



Biochar Misconceptions and the Science

IBI has prepared this document in response to various press releases and reports issued by the groups EcoNexus and Biofuels Watch, including a report titled: *Agriculture and climate change: Real problems, false solutions*. This report states that it was prepared for the June 2009 climate talks in Bonn. It is not a peer-reviewed scientific paper and the qualifications of the authors are not stated. Nevertheless, they bring up questions that are good to ask.

We provide answers below that draw from the published scientific literature. IBI believes that while no answer in science is final, there is sufficient evidence in hand to justify pursuing proper use of biochar as a valuable tool for enriching Earth's soils with stored carbon. We look forward to the continued progress of biochar research and development.

For more information on the questions below, see the resources on the IBI website, www.biochar-international.org. Visit our FAQ section and our IBI Publications page where you will find basic fact sheets, white papers and research summary papers.

Response to questions raised by Biofuels Watch/EcoNexus

The questions and answers below are in response to statements on pages 17-20 of *Agriculture and climate change: Real problems, false solutions*, by EcoNexus and Biofuels Watch, and also from some previous reports and statements by Biofuels Watch.

1. Does IBI promote large monoculture tree plantations, as Biofuels Watch claims, that will decimate native forests and drive indigenous people from their land in order to make enough biochar to meet climate targets?

No. The IBI promotes the use of waste biomass for the production of biochar. Large amounts of agricultural residues, municipal green waste and forestry biomass are currently burned or left to decompose and release CO₂ and methane back into the atmosphere. IBI has produced a preliminary analysis titled, [*How Much Carbon Can Biochar Systems Offset -- and When?*](#), that assumes only biomass from waste streams would be used. This analysis concludes that even a conservative scenario, using only 27% of the world's crop and forestry wastes for biochar, could sequester 0.25 gigatons (Gt) of carbon a year by 2030 with biochar alone. If the energy co-product of biochar production is used to offset fossil fuel use, then the carbon offset potential of biochar more than doubles to 0.6 Gt of carbon a year by 2030.

IBI, like many organizations and individuals, is also concerned about forest preservation. Many people falsely associate biochar production with the historical deforestation that has occurred to provide wood for inefficient, traditional charcoal production for fuel. This is not the strategy that IBI promotes or believes should be implemented for modern biochar production and utilization systems.

The promise of biochar technology as IBI envisions it is to improve soil fertility and reduce emissions, taking into consideration the full life cycle analysis of the biochar systems, including indirect land use change. Logging primary forests to produce biochar would defeat the purpose of biochar, which is to reduce the amount of carbon dioxide in the atmosphere. Properly implemented, biochar production and use will serve the interests of local people and protect native forests while reducing carbon emissions and enhancing the world's soils.

2. Is it true that biochar will soon be patented by big corporations that will prohibit small farmers and gardeners from using it?

While some biochar producers may be able to patent a specific biochar production process or method, there exist a number of open-source, low-cost, clean technologies that can make biochar at the home or village level, and more are in development.

3. Does IBI advocate adding carbon derived from coal, old tires or municipal solid waste to soils as Biofuels Watch alleges?

No. Coal is not a renewable resource. Biochar refers specifically to materials made from present-day biomass, not fossil carbon. Tires and other potentially toxic waste materials are not appropriate as sources of biochar for soil improvement.

4. Is it true, as EcoNexus and Biofuels Watch claim, that there are no significant field trials showing that biochar really benefits soil fertility? Without better information, are the risks too great to consider large scale biochar use at this time?

Field trials using biochar have been conducted in the tropics over the past several years. All showed positive results on yields when biochar was applied to field soils and nutrients were managed appropriately. Large scale field trials have recently begun on highly fertile Iowa Mollisols by the US Department of Agriculture's Agricultural Research Service (USDA-ARS). First year results are positive, yet it will take several years before definitive results are available (Laird, D., 2009)

In addition, we cannot, as Biofuels Watch would have us do, discount the evidence from thousands of years of traditional use of charcoal in soils. The most well-know example is the *Terra Preta* soils in Brazil, but Japan also has a long tradition of using charcoal in soil. This tradition is now being revived and even exported as in the case of a commercial biochar fertilizer production facility that has been operating along Japanese principles in Costa Rica for the last 20 years.

