fertility and increased crop production.

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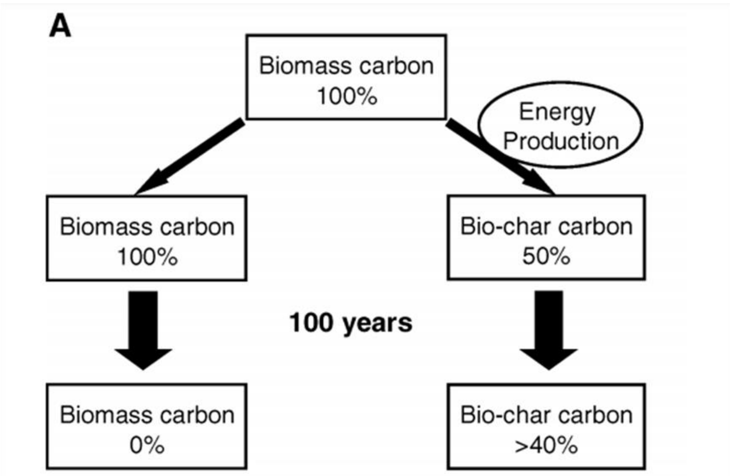
The biochar application leads to considerably greater amounts of C remaining in soil than application of un-charred organic matter. In conventional pyrolysis processes, the conversion of biomass C to biochar C often leads to sequestration of 50% of the initial C depending on the process condition. compared to the low amounts retained after burning (3%) and biological decomposition (<10–20% after 5–10 years), therefore yielding more stable soil C than burning or direct land application of biomass (**Fig. 1A**). The Easychar technology has been able to increase the sequestrated C in biochar achieving up to 74% C in biochar produced from spent grain from distilling **(Fig .1B)**.

For terrestrial ecosystems, C sequestration can be increased by increasing soil C stocks. But soil represents a finite C sink at best, and this may have a low permanency and can be easily depleted upon land use change. The new approach (EASYCHAR approach) to C sequestration in terrestrial ecosystems is through the application biochar to soil, which offers both a large and long-term C sink.



B

Sample ID	LOI (%)	Ash content (%)	Total carbon content (%)	Total nitrogen content (%)
Draff S1	88.96 +/- 0.81	11.04 +/- 0.81	73.83 +/- 0.71	4.976 +/- 0.036
Draff S2	92.49 +/- 0.01	7.52 +/- 0.01	68.27 +/- 0.32	5.336 +/- 0.028
Draff S3	91.49 +/- 0.17	8.51 +/- 0.17	68.75 +/- 0.01	5.785 +/- 0.019

Figure 1 A): C remaining from biomass or biochar after decomposition and charring in soil. B) Loss on ignition (LOI), ash contents, total C and N content for draft-based biochar produced from spent grain from distillery using Easychar technology.

How Much Biochar Can Soil Tolerate?

From the data available to date, it appears that crops respond positively to biochar additions up to 50 Mg C ha^{-1}.

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How Stable Is Biochar?
Stability of biochar critically depends on the production procedure. Greater stability of charcoal produced at 400 °C than 1000 °C against oxidation has been reported. Microbial decomposition of bio-chars is also an important process in soil that is influenced by charring temperature.

What are the other environmental effects of bio-chars in soil?
Apart from the beneficial effects of drawing CO_2 from the atmosphere, biochar applications to soil are also able to reduce the emissions of other greenhouse gases such as methane and Nitrous oxide. In addition to reducing greenhouse gas emissions, bio-char applications to soil have the potential to decrease environmental pollution such as ammonia (NH_3).

Mechanism and Quantification of Carbon Sequestration in Bio-Char Systems

In the conversion of biomass to biochar approximately 50% of the C contained in the biomass is immediately released, leaving a stable biochar residue. This efficiency of C conversion of biomass to biochar is highly dependent on the type of feedstock, and to some extent affected by the pyrolysis temperature (within 350–500 °C common for pyrolysis). With a strong affinity for nonpolar substances and high surface area, biochar can capture and store CO_2 by adsorption in its pores (**Fig. 2**).

Figure 2 CO_2 physisorption on activated biochars

Biomass Energy

In a bioenergy system, the initial loss of C during charring can be used for energy and can off-set fossil fuel use. The energy produced, if used to displace energy produced by fossil fuel burning, leads to a further reduction in emissions. These avoided emissions, rather than sequestered C, are the tradable entities under the current Construction and Design Management (CDM) rules.

Conclusions and recommendations

- Bio-char sequestration represents long term storage of C.
- The release of C sequestered in soil by a subsequent change in practice must be considered.

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- The improvement of pyrolysis and activation conditions to use less energy, chemicals, and reaction time should be considered (i.e. single step pyrolysis and activation of biomass or carbonization of biomass with microwave-assisted pyrolysis.
- The use of renewable energy for charring must be considered.

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