Biochar: A Critical Review of Science and Policy

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Biofuelwatch

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Introduction

As we face catastrophic impacts of climate change, efforts to "engineer" the climate are proliferating along with a host of technofix "solutions" for addressing the many consequences of climate change. Among these is the proposal to use soils as a medium for addressing climate change, by scaling up the use of biochar.

Indeed soils around the globe have been severely depleted of carbon as well as nutrients – in large part due to destructive industrial agriculture and tree plantations as well as logging practices, raising serious concerns over the future of food production. Soil depletion has led many to conclude that improving soils might contribute significantly to addressing climate change as well as other converging crisis, by sequestering carbon, boosting fertility, reducing fertiliser use, protecting waterways etc.

But is biochar a viable approach?

Biochar is essentially fine grained charcoal, added to soils. Advocates claim it can sequester carbon for hundreds or even thousands of years and that it improves soil fertility and provides various other benefits – they seek support in order to scale up production. A common vision amongst biochar supporters is that it should be scaled up to such a large scale that it can help to reduce or stabilise atmospheric concentrations of carbon dioxide.

Research to date on biochar has had mixed results and clearly indicates that biochar is not one product but a wide range of chemically very different products which will have very different effects on different soils and in different conditions. Many critically important issues remain very poorly understood; there are likely to be serious and unpredictable negative impacts of this technology if it is adopted on a large scale and there is certainly no "one-size-fit-all" biochar solution.

Soils are extremely diverse and dynamic. They play a fundamental role in supporting plant, microbe, insect and other communities, interacting with the atmosphere, regulating water cycles and more. Unfortunately, like other such schemes, to engineer biological systems, the biochar concept is based on a dangerously reductionist view of the natural world which fails to recognize and accommodate this ecological complexity and variation.

Biochar proponents make unsubstantiated claims and lobby for very significant supports to scale up biochar production. But these supports have largely not been forthcoming. Nonetheless, vigilance is required. In particular, there is potential that agriculture and soils may be broadly included in carbon markets, which could open new potential for supports for biochar. Likewise, as climate geo-engineering discussions are becoming more prominent and accepted, there is potential that biochar could move forward under that guise.

It is imperative that we do not repeat past errors by embracing poorly understood, inherently risky technologies such as biochar that will likely encourage expansion of industrial monocultures, result in more "land grabs" and human rights abuses, further contribute to the loss of biodiversity, and undermine an essential transition to better (agro-ecological) practices in agriculture and forestry.

The following is a substantially expanded update of our initial 2009 briefing: "Biochar for Climate Mitigation: Fact or Fiction?" It is an interim version with the final report to be published during the UN Climate Conference in Durban in late 2011. Since our first briefing as published, there has been a considerable amount of new research, and many new industry and policy developments for biochar. In this update, we also address criticism of our previous briefing by the International Biochar Initiative.[1]

We hope this report will generate a deeper understanding of the issues and more critical thinking about biochar.

1 www.biochar-international.org/sites/default/files/Biochar%20Misconceptions%20and%20the%20Science.pdf

Chapter 2: What is biochar and what are the claims?

The International Biochar Initiative (IBI) defines biochar as "the carbon rich product when biomass is heated with little or no available oxygen…produced with the intent to be applied to soil as a means to improve soil health, to filter and retain nutrients from percolating soil water, and to provide carbon storage."[2] They thus define biochar primarily by its purpose, not by its physical or chemical properties.

Biochar refers to materials produced through Pyrolysis, which means exposing biomass to high temperatures with little or no oxygen. This produces a liquid fuel called pyrolysis oil or bio-oil, a gas called syngas, and generally between 12 and 40% of (bio) char. Strictly speaking, any type of combustion with restricted oxygen is 'pyrolysis', whether or not the energy is captured: Traditional charcoal making, even the charring of biomass during a wildfire, in a fire-place, etc. are all forms of pyrolysis. The idea behind modern pyrolysis, supported by biochar advocates, however, is to capture and use all of the energy, as syngas and/or pyrolysis oil. Modern pyrolysis is being developed at different scales, ranging from large pyrolysis plants to pyrolytic cooking stoves ('biochar stoves'). Modern pyrolysis is largely still at the pilot- or demonstration stages, with particular problems relating to the fact that pyrolysis oil and syngas cannot be blended with fossil fuels and that syngas has very low energy density when compared to natural gas.

Biochar can also be produced by means of Gasification, which means exposing biomass to high temperatures with a controlled amount of oxygen or steam. This produces mainly syngas and less than 10% of the original biomass into (bio)char. That char can be retained, but is more commonly gasified further until only ash remains. In a recent review of small-scale gasification the authors state: "*In fact, it is possible to convert dry wood or rice husks into gas and electricity. However, it is not as easy as some manufacturers would like to make us believe*... *A comprehensive World Bank study in 1998 examined gasification plants installed in the 1980s and found that virtually all had been taken out of operation due to technical and economic problems*" – a situation which appears not to have changed since then.[3]

Hydrothermal carbonization (HCT) is another method that produces biochar – this involves exposing biomass to moderately high temperatures in water, under pressure and together with a diluted acid which acts as a catalyst. This process, which is still in the very early research and development stages, produces no energy that can be captured. Instead, all of the carbon is turned into a type of biochar or 'bio-coal', with a great variety of chemical structures, depending on the catalyst used. It is being developed to a large part in the context of nanotechnology research.

Of the three methods described, pyrolysis is by far the most important in the context of biochar. No studies exist about biochars produced through gasification and very little is known about the properties of biochar produced through HTC. We found just one study about HTC biochars, a laboratory rather than field study and that found that the carbon was likely to be lost as CO2 within 4-29 years on average, i.e. that it was anything but stable[4] .

Some companies use the term "biochar" to refer to the use of charcoal as fuel (generally a "coal substitute"), in some cases materials made not only from biomass but also municipal waste, tires and coal dust.[5]

The carbon in biochar, charcoal, and even coal, is all "black carbon". There is a broad spectrum of different forms black carbon can take, which confers different properties. Many factors influence the physical and chemical characteristics of black carbon, including the type of biomass used, the temperature to which it is heated, how it is cooled and other variables. Exactly where biochar falls on this spectrum, is ambiguous. What is clear, is that in fact the precise details of the physical and chemical nature of black carbon referred to and used as "biochar", has major implications on how soils and plants are influenced, making it a focus of much research. This is further discussed in detail in chapter 3.

CARBON NEGATIVE

Biochar advocates refer to biochar as a "carbon negative" technology, a logic based first on the false assumption that burning biomass for energy is "carbon neutral", and second that biochar is guaranteed to further sequester carbon in soils for long time periods, taking it a step further as carbon "negative". Both steps in this logic are simply false. The bioenergy industry is under threat due to a growing scientific literature and public awareness that the resulting emissions are in many, if not most cases, even higher than those from using fossil fuels. Even if those emissions may eventually be resequestered by new plant growth, the time frame for regrowth is long – in the case of forest biomass- at least 50-200 years. This time lag between emissions from harvest and burning to regrowth is referred to as a "carbon debt". In the American state of Massachussetts, citizens opposing the construction of 5 new biomass incinerators demanded that the state commission a study – the Manomet Biomass Sustainability and Carbon Policy Report". A key finding of this report: after 40 years, the net GHG emissions from biomass burned for electricity are still worse than coal, even when considering forest regrowth, and worse than natural gas even after 90 years. The state is responding by revising biomass regulations in the Renewable Portfolio Standards. The Environmental Protection Agency has been taking public comment and is grappling with the complexities of accounting for "biogenic emissions", partly as a result of the growing awareness that these emissions cannot reasonably be defined, regulated and subsidized on the assumption that they are categorically "carbon neutral". The second step in the logic – from "neutral to negative" is clearly flawed given the lack of evidence for biochar remaining stable in soils for long periods, reviewed in chapter 3. There is a strong possibility that large scale implementation of biochar could result in very large emissions from harvest, soil disturbance and transport of biomass, from the pyrolysis process and combustion of syngas and bio-oil products, from more transport as biochar is redistributed, from more soil disturbance as it is tilled into soils, and finally from the oxidation of some- potentially large- portion of the biochar and from the "priming" effect that biochar has – causing oxidation of preexisting soil organic matter. All combined would result in a massive increase in emissions, far from being "carbon negative".

