**IBI Research Summary:**

# Biochar Recalcitrance in Soil

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**Question: How long will the carbon from biochar stay in the soil?**

Biochar is not a single material, and its properties vary according to how it is made and from what it is made. The prevailing scientific understanding of biochar degradation in soil is that some portions of it are quite readily decomposable (termed "labile"), while the core structure of the material is highly resistant to degradation (termed "stable"). Analyses of biochar will indicate the relative amounts of labile and stable materials in each biochar material. Depending on how the material is made and from what, the size of these fractions varies.

The degradable portion of biochar (composed of condensates, bio-oils, etc) is usually small and its size can be managed in the production process. Once this portion degrades in the years following application, the leftover will remain in soil for very long periods of time. There is variation in the exact composition of biochars, but basically a charred material will always be more recalcitrant (resistant to degradation) than its uncharred counterpart.

Biochar carbon in *Terra Preta* soils of the Amazon has been dated up to several thousand years old. The Amazon is a tropical climate where organic matter degradation is very rapid due to constantly high temperatures and moisture levels. In Australia, estimates of mean residence time for naturally occurring biochar carbons are 1,300 – 2,600 years (Lehmann et al., 2008). Organic matter decomposition rates in temperate regions are slower and the carbon resides in the soils for much longer periods of time.

Controlled experiments where biochar decomposition is monitored are underway, but results extending over long periods of time are not now available. However, applying scientifically robust mathematical models to describe the degradation of organic matter in soil, and using data available to date, multiple independent estimates show that biochar has a mean residence time in soils on the order of 1,300 to 4,000 years (Cheng et al.

2008, Liang et al. 2008, Kuzyakov et al. 2009, Major *et al.*, 2010).

Another laboratory incubation study found no decomposition of a commercially produced biochar over 100 days (Spokas *et al.*, 2009), while biochar was found to degrade up to 18 times less than un-charred biomass over 2 years, also in the laboratory (Bruun *et al.*, 2009). Several other questions have been raised concerning biochar residence time in soils. These are addressed here:

**1. Could soil tillage cause large carbon releases from soil amended with biochar?**

Soil tillage is known to cause sudden release of $CO_2$ from soils and to accelerate biogenic soil organic matter decomposition. This is one of the downsides of using reduced tillage to sequester carbon in soils: if the soil is ploughed, a portion of soil carbon that has accumulated over several years can be lost very quickly. Due to the chemical nature of biochar, it is a lot more resistant to degradation than other forms of organic matter. Thus, we expect events such as tillage to cause negligible loss of biochar carbon compared to carbon in biogenic soil organic matter. In a laboratory study, soil alone or amended with biochar was incubated and mixing was carried out to simulate tillage. After mixing, $CO_2$ production from non-biochar soil organic matter (SOM) alone increased by a factor of 1.5 to 7, while $CO_2$ production from biochar increased by a factor of 0.5 to 2 (Kuzyakov *et al.*, 2009). So, biochar decomposes more slowly in soil than non-biochar SOM, and when mixing occurs, the stimulation is less intense

**2. If biochar is applied to large land areas, could it encourage carbon-eating microbes to multiply and break down black carbon more easily, leading to increased carbon emissions?**

There is no evidence for this. The fact that *Terra Preta* soils contain so much black carbon after so long a time in a diverse tropical environment that highly favors microbial activity and decomposition indicates this is very unlikely to occur.

**3. Could large amounts of biochar be lost in wildfires?**

Some references have reported that large pieces of charcoal left on forest floors after a forest fire may be burned when subsequent fires move through the same forest. This is true, but is not relevant for biochar-amended soils. Fires may burn surface vegetation but will not oxidize biochar that has been thoroughly mixed with the mineral soils. The term “loss by oxidation” in these reports refers to carbon losses from burning in subsequent wildfires – not to microbial oxidation of carbon, as may be concluded.

**4. Are there other mechanisms that can cause large losses of black carbon from soils?**

One work by Nguyen et al. (2009), reports on carbon dynamics in agricultural soils in Kenya following land clearing by fire. This was not biochar that was prepared by modern pyrolysis methods and then purposefully incorporated into soil, but rather black carbon

left from clearing of forests for cultivation. The temperature at which this black carbon was produced probably varied significantly and a substantial fraction was likely formed at lower temperatures than in a modern biochar pyrolysis facility. This study reports a loss of 70% of black carbon from the topsoil over 20-30 years. The change likely involved a number of processes, including decomposition of the labile fraction of the black carbon, lateral erosion away from the site, and transport below the sampling depth in the soil by tillage, earthworms and water leaching. The authors found that after the initial phase of unattributed rapid carbon movement and/or loss, the black carbon fraction in the soil remained stable for 70 years, up to the present. It is important to acknowledge that even if black carbon or biochar changes location or is leached into the subsoil, very little of the carbon is lost to the atmosphere, i.e., it is still sequestered. Further research is warranted to determine how much carbon loss in this situation was attributable to decomposition and how much to physical transport.

In summary, a good deal is known about the recalcitrance of biochar in soil. Certainly there is enough information to make conservative estimates in most cases that are suitable for basic carbon accounting.

## REFERENCES ON RECALCITRANCE OF BIOCHAR IN SOILS


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