Biochar's Unproven Claims

Note: A detailed (interim) Biofuelwatch report, "Biochar: A Critical Report of Science and Policy can be downloaded from www.biofuelwatch.org.uk/2011/a-critical-review-of-biochar-science-and-policy/ **.**

What is biochar and what do 'biochar' studies actually look at?

The term biochar is commonly used to describe char which has been produced through modern pyrolysis with heat capture and which is added to soils. Yet very few of the studies on which claims about biochar are based have actually looked at this. Most have looked at the use of traditional charcoal, or charcoal and soot left over after wildfires or swidden agriculture, and some even at soot deposited after fossil fuel burning. The biochar literature thus includes the full range of black carbon found in soil. The structural properties and chemical nature of different forms of black carbon varies widely depending on what type of biomass it is made from, how it is made and various other factors. For example, biochar made from rice husks pyrolysed at 400 degrees C for 1.5 minutes and then cooled down rapidly, will behave very differently from rice husks pyrolysed at 500 degrees C, or cooled down slowly – and both are very different from biochar produced from pine wood pyrolysed at 800 degrees C for a couple of seconds. Because of the very different properties that these different forms of black carbon possess, in combination with the even greater variation in soils and soil conditions, it is impossible, based on current knowledge, to draw viable, general conclusions about the impact of biochar on soils and plant growth.

Only around 11 peer-reviewed field trials have been published, their results vary greatly, even within individual studies and only 3 of them lasted longer than two years.

Biochar is not Terra Preta

One thing that is clear: biochar – whatever its properties - is not Terra Preta. The highly fertile, and carbon rich soils in Central Amazonia are widely cited as evidence that biochar works to store carbon and improve fertility. However, modern biochar bears little resemblance. Terra Preta soils were produced using a diverse array of materials including not only black carbon but also animal bones, compost, pottery shards etc., using processes that are only partly understood. It is known that the farming methods during the period when terra preta was created involved perennial crops, intercropping and permanent tree cover - very different from industrial monocultures on which biochar has largely been tested. The evidence does not support an analogy between Terra Preta and modern biochar.

Is biochar a reliable way to store carbon in soils?

For our detailed report, we analysed the results of all peer-reviewed biochar field studies which we could find through a literature search – 11 different trials in total. Our concerns that the findings from the studies do not appear to back claims that biochar can be relied upon to sequester carbon have since been backed by a soil science review published in Nature (tinyurl.com/62xxmmr). The article, written by team of 14 soil scientists from 12 research institutes, amongst them the Chair and an Advisory Board member of the International Biochar Initiative, shows that the fate of any soil carbon, including biochar carbon, cannot be predicted by looking at its molecular structure or what happens to it under laboratory conditions. The case for biochar rests to a large extent on laboratory analyses and studies which show that fire-derived or black carbon – the carbon contained in biochar – is more resistant to degradation under conditions of high temperatures or acids than other soil organic carbon. According to the new soil science review, this is nowhere near as relevant as scientists used to think. What happens to any carbon in soils depends to the largest part on environmental conditions and on its interaction with complex soil ecosystems. Black carbon "is not intert but its decomposition pathways remain a mystery." In one field experiment, black carbon was "even observed to decompose faster than the remaining bulk organic matter". Therefore, "sequestration strategies based on adding recalcitrant material to soils, whether through plant selection for recalcitrant tissues or through biochar amendments, must be re-evaluated." It is not yet possible to "develop simple (that is, policy-relevant) quantitative relationships between biochar additions and expected sequestration".

Of the 11 peer-reviewed field trials which we found, only 5 looked at what happens to soil carbon when biochar is added and one of those (tinyurl.com/3nvyg66) looked at 'charred soil' rather than what most people would regard as biochar.

In a 4-year study in Colombia (tinyurl.com/3nbkneo), two years after a high level of biochar (20 tonnes per hectare) was applied, the plots with biochar held significantly *LESS* carbon than those without. In a separate two-year study from Colombia (tinyurl.com/3jldgth), biochar made no significant difference to soil carbon, except when a very large amount (116 tonnes per hectare) was used.

In an 18-months long trial in Western Kenya (tinyurl.com/3n29ywg), Tithonia leaves, manure, sawdust and biochar were applied to different plots on four different soils (with different levels of existing soil carbon). At the end of the trial, soils amended with biochar had the highest overall carbon levels in only one out of four soil types. On one soil type, there was no statistically significant difference between carbon levels from Tithonia, manure or biochar, on a third soil, sawdust fared best and on the fourth soil, whatever was added to the soil made no difference to soil carbon.