In general however, it would seem that the most useful working definition of biochar might be 'char left behind after modern biomass pyrolysis' - after all, that is what biochar advocates actually promote. Unfortunately, this is not reflected in most biochar studies. Modern pyrolysis is largely still at the pilot stages, i.e. it does not exist at a commercial scale and biochar produced this way is still difficult to obtain. Of the 13 peer-reviewed biochar field studies (based on 11 different trials) which we found in the literature[a] only two used biochar from modern pyrolysis; all of the others looked at traditional charcoal which was ground up, often by crushing it under the wheels of a tractor. Many studies about 'biochar properties' are not even confined to charcoal or biochar that has been produced intentionally but instead look at charcoal remains from wildfires or swidden agriculture, or in some cases even at carbon deposited as soot from biomass or fossil fuel burning[6].

a The definition of a 'field study' used here is one where biochar has been newly applied to plots of soils on which crops or other plants are then grown.

Terra preta

According to the UN Food and Agriculture Organization (FAO), some terra preta soils may be up to 2,500 years old. They are found in patches, generally along the Amazon and tributaries, and are otherwise surrounded by the infertile soils typical of this region. Researchers have found evidence of "garden cities" along the Berbice River in Guyana Amazon: areas with rich Terra Preta soils where a large variety of trees, shrubs and perrenial crops were grown in long crop cycles with intercropping and seasonal flooding. The soils contain large amounts of turtle shells, fish and mammal bones, pottery shards, kitchen waste and human excreta – as well as charcoal. These provide insights into the production of Terra Preta, but as the FAO states: " The knowledge systems and culture linked to the Terra Preta management are unique but have unfortunately been lost. Amazon Dark Earths are, however, still an important, yet threatened resource, as well as an agricultural heritage that needs better scientific understanding". Win Sombroek, described as the "founding father of the carbon-negative biochar initiative" had prior to his death, worked to "replicate and emulate the anthropogenic black earths of the pre-Colombian Indian tribal communities."

Many soils around the world do contain charcoal – from wildfires and in some cases likely the result of swidden cultivation in the past. British researchers have begun studying ancient dark, carbon-rich soils in different West African countries, the African Dark Earths Project. Problematically, the project aims combine studying "indigenous knowledge and practices" with looking at "the value now attributed to biochar for soil enhancement, carbon sequestration and clean energy production". As with terra preta, this raises the concern of indigenous knowledge being appropriated and used to help attract subsidies and carbon offsets for biochar entrepreneurs and companies in the North. Various patent applications and trademarks for biochar and 'terra preta' production have already been submitted by companies.

Traditional terra preta methods appear to be a lost art - according to an agronomist with 35 years experience working with small farmers across different states in Brazil, the deliberate use of charcoal as a soil amendment was never encountered (she had only heard about biochar in the context of carbon offsets). Elsewhere there are anecdotal reports that farmers in the Batibo region of Cameroon use charcoal made by burning mounds of grass covered by earth as a soil amendment. The indigenous Munda communities in Northern India reportedly add charcoal from cooking stoves with burnt grass and farmyard manure to their soils.

Biochar advocates claim that burying charcoal in soils is a viable means of sequestering carbon for hundreds or even thousands of years. According to the IBI, biochar could sequester 2.2 billion tonnes of carbon every year by 2050 and that carbon would be stored in soils for hundreds or thousands of years. This and similar claims are repeated over and over in biochar literature. In addition, they state that using syngas and pyrolysis oils to displace burning of fossil fuels, will further reduce carbon in the atmosphere. Advocates claim that using biomass is carbon neutral, but that biochar goes yet further to be "carbon negative" because not only will trees/plants grow back, but also some portion of the carbon from each generation of biomass produced and charred will supposedly be more or less permanently sequestered.

The assumption that biochar carbon will remain stable in soils for hundreds or thousands of years is based on making an analogy between modern biochar and ancient Terra Preta soils. Terra Preta, also called "Amazon Dark Earths" are soils made by indigenous peoples in the Amazon region long ago, using charcoal along with various other materials. Those soils remain highly fertile and carbon rich hundreds and even thousands of years later. The processes involved in creating Terra Preta are no longer known, but likely bear little resemblance to modern biochar. The addition of modern biochar to soils as it is has been practiced in the limited number of field tests to date, involves industrial agriculture practices – monocultures, using some combination of biochar with synthetic fertilizers, manure, or both, as well as pesticides and other agrochemicals. Terra Preta soils contain charcoal, but this is likely the extent of any commonality.

Given that there are so many known, and likely more unknown differences between modern biochar practices and the creation of Terra Preta, it is a stretch to draw the analogy. Yet some companies even refer to their biochar products as "Terra preta", or make claims that use of their biochar will enable users to turn their soils into Terra preta.[7]

What is deeply concerning is that the long term stability of biochar carbon in soils, the basis for claims that biochar is a viable solution for climate change - is *assumed* on the basis of this weak analogy. A review of research on the stability of biochar carbon in soils is therefore quite important, and follows in chapter 3.

Irrespective, many biochar advocates envision very large scale global deployment with the idea that it will contribute significantly to reducing greenhouse gas emissions. James Amonette describes the potential for sequestering 130 billion tones of CO2 over a century. Jim Fournier goes so far as to claim that biochar could resequester all carbon ever emitted from fossil fuel burning over 50 years. While some biochar advocates have been adamant in claiming that only "wastes and residues" should be used for biochar production, clearly many have no hesitations in calling for quite large scale land conversion and dedicated plantations for biochar feedstocks. An article published in Nature Communications and authored by members of the International Biochar Initiative examined the "theoretical potential" for biochar.[8] They claim that very large scale implementation of biochar on a global scale could reduce global emissions of greenhouse gases by 12% annually. This number is based on calculations of biomass availability that would require fantastic infrastructure and capacity to harvest and transport large quantities of biomass from virtually all landscapes, process in pyrolysis facilities, and then redistribute the biochar and till it into soils – over very large areas of the earth's surface. They also base this number on the conversion of over 556 million hectares of land to the production of biomass crops for char production. All based on the assumption that biochar actually "works".

At the pinnacle of large scale biochar promotion is the push to have biochar considered as a viable means for climate geo-engineering, under the category of technologies that are referred to as "Carbon Dioxide Removal" (CDR). Members of IBI submitted a recommendation to the Royal Society consultation on geo-engineering and a number of IBI science advisory committee members advocate directly for biochar as climate geo-engineering, (or indirectly – by advocating very large scale deployment and land conversion). In this context, advocates have taken to describing biochar as a means to "manage" and "enhance" the carbon cycle to withdraw more CO2 from the atmosphere.[9]

In addition to the claims regarding the potential for biochar to sequester carbon, other claims are also made, including 1) that biochar improves soil fertility, therefore can increase crop yields and reduce fertilizer demand. 2) that biochar reduces N2O emissions from soils, 3) that deforestation can be reduced by transitioning from traditional slash and burn to "slash and char" agriculture, and 4) that pyrolytic (biochar producing) cookstoves can benefit the poor by providing more efficient and cleaner cookstoves while at the same time providing a soil amendment that will enhance yields. Each of these claims is also analyzed in more detail in the following chapters.

2 http://www.biochar-international.org/biochar/faqs#question1

3 Dimpl, E, Blunck, M. 2010: Small-scale Electricity Generation From Biomass: Experience with Small-scale technologies for basic energy supply: Part 1: Biomass Gasification. Gtz, commissioned by the Federal Ministry for Economic Cooperation and Development

4 Effect of biochar amendment on soil carbon balance and soil microbial activity S. Steinbeiss et al, Soil Biology & Biochemistry 41 (2009)

5 See for example: http://www.carbonbrokersinternational.com/ This website states: "we sell sustainable, renewable replacements for fossil fuel. We offer coal substitutes, bio crude oil, activated carbon and soil biochar… Carbon products resulting from the waste conversion process offer an additional revenue stream in the form of biochar, coal substitute and activated carbon. These products can be used as a substitute for coal based activated carbon, metallurgical coke and for power generation, cooking and heating, a fertilizer enhancer/soil amendment, and many other uses currently using coal."

6 See for example Black carbon contribution to stable humus in German arable soils, Sonja Brodowski et al, Geoderma 139 (2007) 220-228

7 See, for example: http://www.alibaba.com/product-free/113485176/Terra_Preta.html

8 Sustainable biochar to mitigate global climate change, Dominic Woolf et al, Nature Communications Vol 1, Article 56, 10th August 2010

9 See for example: Geo-engineering is the artificial modification of Earth systems to counteract the consequences of anthropogenic effects, such as climate change. Large-scale (industrial) deployment of biochar thus qualifies as a geo-engineering scheme. F. Verheijen1, S. Jeffery1, A.C. Bastos, M. van der Velde, I. Diafas,

http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR24099.pdf

Chapter 3: Does the science support the claims?