The Japanese tradition is described in this paper from Ogawa, M., Osaka Institute of Technology, Charcoal Use in Agriculture in Japan, Keynote address, Asia Pacific Biochar Conference, 17-20 May 2009:

“...use of charcoal dwindled to 30,000 t/year by the 1980s but in the 1970s scientists began promoting its production and use, and in 1986 a technical group was established to study carbonization technology, soil amendment in agriculture and revegetation, activation of microorganisms and water purification. In 1990 the research results were published and widely distributed, and charcoal and wood vinegar were authorised for soil amendment by the Ministry of Agriculture, Forestry and Fishery.”

The Brazilian and Japanese traditions together provide long-term evidence of positive biochar impact on soils.

Recent research also documents the nearly ubiquitous occurrence of biochar-type materials in soils globally (Skjemstad et al., 2002; Hammes et al., 2008; Krull et al., 2008; Lehmann et al., 2008; Laird et al 2008). While these were generated from wildfires, they share the basic properties with biochar generated from woody and grassy feedstock. In fact, soils high in natural biochar found in fire-prone grasslands like the North American Prairie are some of the most fertile soils in the world.

While the larger questions concerning overall biochar benefits to soils have been answered in the affirmative, significant questions remain, including the need for a better understanding of some of the details of biochar production and characterization. Work is ongoing to develop methods for matching different types of biochar to soils for the best results. IBI is working with private and public researchers around the world to develop protocols to answer these questions.

5. Biofuels Watch and EcoNexus question whether biochar will last long enough in soil to be counted as a carbon offset. They also speculate that at some point in the future it could all be released into the atmosphere at once in a devastating “carbon time bomb.” Do we really know that biochar will be stable in soils?

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).

Soil tillage is known to cause sudden release of CO₂ from soils and to accelerate decomposition of soil organic matter. 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. Biochar is intimately mixed with soil, interacts with its constituents and is stable in that environment. It does not depend on any form of containment.

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

6. EcoNexus and Biofuels Watch attempt to show that large fractions of biochar can be lost over short periods by quoting studies that look at black carbon left by fires. Are these studies relevant?

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.

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.

7. Biofuels Watch and EcoNexus warn that if biochar was applied to large areas of land, carbon-eating microbes might multiply and break down black carbon more easily, leading to increased carbon emissions.

There is no evidence for this concern. 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.

8. These critics also cite a study of charcoal in boreal forests as evidence that “adding biochar to soil could actually worsen climate change due to potential losses of soil organic carbon.”

There is no evidence or research indicating that biochar could trigger additional carbon releases from soil. This concern stems from the results of a study by Wardle et al (2008). The study placed mesh bags of charcoal in the humus layer (consisting of needles and litter, usually called an organic or O horizon, not a mineral soil) of a forest and observed a subsequent loss of carbon. Increased microbial respiration is one possible mechanism for the observed carbon loss, but the investigators did not measure the physical transport of carbon to areas outside the mesh bags they used in the experiment. Organic carbon that is leached into deeper, mineral layers of soil has repeatedly been shown to become stabilized by interactions with minerals, and thus to remain within the soil system.

A recent study testing this very same interaction between litter, char and soil organic matter in a laboratory incubation (Bruun, et al, 2009) found no evidence that biochar increases the decomposition of soil organic matter. The authors conclude: “There is thus no indication the carbon sequestered in the biochar will be offset by an increased release of carbon dioxide because of increased decomposition of soil organic or recently added plant litters. All of this supports the assertion that biochar presents a potentially very effective method for soil carbon sequestration.” The same conclusion was drawn from two further studies (Liang et al., 2009; Spokas et al., 2009) that used more comprehensive approaches than the study by Wardle et al. (2008).

Finally, the effect of biochar on plant growth was not captured in the system studied by Wardle et al. (2008) and this can make a significant difference in the total carbon accounting. A study by Major et al. (2009) showed a net gain in soil organic carbon beyond the biochar additions that was caused by greater plant productivity and accumulation of dead roots and other organic matter in the soil. Consequently, with more organic matter available to microbes, soil respiration was greater. Such greater carbon cycling should not be identified as a loss of soil carbon caused by biochar additions. The Major study stresses the fact that the effect of biochar on non-biochar soil carbon must be studied in the field, at a scale that includes plant reactions to the presence of biochar.

9. Could biochar worsen climate change through changes in albedo or impacts from airborne black dust?

After centuries of agriculture, soils globally have become depleted of carbon, compared to pre-agricultural conditions. Agricultural development goals include restoring carbon to carbon-depleted soils. Adding any form of carbon to soil, not just biochar, changes soil albedo (a measure of sunlight reflectance). Fortunately, darker, carbon-rich soils are more fertile and will be more easily re-vegetated. Vegetation has a lighter albedo, so the albedo problem is neither specific to biochar nor a simple cause and effect but requires detailed study.

