

Is Biochar Valuable for Carbon Sequestration?

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Carbon pools

Like all mineral elements, carbon is neither created nor destroyed; it cycles. An atom of carbon in atmospheric carbon dioxide (CO₂), for example, can become part of the cellulose in an oak leaf by the processes of photosynthesis and polymerization. When the leaf decomposes, that same carbon atom might become part of humus in soil. All carbon slowly circulates between 5 global pools. In this example, the carbon atom moves from the atmospheric pool to the biotic pool to the soil pool.

The table below describes the 5 carbon pools. **Note:** Pg is the abbreviation for Petagrams. A Petagram equals 10¹⁵ g, or one billion metric tons.

Pool	Examples	Quantity of C	Characteristics
Geologic	Limestone, marble	83 million Pg (includes about 4,000 Pg of fossil fuels)	Very stable; no net change
Oceanic	Pacific and Atlantic oceans	38,000 Pg	Increasing acidity decreases oceanic pool CO ₂ capacity; small changes can dramatically increase atmospheric pool CO ₂
Soil (to a depth of 1 m)	Compost, peat	2,300 Pg	Conversion to agriculture causes carbon loss; carbon can be restored and can accumulate
Atmospheric	CO ₂ , CH ₄ , CFCs	820 Pg (in 2008)	Slowly growing (with CO ₂ increasing by 3 ppm per year)
Biotic	Redwood trees, ants, elephants, bacteria	550 Pg	Essentially stable

Each of these pools is dynamic, that is, constantly changing. Through certain processes carbon is added to each pool and by other processes, it is removed. When additions to a pool exceed removals, the pool expands.

Photosynthesis and other chemical reactions build CO₂ into structural plant molecules. As long as a tree lives, it traps carbon in the biotic pool. Huge old trees store much more carbon than do small young saplings. When a tree burns or dies and decays, it releases its CO₂ back to the atmospheric pool. When a tree is cut, its sawdust decays rather quickly. Lumber made from the tree continues to store carbon until it is burnt or decays.

Global warming

Combustion of fossil fuels moves carbon from the geologic pool to the atmospheric pool, producing our most

abundant greenhouse gas, CO₂. Greenhouse gases accumulating in the atmosphere retain more heat near the earth's surface. As CO₂ continues to accumulate, the atmospheric carbon pool expands, producing more warming.

Global warming threatens the survival of our civilization. To limit global warming we must reduce CO₂ output and divert carbon into another pool. Trapping or storing carbon is termed carbon sequestration. The soil pool offers the most potential for carbon sequestration.

Biochar

Ancient Amazonians in what is now Brazil produced biochar, or biological charcoal, by smoldering crop waste and saplings and vines collected when clearing land for gardens. Smoldering is burning with little oxygen, typically in a trench or pit covered with soil or clay except for a smoke hole. North American pioneers used smoldering to make charcoal from tree trunks, stumps, and roots. They sold the charcoal to obtain income.

Amazonians tilled the biochar into their gardens. This produced *terra preta*, or black earth. Soil in their gardens without biochar contains 0.5% carbon. Soil in their gardens with biochar contains 9% carbon. Interestingly, biochar does not oxidize. It persists; biochar in Amazonian forest soil has been documented to remain for up to several thousand years! This long-term carbon sequestration benefits humanity.

Terra preta holds mineral ions, especially cations (Ca⁺⁺, Mg⁺⁺, and K⁺), making them available for plant use. It also holds phosphate, an anion. All these minerals enrich the soil. Recent experiments prove that the presence of biochar increases bean production by 46%. Because biochar acts as a fertilizer, it provides a second major benefit to humanity.

Pyrolysis

The modern technique used to produce biochar is termed slow pyrolysis (literally "fire splitting"). Pyrolysis of plant or animal matter generates 3 products: biochar, biofuel, and syngas (synthetic gas). Biofuel can be used as a substitute for diesel fuel and syngas can be used to generate electricity. Only modern pyrolysis units can recover biofuel and syngas.

When burned at about 500° C, the optimal temperature, approximately 50% of the biomass becomes biochar. Produced at this temperature, biochar has enormous surface area, a high capacity to hold cations, and a high pH, all of which are desirable characteristics of fertilizers. Biomass such as bagasse (sugar cane stalks that have had the juice squeezed out of them) and switchgrass, which are now converted to ethanol, could be more efficiently made into biochar.

By its presence, biochar reduces anaerobic soil conditions. This can decrease the emissions of 2 potent greenhouse gases, methane (CH₄) and nitrous oxide (N₂O). These retain many times (23x and 296x, respectively) the heat that CO₂ retains in the atmosphere.

Given that about 8% of atmospheric CO₂ is absorbed by plants every year, converting a fraction of this to biochar will have a dramatic impact. It has the potential to sequester Gigatonnes (a Gigatonne equals 10⁹ metric tons; a metric ton equals 2,200 lbs) of carbon every year. **Note:** *A Gigatonne equals one Petagram.*

Is biochar valuable for carbon sequestration?

Professor Tim Flannery, Australian author of an early, notable book on global warming, *The Weather Makers*, states,

Biochar may represent the single most important initiative for humanity's environmental

future. The biochar approach provides a uniquely powerful solution, for it allows us to address food security, the fuel crisis, and the climate problem, and all in an immensely practical manner. . . .

Biochar represents a cornerstone of our future global sustainability. With the appropriate political and technical recognition, promotion, and adoption, it will change our world forever, and very much for the better.

Sources

Flannery, Tim. August 2008. An Open Letter on Biochar from Professor Tim Flannery.

Lehmann, Johannes. 2007. Bio-Energy in the Black. *Frontiers in Ecology and the Environment* 5(7): 381–387. <http://www.frontiersinecology.org/>.

Lehmann, Johannes, John Gaunt, and Marco Rondon. 2006. Bio-Char Sequestration in Terrestrial Ecosystems—A Review. *Mitigation and Adaptation Strategies for Global Change*, 11:403–427.

Further study

You can guide your class in explorations of the carbon cycle and global warming with exercises from the 2nd edition of the [Environmental Science Workbook](#). Published in 2008, it is now available from Carolina Biological Supply Company. Exercise 7 focuses on air, exercise 9 focuses on soil, and exercise 29 introduces global warming. In exercise 29, students with access to a computer can estimate their personal carbon footprint, i.e., the amount of CO₂ their activity adds to the atmospheric pool each year.



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