Part 1: Biochar and the carbon cycle

The UK Biochar Research Centre describes the key premise of biochar being promoted for climate change mitigation: "Annually, plants draw down 15-20 times the amount of CO2 emitted from fossil fuels…Since the plant biomass is relatively constant globally, the magnitude of new plant growth must be approximately matched by harvests, litterfall, etc. Intercepting and stabilizing plant biomass production reduces the return of carbon to the atmosphere, with a relative reduction in atmospheric CO2."[10]

Plants contain over 80% as much carbon as the atmosphere, soils 2.1 times as much[11]. However, ecosystems, including soils, tend to recycle carbon as they recycle nitrogen and other nutrients. This is not the full story: In recent decades, land-based ecosystems have drawn down or sequestered more than a quarter of all the carbon emitted annually from fossil fuel burning and deforestation, while oceans have been absorbing as much carbon again. This is a direct response to climate change, yet as the climate continues to warm rapidly and ecosystems are being degraded and destroyed further, the biosphere might well in the future release more carbon than it draws down, further accelerating warming[12]. The idea behind biochar is to reduce the amount of carbon that is naturally being recycled by plants and soils and instead to 'stabilize' it by turning wood, grasses, crop residues and other biomass into charcoal. A proportion of the carbon in plants would be turned into 'additional' carbon in soils and new crops, trees and other plants would then further capture more carbon dioxide (CO_2) from the atmosphere before once again being removed and charred. Over time, this was reduce the amount of CO_2 that would otherwise have been in the atmosphere and thus reduce global warming. An additional benefit would come from using the energy released during charring (pyrolysis) to replace some fossil fuels that would otherwise have been burnt.

As the UK Biochar Research Centre admits, this would need to be done successfully on a very large scale to make any difference to the climate: "On a scale of millions of tonnes needs to occur, preferably hundreds of millions of tonnes"; others have spoken of billions of tonnes.

The rationale behind biochar for climate change mitigation is thus fundamentally about geo-engineering: It is about manipulating the carbon cycle to 'improve' it by 'stabilizing' large amounts of plant carbon in soils rather than allowing them to be naturally recycled.

For this scheme to work, three conditions would need to be fulfilled:

First, one would need to be sure that a large proportion of the carbon contained in biochar will in fact be stable over long periods.

Second, adding biochar to soils would need to lead to an overall increase in soil carbon. This means it must not cause other soil carbon to be emitted as CO2, at least not a significant proportion of it.

Finally, charring hundreds of millions (or billions) or tonnes of biomass would need to be done without, either directly or indirectly, resulting in more carbon emissions than those 'saved' through biochar. Not only would there have to be a way of avoiding deforestation, wetland or grassland destruction for biochar, but even if residues were used, the carbon 'gains' from turning them into biochar would have to be greater than those from leaving them in the soil would have been.

Even if the biochar 'carbon balance' was indeed positive, one would still have to consider other climate impacts, such as biochar's likely effects on the earth's reflectivity or 'albedo', which also plays an important role in climate change (discussed below).

To further investigate these assumptions, we must first return to the question "what is biochar?" According to Kurt Spokas, a soil scientist with the US Department of Agriculture[13] biochar, though produced mainly for the purpose of carbon sequestration, "covers the range of black carbon forms".

Hence, in order to understand how biochar affects soils, including soil carbon and soil fertility, we need to understand what black carbon is - or rather what the 'range of black carbon forms' are.

What is black carbon and how do different forms of black carbon vary?

Black carbon is generally defined as 'the product of incomplete combustion'. When wood or other biomass is exposed to high temperatures, whether in a wildfire or a charcoal kiln, etc., it undergoes various and complex chemical transformations, starting with hydrogen and oxygen and other volatile compounds being released. If the biomass does not burn completely to ash during a fire, or if the process is controlled and oxygen is limited, then char or charcoal will remain at the end. Furthermore, particularly during an open fire, some of the carbon particles, rather than all turning into carbon dioxide, will instead be released as soot. All of the carbon-rich compounds, ranging from slightly charred logs to charcoal to soot are called black carbon. Yet chemically, they are extremely different. For example, partially charred wood will have a chemical structure similar to the original wood and its particles will be fairly large, at least initially. At the other extreme, soot particles do not resemble the original biomass (or fossil fuels) which they came from in any way - they are virtually identical, no matter what source of biochar they are derived from, and very tiny. Many soil scientists speak of a 'black carbon continuum', ranging from partially charred biomass to soot[14]. In between the two extremes, one can find a whole range of different forms of black carbon, with different chemical properties and components, different molecule structures, differences including in how stable they are and in their ability to adsorb (see footnote[b]) for example nutrients, water or microbes.

This background is essential for understanding the debates about biochar because it explains why, as Kurt Spokas has illustrated, "biochar is not a description of a material with one distinct structure of chemical compositions". Even if one was to only look at studies about biochar produced through modern pyrolysis - which would mean ignoring the vast majority of studies on which claims about biochar are based - one would still be looking at very diverse materials. In modern pyrolysis, temperatures can range from 400°C or even less to as high as 1000°C (more commonly up to 800°C), and biomass can be exposed to high temperatures for half a second to 30 minutes[15]. The type of biomass and the way the biochar is cooled down and stored will also make a significant difference to its properties.

This immediately raises questions about any claims about 'universal' impacts of biochar, for example on soil fertility or soil carbon. If there is a wide range of very different biochars then one would expect their impacts on soils to also vary. The evidence for this will be discussed further below.

How stable is biochar carbon?

According to Johannes Lehmann, soil scientist and Chair of the International Biochar Initiative (IBI), 1-20% of the carbon in biochar will react with oxygen and turn into CO2 relatively early on, while the remainder will be stable for several thousands of years[16]. Is such a degree of certainty really borne out by the evidence? And does it apply to the full range of different biochars in different soil conditions or, otherwise, can anyone predict to which biochars it will apply in which soils?

Claims by Lehmann and other biochar advocates rely largely on three different sources of evidence:

- Laboratory incubation studies, whereby samples of soil with black carbon, or biochar mixed with solutions of microbes are kept at steady and usually warm temperatures for periods of time and then analysed;

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b Adsorption means that particles, such as minerals, nutrients or water adhere or stick to the surface, in this case the surface of biochar particles.

- Studies of older black carbon found in soils, commonly black carbon from former wildfires, but also 'terra preta' (see box);
- Field studies in which losses of black carbon are being measured.

There are problems with each type of evidence.

The UK Biochar Research Centre pointed out in their 2010 biochar review: "*As yet, there is no agreed-upon methodology for calculating the long-term stability of biochar.* " Different studies, including different laboratory incubation studies, rely on different methodologies and their results therefore are often difficult to compare.

Virtually all ***laboratory incubation studies*** have found that some black carbon is turned into CO2 but that most of this 'loss' happens early on and that the rate at which it happens decreases over time. Lehmann and others have argued that this is because a small proportion of the biochar carbon is unstable or 'labile' and will quite quickly be turned into CO2, whereas the remainder of the carbon will be far more stable. Observations of the chemical structures of biochar support the hypothesis that some biochar carbon particles are inherently less stable than others, although a 'two-types-of-biochar-carbon' model is rather simplistic[17]. If one extrapolates from studies which show early biochar carbon losses, the results can therefore be biased and underestimate the length of time the carbon will remain sequestered in soils. But there is another bias in the opposite direction: Many studies have shown that there are soil microbes and fungi which can turn black carbon (even black carbon which chemically appears very stable) into CO2[18]. Soil incubation studies will at best contain a small sample of the microbes, and often none of the fungi that are found in the soils which are studied. What is more, the microbes in the laboratory incubation studies tend to diminish over time for many different reasons, hence biochar losses due to microbes would also automatically diminish[19]. Laboratory incubation studies thus cannot replicate what happens in 'real life' field conditions.