Small particles of black carbon are produced from the incomplete combustion of fossil and biomass fuels. When deposited on snow and ice, they are able to absorb heat and energy. The smallest black carbon particles associated with biochar production and application are much larger, in the millimeter range, than the particles associated with global warming, in the nanometer range. Thus application of biochar would result in little opportunity for long-range transport and deposition into the sensitive Arctic and mountain regions.

Dust is a certainly a concern with biochar application, but best practices require that biochar applications be done during periods of low wind to prevent the blowing of fines. Agricultural techniques already exist to apply powdered fertilizers and other amendments. Several techniques are available to help keep wind losses to a minimum: biochar can be pelleted, prilled, mixed into a slurry with water or other liquids, mixed with manure and/or compost, or banded in rows. The optimization of biochar application to soil is important, and the farm technology and methods are available.

10. Biofuels Watch and EcoNexus cite uncertainty about biochar's ability to retain soil moisture.

More studies are needed on the question of water retention, but the results so far consistently show benefits in sandy soils where this function is most needed. The Australian national science agency, CSIRO, released a comprehensive review (*Biochar, climate change and soil: A review to guide further research*) of biochar in February 2009, co-authored by Rothamsted Research and Newcastle University in the UK. The CSIRO review looked at work done on biochar impact on soil moisture retention. While it found

few studies that directly addressed soil moisture retention with biochar, it found that “Many studies where the effect of biochar on crop yield has been assessed have cited moisture retention as a key factor in the results.”

CSIRO cited a study (Gaskin et al., 2007) that found water retention doubled in a loamy sand soil, and a study of *Terra Preta* (Glaser et al., 2002) that showed an 18% higher water retention than adjacent soil.

A case study in Ghana illustrates the significance of biochar augmented water retention in a dryland crop:

Case Study 5 – Example of highly diverse cropping system (maize, yam) with secondary forest in Ghana managed with biochar over 20 years. Farmer reports 100 percent increase in yields. “Her perception is that the underlying mechanism for the effects she sees is entirely physical, citing two factors: enhanced rainwater infiltration and enhanced soil moisture retention. In drought-susceptible sandy soils – prevalent in most parts of Ghana – crop performance is considerably governed by the timing and extent of rainfall, and its effect on crop establishment and maturation.”

From: Lehmann, C.J. and Joseph, S., 2009. Biochar systems. In: Lehmann, C.J., Joseph, S. (Eds.), *Biochar for environmental management: science and technology*. Earthscan.

11. Biofuels Watch and EcoNexus say biochar could introduce toxic compounds to soil

In its report titled *Biochar, climate change and soil: A review to guide future research*, the Australian science agency CSIRO states, “...the apparent success and longevity of the civilization that created the *terra preta* provides some reassurance as to the long-term safety of biochar incorporation to soil...Nonetheless, a critical and non-prescriptive experimental analysis of risks that might arise from the deployment of biochar has not been undertaken according to modern criteria...” Below is a brief summary of the potential toxic compounds that could be associated with biochar:

Heavy metals. Some feedstocks that could be used for biochar might contain heavy metals, however, these are unlikely to be present in harmful concentrations in agriculture and forestry wastes. Caution is necessary in choosing feedstocks to avoid those containing toxic compounds. Treated lumber is an example of biomass that should never be used to produce biochar. There are rules for metal contents in soil-applied materials like composts and sludges, and biochar should be subject to such rules. The IBI is able to provide the expertise through its members to advise in the development of guidelines that would meet environmental standards.

PAHs. Polycyclic aromatic hydrocarbons (PAHs) are chemical compounds that are produced as byproducts of fuel burning (whether fossil fuel or biomass). Some PAHs are

carcinogenic to humans, but many are not. PAHs are found naturally in soils as a result of wildfire and many microbes are able to metabolize them. An investigation by M. Jones, et al (2008) found PAHs in biochar amended soils to be at levels similar to or below PAH concentrations found in many unamended soils. One analysis of PAH profiles in biochar samples found a lower concentration of PAHs than in char formed by a prescribed burn in pine forest (Brown, 2006).

Dioxins. Dioxins are predominantly formed at temperatures above 1000 degrees C. Most pyrolysis technology operates well below that temperature. Dioxins should not be a concern with biochar, but any proposed high temperature pyrolysis technology should be assessed and monitored for possible dioxin production.

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