In a study in Central Amazonia (tinyurl.com/5t838f6), biochar on its own and in most combinations with other fertilisers did not significantly improve soil carbon five months after it had been applied.

In the fourth relevant study, in the Philippines, adding biochar did raise soil carbon levels on two soils over 2-3 levels, but reduced them on a third soil.

Field study results so far thus suggest that biochar is not a reliable way to increase soil carbon. It is not clear what happened to the 'lost' carbon in different studies: Some biochar carbon might simply not have been very stable. Some biochar may have stimulated soil microbes which then turned existing soil organic carbon into CO2. And some may have been lost through erosion. In sum, scientists are far from being able to predict and control the behaviour of black carbon additions to soils.

Albedo impacts

Airborne black carbon has a very powerful, though short lived impact on warming. Some forms of biochar include very small particles – as small as black soot – which makes application and handling difficult. Even larger particles tend to break down to a very small sizeover time. Small particles can be borne aloft and contribute to warming just as soot particles do. No peer-reviewed research has been done to look at this effect.

Reducing nitrous oxide emissions?

Advocates claim that biochar can reduce nitrous oxide emissions from soils. This claim is largely based on laboratory studies. We could find just one field study which has looked at biochar impacts on N2O. That study looked at the impact of biochar on cow urine in pastures. Extremely large quantities of biochar (30 tonnes per hectare) were required to reduce emissions.

Improving yields and benefiting the poor?

Smallholder farmers and rural poor are not likely to be able to afford modern pyrolysis facilities, nor can they afford to convert portions of their land to producing large amounts of biomass for production of biochar rather than food. This is especially problematic if the claims for improving yields are not proven true. Of the 11 field trials, 8 looked at yield impacts of biochar. The results are mixed: in some cases yields improved, while in others they did not, or even declined. In those cases where yields were raised, the reasons identified were all ones associated with short-term impacts - unlike Terra Preta there was no evidence that biochar improved plant growth by changing the structure of soils long term (e.g. by raising the cation exchange capacity).

The question of scale

The International Biochar Initiative (IBI) claims that biochar can sequester up to 2.2 billion tonnes of carbon every year by 2050, by sequestering carbon which will remain in soils for hundreds or thousands of years, offsetting fossil fuel combustion by replacing it with the syngas resulting from pyrolysis, and also meanwhile reducing emissions of nitrous oxide from soils. the UKBRC has supported the use of biochar for geoengineering and spoken of a 'conservative' estimate of 1 billion tonnes of biochar carbon being sequestered annually, and possibly as much as 5.5-9.5 billion tonnes (tinyurl.com/3o3kwnd). This would require a lot of carbon - as well as evidence for 'carbon benefits' not backed by the overall results of field studies.

In order to apply biochar at rates that have any impact on soils – generally at least 10 tonnes per hectare – over hundreds, thousands or even millions of hectares of land, would require massive quantities of biomass to be harvested and pyrolized. Only 12-40% of biomass is turned into biochar with modern pyrolysis. For 'biochar stoves', the maths don't add up: It would take a family decades to produce 10-20 tonnes of biochar, the amount used in most field trials for one hectare.

In 2010, an article was published in Nature Communications, with two leading IBI members amongst the authors, which claimed that 12% of annual greenhouse gas emissions could be offset with biochar. Although the study was publicised in the media as being mainly about 'waste', the findings were based on the assumption that 556 million hectares of land would be converted to biochar production. This is 20-25 times as much as the land used worldwide to produce biofuels today.

Already "land grabs" are resulting in violent evictions and human rights abuses. Adding enormous demands for biomass for biochar production will fan the flames of such conflicts.

Policy implications

The difficulties inherent to measuring and verifying carbon in natural ecosystems is one of the main reasons that the use of lands as "carbon sinks" has been limited. There is now however a strong push to include soils and agriculture into carbon markets. Biochar advocates are eagerly promoting biochar's inclusion in these markets, for example, in Australia's Carbon Farming Initiative, the Alberta Offset Scheme (seeking to use biochar as an offset for emissions from tar sands extraction) and the Verified Carbon Standard Agency. Other regional and national carbon markets also appear poised to embrace soil carbon marketing. The evidence summarised above illustrates some of the most serious concerns about including biochar into carbon markets.