Studies of older black carbon in soils have been undertaken to estimate how long some black carbon can remain in soils. The basic idea is to compare the amount of black carbon found in soils with the amount estimated to have been produced by fires in the past, in order to extrapolate how much would have been lost compared to how much remained stable. There are major problems with this approach: Firstly, when the carbon is dated, the date generally relates to when the original tree or other vegetation grew, not the date it burned down and got partly charred. Secondly, the assumptions about how much black carbon would have been produced by fires in the past rely to a large part on how much biomass carbon is converted to black during fires, yet this conversion rate varies greatly, quite apart from the fact that past fire regimes are very difficult to reconstruct. There is no doubt that the rate of black carbon left behind after wildfires will vary according to the intensity and duration of fires, the type and amount of vegetation burned, etc. A scientific commentary article by Rowena Ball cites literature estimates ranging from 3-40% of original biomass carbon being turned into black carbon during wildfires[20]. A scientific review by Johannes Lehmann et al suggests that on average only 3% of biomass carbon is turned into black carbon during fires[21]. An experimental burning trial in Germany, on the other hand, found 8.1% of the original carbon being turned into black carbon in a wildfire which mimicked what is known about Neolithic swidden agriculture[22]. The maximum 40% biomass carbon to black carbon conversion figure[23] is far higher than what more recent studies have found and indeed a later study co-written by one of the co-authors of the former study suggests a much lower figure (4% of overall biomass carbon and 14% of burned biomass carbon turning into black carbon)[24]. However, the 3% figure suggested by Lehmann et al is at the lowest end of estimates and far below what was measured in the German trial. The differences between estimates are important: If the amount of charcoal historically produced during fires is underestimated then it will appear that a lot more of it has remained stable over long periods. If the original amount of charcoal was 2-3 times higher than estimated by some authors, then only between half and a third as much black carbon will have remained stable in soils compared to the authors' estimates.

Regardless of the methodological problems, studies illustrate a great variety in the average length of time that black carbon remains in different soils in different climate zones. For example, a study by Lehmann et al in Australia suggested that black carbon remained stable in soils on average for 1,300-2,600 years, although that study relied on modeling based on assumptions about past fire patterns which are impossible to verify [25]. A study of Russian steppe soil showed black carbon remaining in soil for a period between 212 and 541 years[26]. On the other hand, a study by Nguyen et al based in Western Kenya found that, on land understood to have burnt eight times over the past century, 70% of the black carbon was lost over the first 30 years[27]. Another study compared two dry tropical forest soils in Costa Rica, only one of which had been exposed to regular fires and thus black carbon formation in the past. Although the soil which had been exposed to regular fires had a higher black carbon content, the "mean values were not significantly different" and, furthermore, the authors highlighted the difficulties in identifying and quantifying black carbon and the lack of an agreed method to do so [28]. The (common) methods which they used had uncertainties of 40-50% and, given those uncertainties, it could not be shown whether or not centuries of regular fires at one site had actually led to the soil having any more black carbon than the other soil where vegetation had not been burned regularly. The studies in Western Kenya and Costa Rica only looked at carbon found in the top 10 cm, so they would have missed counting any black carbon that had moved deeper down in the soil, as could be expected from other studies. A study in Zimbabwe compared black carbon contents of two soils, one protected from fire which had not been exposed to burning for the past 50 years, the other regularly burned during that time. The authors calculated from the differences in black carbon content that the average period for which black carbon remained in the top 5 cm of soil was less than a century[29]. Yet another study, looked at black carbon concentrations in soils underneath a Scots pine forest in Siberia which had been regularly exposed to fire[30]. The authors found low levels of black carbon which they could only partly explain through the fact that less biomass would have been turned into black carbon during forest fires compared to fires in tropical forests. They suggested that black carbon loss through erosion or downwards movements, deeper into the soil, were both unlikely reasons and that, instead, black carbon in the study had "low stability against degradation". The results of studies that look at black carbon naturally found in soils, including due to wildfires, are thus very mixed, suggesting residence times of a few decades to millennia, probably depending on different types of black carbon, climate zones, vegetation etc. – and also on different methods used by researchers. The reasons for black carbon losses in different cases are not known. They may include erosion and downward movement of black carbon,both of which could mean the carbon was still stable, just elsewhere. However, in the Siberian study the authors felt this was not likely. In sum: it is quite possible that most of the black carbon lost in other studies may have been turned into CO2, and there is no way to estimate how much was lost over time without knowing how much was generated in the first place.

Field study indications about the stability of black carbon: Because laboratory studies using sterile soils and controlled conditions have limited applicability, field studies are essential for understanding the impacts of different biochars in different conditions. Unfortunately, the number of peer-reviewed field studies is small. We have found 13 peer-reviewed studies based on 11 different field trials. One of those looked at soil underneath charcoal kilns, i.e. at soil which had itself been pyrolysed[31]. Overall carbon levels were reduced in those soils – but pyrolysing soil is rather different from most people's idea of biochar, where pyrolysed biomass is added to soils which have not been burned themselves. Of the remaining field trials, only five considered the impact of biochar – or rather of crushed traditional charcoal – on soil carbon and in all but one of those studies, the results did not distinguish between black carbon and soil organic carbon previously found in the soil or newly accumulated. The studies, which will be discussed below, thus say far more about the overall impacts of biochar on soil carbon – which is also most relevant to the question whether or not biochar can sequester carbon and theoretically (ignoring land use change), mitigate climate change.

Conclusions about the stability of black carbon

What is certain is that, on average, black carbon does not react with oxygen as easily as other forms of carbon found in soils. After all, some of the tests used to identify black carbon involve exposing carbon to high temperatures of 375°C and/or to acids, on the assumption that all of the carbon that remains after such conditions must be black carbon. It is also clear that some black carbon in certain circumstances will remain in soils for thousands of years – although on the other hand, some soil carbon which is not black carbon and which has is found in deeper soil levels is also several thousand years old[32]. What the evidence does not support is the claim that the great majority of all black carbon will remain stable for long periods -. One scientific literature review[33] suggests that six different factors control the storage and stability of black carbon in soils: Fire frequency (with more frequent fires turning more biomass carbon into black carbon, but also turning more black carbon into CO2), the type of original biomass and the conditions under which it was burned, soil turbation (i.e. disturbance and mixing of different soil layers), the presence of different minerals such as calcium and phosphorous in soils, different communities of microbes, whose ability to degrade black carbon will vary, and land use practices. All those variables, together with the problems linked to measuring black carbon and predicting or deducing its stability, make claims such as the International Biochar Initiative's assertion that "scientists have shown that the mean residence time of this stable fraction is estimated to range from several hundred to a few thousand years"[34] appear rather naive.

Does biochar lead to an overall increase in soil carbon?

There are different reasons why biochar might fail to lead to an overall increase in soil carbon, which do not relate to the stability of the black carbon in the biochar:

One possible reason can be ***erosion, either by water or wind***. If biochar erodes then its carbon will not automatically turn into CO2 but might still remain stable, albeit somewhere else. However, given the different factors which influence its stability discussed above, it will be even more difficult to make any prediction if the biochar ends up in an unknown place under unknown conditions. Some black carbon which ends up washed into in ocean sediments may remain there for longer periods than it would have done in soil[35], for example, whereas some may be transported to sites where it will be exposed to conditions making it less likely to remain stable.

One study, which looked at the fate of black carbon from swidden agriculture on steep slopes in Northern Laos, found that it was significantly more prone to water erosion than other soil carbon, due partly to its low density and weight[36]. The same properties also make black carbon, especially smaller particles, prone to wind erosion[37]. Wind erosion of black carbon raises particularly concerns with regards to global warming impact, which are discussed below.

Another reason why biochar might not lead to an overall increase in soil carbon is called '***priming', i.e. biochar additions causing the loss of other, per-existing soil carbon.*** When carbon-containing matter – whether biochar or any type of organic carbon – is added to soil, it can stimulate microbes to degrade not just newly added carbon but also soil carbon which had previously been relatively stable. [c]. Whether or to what extent such priming happens depends on various and still poorly understood factors. According to the soil research institute SIMBIOS Centre, "to make progress in this area, it would be necessary to first understand why some fractions of the organic matter present in a soil are not degraded under normal conditions (in the absence of priming)"[38] Given the general gaps in knowledge of this priming effect it seems highly unlikely that any one study could 'prove' whether or not biochar will always cause priming and thus the loss of existing soil carbon, or how serious this effect will be. After all, priming depends on the responses of different soil microbes, yet scientists have so far only been able to culture and thus closely observe 1% of soil bacteria species and none of the multitude of varieties of soil fungi [39]. A widely reported Swedish study involved placing mesh bags containing charcoal or humus or a 50:50 mix of charcoal and humus into boreal forest soil for a period of 10 years. At the end of the trial, the amount of carbon in the mesh bags with the charcoal and humus mix was significantly less than could have been expected from the carbon contained in either the charcoal or the humus bags [40]. A comment by Johannes Lehmann and Saran Sohi argued that the results may reflect the loss of carbon in charcoal and that 'priming' might be less likely because most of the carbon loss occurred during the first year of the trial [41]. In response, the authors pointed to the fact that very little carbon was lost from the charcoal-only bags and that most 'priming', by its nature, occurs early on [42]. Different biochar studies, most of them laboratory ones, have had very different results: some demonstrated biochar can cause microbes to turn existing soil carbon into CO_2, others demonstrated that it may have no effect on losses of existing soil carbon and that, in some circumstances, it can even reduce losses (an effect called 'negative priming'). One laboratory study looked at the impact of 19 different biochars on five different soils, in each case using a very high rate of biochar application, equivalent to 90 tonnes per hectare [43] Initially, biochar additions increased the rate at which existing non-black soil carbon was lost in most of the biochar- plus-soil combinations. Later on in the trial, a variety of outcomes were evident: in some, the rate of soil carbon loss continued to be higher with than without biochar (though the rate of carbon loss slowed compared to what it had been early on in the experiment), in others, there difference disappeared and in yet others, soil carbon losses were slowed down in the presence of biochar. One problem with that study however is that all soil and biochar samples were inoculated with soil microbes taken from a forest floor, not from the actual soils being tested, which means that the microbes which degraded some of the carbon were not the ones which would have been present had this been a field rather than a laboratory trial. Priming has also been observed in other laboratory studies. For example in one study switchgrass residue was added to soils with biochar, the biochar increased carbon losses from that residue[44]. In sum: biochar can cause a proportion of other carbon in soils to be turned into CO_2, but this effect depends on the particular type of biochar, as well as the nature of the soil and on any organic residue added to soil and is thus very difficult to predict, particularly since relatively few studies have been published which look at this possibility.

Field study results

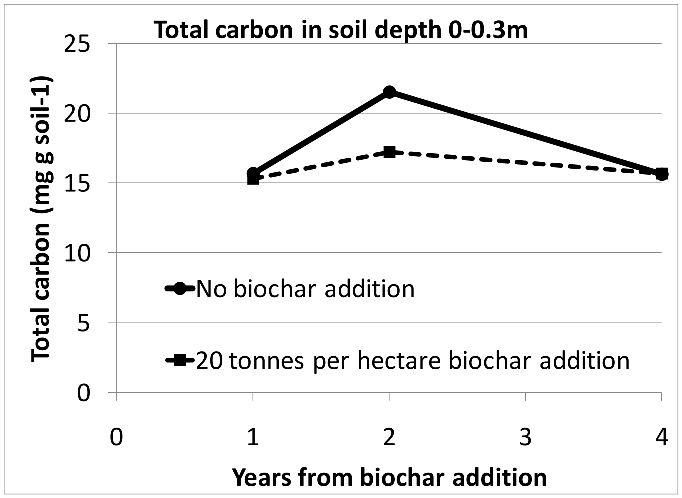
The five peer-reviewed field studies which look at biochar impacts on soil carbon do not clearly identify what exactly happened to which type of carbon in soil. Nonetheless, they provide the best 'real-life test' of the claim that biochar, at least at the field level, can be relied on to sequester carbon. So far, only two biochar field trials have been published which have lasted for more than two years, both of them four-year long trials. A larger number of longer- or even medium-term field studies would show more clearly how different biochars impact carbon in different soils. What

c For the purpose of this report, we are using the term 'priming' only to refer to biochar stimulating soil microbes to degrade other carbon in soil and residues. Elsewhere, however, it is also used to refer to the loss of biochar carbon through microbes, stimulated by other soil carbon, an issue discussed separately above.

those published so far show, however, is that biochar impacts on soil carbon are variable, unpredictable and by no means always positive.

Field trial on savannah soil under a maize and soya rotation, Colombia[45]

This was a four-year field study, in which biochar at the rate of 0, 8 and 20 tonnes per hectare was applied (together with the same fertilisers) to relatively carbon-poor soil from which savannah vegetation had just been cleared. Maize and soybean were grown in rotation. Total soil carbon was tested after one, two and four years although on the plots with 8 tonnes/hectare of biochar, it was only measured once, after four years.



In the first, third and fourth year, there was no statistically significant difference between amounts of carbon in different plots. Even a high biochar rate of 20 tonnes per hectare had not increased soil carbon. In the second year, the plots which had been amended with biochar held significantly less carbon than those without. It is not known how much of this was due to the loss of biochar or other organic carbon, although biochar had effects on crop yields and soil properties through the trial, so at least some of it must have remained in the soil, making the loss of other soil carbon ("priming") more likely. In the third and fourth year, carbon levels recovered on the plots with biochar, though they did not exceed the control plots and this is understood to be due to higher crop yields. Greater crop growth and yields will, temporarily, lead to crops depositing more carbon in the soil.

Field trial on savannah soil under regrowing native savannah vegetation, Colombia[46]

This was a two-year trial in the same region as the four-year one discussed above. Native savannah vegetation was removed before biochar application but then allowed to regrow. Biochar was applied at the rates of 0, 11.6, 23.2 and 116.1 tonnes per hectare. ***After two years, there was no statistically significant difference in the amount of carbon found in the top 30cm of soil between the plots with no biochar and those with 11.6 or 23.2 tonnes of biochar per hectare.*** Only a very large amount of biochar addition - 116.1 tonnes per hectare resulted in significantly higher carbon levels, than control plots. It is uncertain what happened to the 'missing carbon'. The authors of the study measured the amount of black carbon and other carbon emitted as CO2 from the soil ('soil respiration') and found that only 2.2% of the biochar carbon was lost that way. Other soil carbon was lost at a higher rate from plots with biochar, than from those without biochar – 40% higher in the first and 6% higher in the second year, but that was not enough to account for the missing carbon. There may have been problems with those measurements in that they were supposed to have been done on small 'rings' kept free from vegetation, but the authors suggest that the readings might have been influenced by plant growth, which indicates that the rings might have got overgrown, which would have distorted the results.

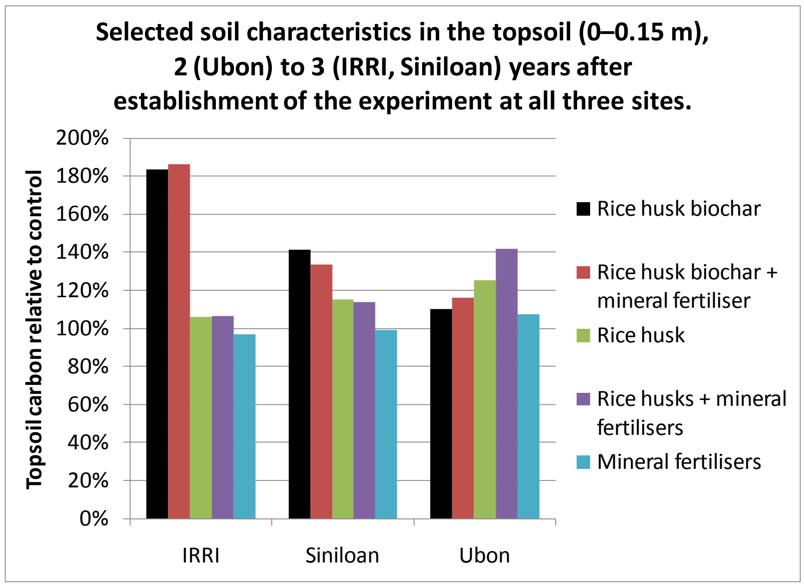
According to the lead author water erosion may have played an important role [47]. However, erosion was not measured and it appears surprising in that the ground was relatively flat and savannah vegetation would have grown back very quickly, which should have minimised or stopped water erosion. In sum: the results indicate that very large amounts of carbon simply disappeared and are unaccounted for.

Field trial in Central Amazonia, Brazil, under rice and sorghum cultivation[48]

Results from two years of a field trial in Central Amazonia have been published. This took place on the same type of highly-weathered soil from which Terra Preta is understood to have been created. Secondary forest was cleared for the trial and different plots were amended with different combinations of mineral fertiliser, charcoal, chicken manure, burned and unburned leaf litter and compost. They were then cultivated first with rice and then with sorghum. ***After five months, soil carbon was measured. Total soil carbon was not significantly higher when charcoal or most of the combinations including charcoal were used, compared to controls.*** They were only significantly higher for a combination of charcoal plus mineral fertiliser plus compost. After the second harvest, soil carbon was only measured on control plots, those with mineral fertilisers only and those with combinations of compost and charcoal. Plots with either compost and charcoal plus mineral fertilisers had higher total carbon than those with compost only or mineral fertilisers only (those with charcoal only were not tested for soil carbon at that time). No carbon measurements were done for the two later harvests.

Field trial in the Philippines, under rice cultivation[49]

This was a four-year field trial on three different soils under rice cultivation in the Philippines. Different plots were amended with 1) biochar made from rice husks (at a rate of 16.4 tonnes/hectare) or 2) uncharred rice husks, with or without mineral fertilisers, or 3) left unamended or 4) with mineral fertilisers only.

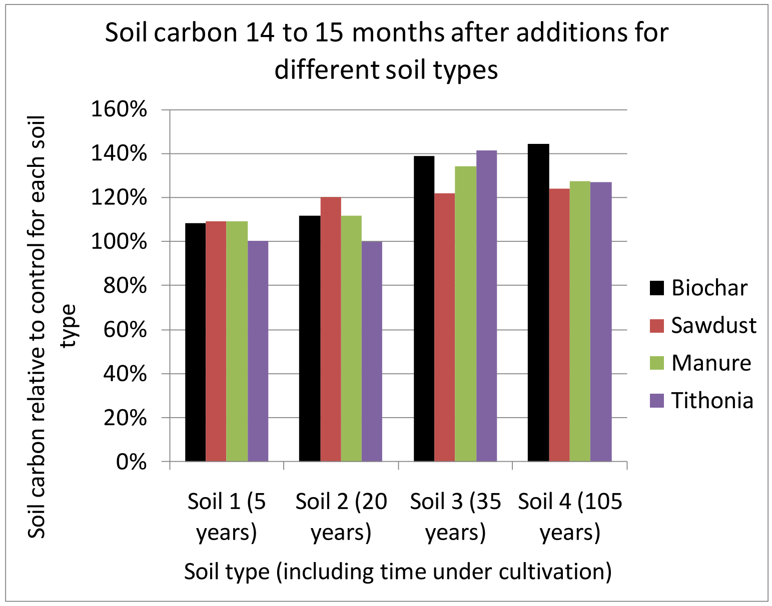


After 2-3 years, soil carbon levels were higher on plots with biochar (with or without fertilisers), compared to both control plots and those with uncharred rice husks on two types of soil. On the third soil, total carbon was higher on the plots with biochar compared to the control plots or those with fertiliser only, but they were highest on plots amended with uncharred rice husks.

Field trial in Western Kenya under maize cultivation[50]

An 18 month study was conducted on four different soils, which differed according to how long they had previously been under continuous cultivation – 5, 20, 35 and 105 years. The longer the soils had been under cultivation, the less carbon they contained. For each soil, plots were amended with biochar, manure, sawdust, fresh Tithonia leaves (commonly used as green manure) or left as controls. At the end of the trial, biochar-amended plots had the highest carbon concentrations on only one of the four soils – the one which had been cultivated the longest. On another soil, biochar, manure and Tithonia all raised carbon levels compared to controls, with no significant difference between them; on a third, sawdust resulted in the highest carbon levels and on another, there was no significant difference in soil carbon between any of the plots, including controls. Thus, although biochar increased soil carbon compared to plots without any amendments, it did not perform any better in that respect than other organic residues.

Summary results from field studies



The five relevant field studies involved 11 different soils/vegetation. If we look at those as 11 separate 'samples' then there would have been no carbon sequestration compared to unamended control soils on five samples (excluding the unrealistically high rate of 116.1 tonnes/hectare in one of those trials) and a temporary net carbon loss linked to biochar on one of those. In three samples, biochar resulted in higher total carbon compared to largely unamended soils, but not when compared to common alternative soil amendments. And in three samples, biochar did result in more carbon sequestration than the alternatives tested, though a different range of alternatives was used in different studies. The basic proposition of most carbon sequestration offset projects – an increase in soil carbon compared to what would have happened in the absence of the project (i.e. common farming practices in an area) – would thus have been met in only three out of eleven cases, at least over the short duration of the trials.

Part 2: Climate impacts of airborne biochar

When black carbon becomes airborne, it absorbs solar energy rather than reflecting it back into space and thus contributes to global warming. The effect is worsened when black carbon particles, which can travel for thousands of miles, are deposited on snow or ice and accelerate melting[51]. The warming effect of black carbon is short-lived but so powerful that NASA scientists suggest that, evened out over a century, airborne black carbon particles have 500-800 times the warming effect of a similar volume of CO_2[52]. Airborne black carbon has been mainly discussed in the context of soot, since soot particles are particularly small, i.e. in the submicron range. However, some fresh biochar particles are in the same size range as soot which would make them as liable to becoming airborne, as dust particles which can also become airborne. For example, in a non-peer-reviewed field trial study in Quebec "an estimated 30% of the material was wind-blown and lost during handling, transport to the field, soil application and incorporation"[53]. The particle size of the biochar produced by the company which supplied that trial was analysed by the Flax Farm Foundation, who found that it "approaches a low of 5 µm in size"[54]. This is smaller than the size of many (airborne) soot particles. Furthermore, according to a report published by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), "the size of biochar particles is relatively rapidly decreased, concentrating in size fractions <5µm diameter"[55]. In other words, over time, larger biochar particles are likely to also break down to the size of black soot particles. Given that wind erosion of black carbon is well documented[56], it seems surprising that no scientific literature has been published about the potential warming effects of airborne small biochar particles. The magnitude of the warming effect of black carbon in the atmosphere is such that, if even a small proportion of biochar particles was to become airborne, this is likely to reverse any of the proposed 'climate benefits' of biochar (themselves unproven).

Part 3: Biochar impact on nitrous oxide emissions from soils

Nitrous oxide is the third most important greenhouse gas involved in global warming, after carbon dioxide (CO2) and methane. Its warming effect is about 300 times as strong as that of the same volume of CO2. Nitrous oxide is produced by soil bacteria as a natural part of the nitrogen cycle, but the amount produced that way has been greatly increased by the use of nitrogen fertilisers as well as fertilisation with large quantities of manure.

The International Biochar Initiative's prediction about the amount of greenhouse gas emissions that could be 'offset' by biochar relies partly on the assumption that biochar will reduce the amount of nitrous oxide emitted from soils[57]. However, only one peer-reviewed field trial has looked at the effect of biochar on nitrous oxide emissions. That trial, which took place on pasture in New Zealand, compared the impacts of 15 and 30 tonnes of biochar per hectare compared to none when added to patches of cow urine[58]. The higher amount of biochar reduced N2O emissions from the cow urine by 70%, but the lower amount had no statistically significant impact. According to the UK Biochar Research Centre review, only one peer-reviewed (short-term) laboratory study exists which found reduced nitrous oxide emissions with biochar use. A greenhouse gas trial in Colombia reported to have shown a 50% reduction in nitrous oxide emissions from soybean production with biochar, was never published[59]. Three laboratory studies with conflicting results also remain unpublished. There thus appears to be far too little evidence for drawing any conclusions about biochar impacts on nitrous oxide emissions.

TERRA PRETA

Terra preta soils, found in Central Amazonia, are frequently cited as 'evidence' for the beneficial properties of biochar in soils. The soils, which are highly fertile and rich in carbon, including black carbon, are found mostly in patches of, on average, 20 hectares , though in some cases up to 350 hectares, mostly, though not exclusively, along the Amazon and its tributaries. Terra preta soils are associated with past farming practices by indigenous communities around 500 to over 2,500 years ago. According to the Food and Agriculture Organisation, "the knowledge systems and culture linked to the Terra Preta management are unique but have unfortunately been lost"; what is, however, known is that it the farming methods involved "diverse organic nutrient sources...such as fish residues, turtle shells, weeds and sediment from the rivers, manures, and kitchen waste other than fish" . Furthermore, Terra preta is characterised by an abundance of pottery shards and minerals left behind from ceramics Sediments from seasonal river flooding played a role in at least some places and evidence that perennial trees and shrubs as well as long-crop cycles all played a role in those pre-colonial farming methods. Charcoal was thus only on component in a complex biodiverse farming system and soils amended with biochar, unsurprisingly, have different properties from Terra preta.

Part 4: Biochar and crop yields

According to the International Biochar Initiative, biochar can boost food security, discourage deforestation and preserve cropland diversity...Biochar can improve almost any soil. Areas with low rainfall or nutrient-poor soils will most likely see the largest impact from addition of biochar"[60]. This claim suggests that biochar will usually improve crop yields.

The large variations between different biochars as well as different soils suggest that impacts on crops are likely to differ, too. The UK Biochar Research Centre review identifies the different ways in which biochar can affect crop yields, which are discussed below. The additional comments and explanations about each effect are the authors', i.e. not taken from the UKBRC report.

a) As discussed above, a proportion of ***biochar carbon*** is easily degradable and ***provides food for soil microorganisms***. Those microorganisms will then build up stores of nutrients in soils which are needed by plants. However, this can also be a negative short-term effect: Compared to plant residues, compost or manure, biochar contains a high proportion of carbon relative to nitrogen. If a soil is already nitrogen limited, then microbes, stimulated by the carbon which they digest, can proliferate and out-compete plants – using up the accessible nitrogen. This can suppress plant growth and thus crop yields temporarily, during the first harvest or year.

b) Fresh biochar contains different proportions of ***ash, which is rich in minerals*** and benefits plant growth. This is a temporary positive effect, allowing biochars rich in ash to serve as a fertiliser early on, until the minerals have been depleted. That fertiliser effect may be delayed and extended if minerals adsorb to the pores in the biochar and thus become available to plants only more gradually.

c) Most, though not all, biochars are alkaline. Adding anything alkaline – including ***alkaline biochar - to acidic soils*** can boost plant growth. This is because acidic soils make it less possible for plants to absorb key soil nutrients, such as nitrogen, phosphorous, potassium, calcium and magnesium. Furthermore, acidic soils have increased concentrations of some trace metals, such as aluminium, which are toxic to plants in larger quantities. Biochars can only make soils more alkaline for a limited period of time, possibly a few years.

d) One important measurement of soil fertility is called the ***Cation Exchange Capacity (CEC)***. The CEC measures the ability of soils to hold and to release to plants various different elements and compounds, including soil nutrients such as calcium, magnesium, potassium and sodium. It is important for the ability of soils to retain nutrients and to protect groundwater from some forms of contamination. Highly-weathered tropical soils tend to have a low CEC, whereas the CEC is high in Terra Preta. The high CEC of Terra Preta, appears to be linked to the black carbon content, and so improving CEC has been cited repeatedly as a likely 'benefit' of biochar, including by companies[61] There are two problems with that claim: First, soil scientists distinguish between the 'potential CEC' and the 'effective CEC' and the latter is thought to be linked most closely with soil fertility, yet that is not particularly high in Terra preta, which means that different properties may be responsible for the high fertility of those soils [62]. Secondly, it is thought that the charcoal remains in Terra preta would only have gained a high CEC over time, as a result of slow changes to black carbon in soils over a long period of time[63]. According to a laboratory study in which samples of biochar was incubated for a year at different warm and high temperatures, it was concluded that it would take around 130 years for biochar particles to have undergone the changes found in black carbon particles in Terra preta which are responsible for Terra preta's high CEC[64]. Although some increase in CEC could be expected sooner, especially in a warm climate, it is still a very slow process, except in the case of certain biochars such as those made from cow manure[65] or some biochars produced at relatively low temperature, around 350°C[66].

e) Other changes to soil properties: All biochars are porous. Depending on their pore sizes and distribution (which vary greatly), they can hold water and adsorb various chemicals, including nutrients, pesticides, etc. It is also thought that the porous and light nature of biochar can help to improve the structure of compacted soils and improve soil aggregation[d]. Again, the effects which different biochars of different ages have on different soils vary greatly. For example, the impact of biochars on the water holding capacity of soils varies with different biochars and different soil types and the 'positive' impact can be reduced or negated by the fact that fresh biochar particles can be water-repellent. For example, in a laboratory trial, biochar produced through fast pyrolysis increased the water holding capacity of a sandy loam soil by nearly one third, but biochar produced through slow pyrolysis had a very small impact on water retention, apparently too small to be statistically significant[67]. And in a laboratory study which looked at the impact of two different

d Well aggregated soils are ones in which soil particles are hold together well, for example by organic matter, moist clay, fungi, etc. and which are more stable and less prone to erosion. Pores within and between 'clumps' of soil particles allow air, water, microbes, nutrients and organic matter to be stored.

biochars on three soil types from Ghana, the water holding capacity was increased, but it was higher when biochar was applied at a relatively low rate of 5 tonnes per hectare compared to a higher rate of 15 tonnes/hectare[68].

f) Providing a habitat for micro-organisms: At least some biochars have pores large enough to provide shelter for various soil microbes as well as the hyphae[e] of beneficial fungi, and helping microbes and fungi to access nutrients. Of particular interest is the link between black carbon and mycorrhizal fungi, small, diverse fungi which enter into a usually symbiotic relationship with plant roots, helping plants to access various mineral nutrients and receiving sugars in return. Terra preta appears to provide a rich habitat for mycorrhizal fungi. There are several different ways in which black carbon could support such fungi, as well as other microorganisms, although biochar's high ratio of carbon to nitrogen could, in the short term, have a negative impact on microorganisms as described previously[69].

What do field studies show?

The lack of longer-term field studies makes it impossible to predict what the long-term effects of different biochars on soil fertility and soil properties will be. Long-term effects are particularly important because of the relatively large quantities of biomass required to produce biochar. Most trials have involved applying biochar at a rate of at least 10 tonnes per hectare, which would require at least 40 tonnes but more likely 50-60 tonnes of biomass to produce. If biochar could be relied upon to raise crop yields or, more likely, to reduce the use of mineral and/or organic fertilisers over long periods, this would increase the likelihood of it becoming economically viable without subsidies or carbon offsets, at least for large farmers, agribusiness and other plantation companies who can afford upfront payments and investments. For example, interim results of a Cornell University Life Cycle Assessment suggest that several decades of expected higher yields with lower fertiliser use greatly increases the economic potential of biochar[70].

So, does biochar application reduce fertilizer demand and increase crop yields? What is the evidence? Eight of the peer-reviewed field trials which we have found look at biochar impacts on soil fertility. Those include the trial involving 'charred soil' rather than biochar, leaving us with seven relevant field trials.

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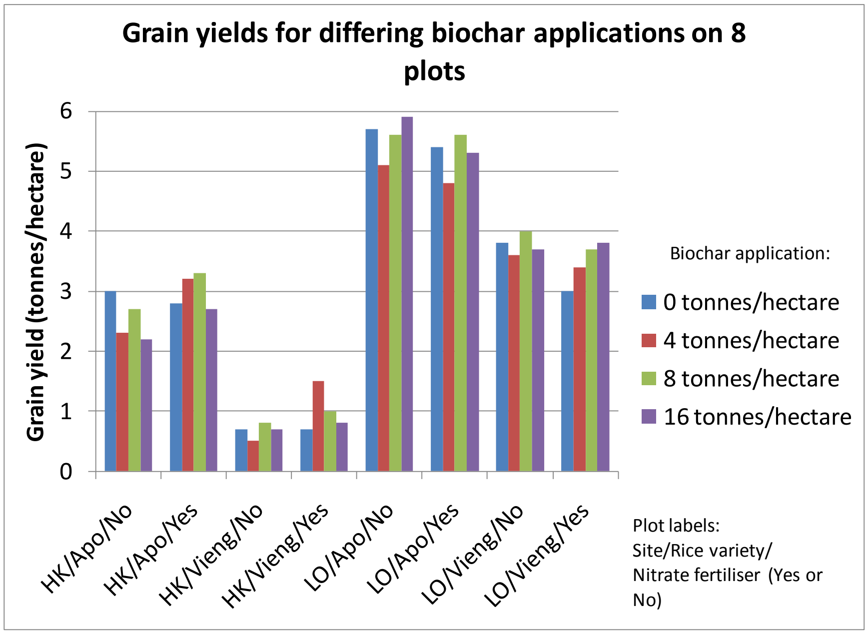
e Hyphae are the long, branching structures which most fungi have and on which they rely to access nutrients.

Field trial involving biochar for rice production in Northern Laos[71]

This was a six-month trial which involved three different field experiments, involving traditional charcoal applied at rates of 0, 4, 8 and 16 tonnes/hectare, with and without mineral fertilisers, with two different rice varieties grown. Impacts on crop yields varied greatly, from negative to neutral to positive.

Biochar appeared to increase the water holding capacity of soils, but to reduce the availability of nitrogen to plants, particularly if used in larger quantities.

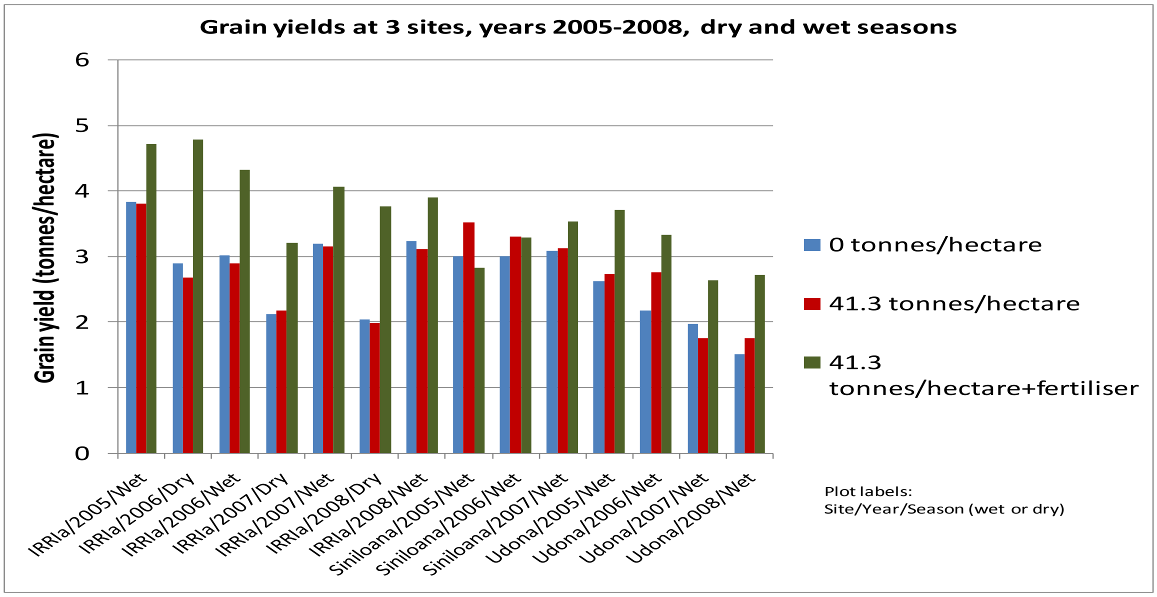


Field trial looking at the impacts of pine chip and peanut hull biochars on soil cultivated with maize in the SE US[72]

This was an 18 month trial using biochars made from either pine chips or peanut hulls at rates of 0, 11 and 22 tonnes per hectare, with and without nitrogen fertilisers. The maize was irrigated, though not enough to prevent drought stress in the second year.

Field trial in the Philippines, under rice cultivation[73]

This trial has been described above in relation to soil carbon impacts. At one site, the effect of biochar on grain yield was generally negative, possibly due to the high proportion of carbon in relation to nitrogen, which may have suppressed nitrogen take-up by plants. At the second site, different treatments with fertilisers and/or biochar made little difference overall. At the third site, combinations involving biochar mixed with mineral fertilisers and/or rice husks achieved the highest yields during three of four harvests, but biochar on its own had no effect.

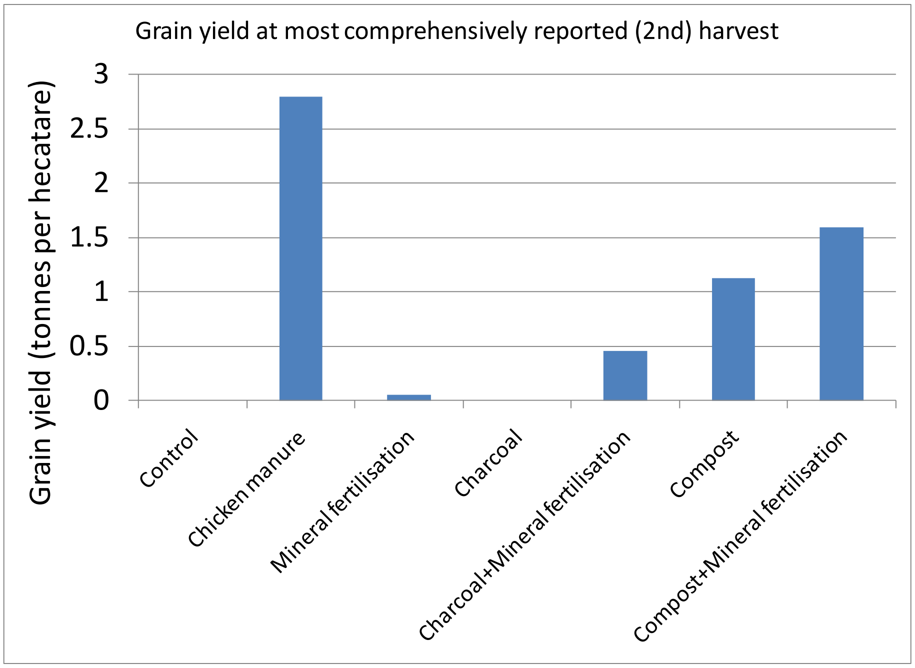


Field trial on savannah soil under a maize and soya rotation, Colombia[74]

This trial has been described above in relation to soil carbon impacts. Maize yields were measured annually for four years, soybean yields during the fourth year only. During the first year, biochar had no statistically significant impact on crop yields. During subsequent years, it raised maize yields, applying 20 tonnes per hectare of biochar raised maize yields more than 8 tonnes per hectare. In the fourth year, all maize yields declined sharply, although yields on plots with biochar were significantly higher than those on control plots, on which only mineral fertiliser had been used. Soybean yields were not affected by biochar.

Field trial in Central Amazonia, Brazil, under rice and sorghum cultivation[75]

This trial has been described above in relation to soil carbon impacts. Both overall biomass and grain yields were highest when chicken manure was applied, followed by a combination of compost and mineral fertilisers. Applications of biochar on its own were associated with the lowest yields other than those for control plots and in the second year, soil amended with nothing but charcoal did not support any growth of crops at all.



Field trial in South Sumatra, under maize, cowpea and peanut cultivation[76]

This was a short, three month trial, with three different sites. The experiments at two sites took place a year earlier than those at the third. Traditional charcoal was produced from Acacia wood waste from pulp and paper production and applied to fields on which maize, cowpea and peanut were grown. Three different locations were selected: One was located in the garden of a farmhouse, a second in a garden reclaimed from a chicken farm, and a third on former grassland which had recently been turned into farmland. The two treatments compared at the first site were mineral fertiliser alone and mineral fertiliser combined with charcoal, with control plots being unfertilised and unamended. At the first site, yields of maize and peanut were significantly greater when charcoal and fertilisers were combined than when fertiliser alone was used, whereas charcoal had no significant impact on cowpea yields. Maize yields doubled when charcoal was added to fertilisers. At the second site, there was no statistically significant difference between the two treatments, both of which raised yields compared to the unfertilised control plots. At the third site, overall maize yield increased significantly when charcoal was added to fertilisers and resulted in similar yield increases when it was applied on its own, compared to plots amended with mineral fertilisers only.

This is the only field trial described here which did not use the "randomised block design with replicates" method which has been described as good practice in the International Biochar Initiatives guide to biochar field trials. This makes the results of this study less reliable than others.

Field trial in Western Australia under wheat cultivation[77]

This was a short, 3-4 months field trial on acidic sandy clay loam in Western Australia. Charcoal was made from oil mallee (Eucalyptus oleosa) after extraction of the oil. Different combinations of charcoal, at rates of 0, 1.5, 3 and 6 tonnes per hectare and either water-soluble mineral fertilisers or slow-release mineral fertilisers inoculated with mycorrhizal fungi were tested, with nitrogen and phosphorous fertilisers applied to all plots. When soluble fertilisers were used, only one biochar combination out of six (6 tonnes per hectare of biochar and 30 kg/hectare of fertiliser) significantly improved yields. Biochar raised yields in combination with the inoculated mineral fertilisers.

Summary findings from field studies

Field trials illustrate the variable and as yet unpredictable impact which biochar has on crop yields, which can be positive, negative or neutral, depending on different types of biochar, soils and even crop varieties, and on combinations with different organic and mineral fertilisers. Although biochar researchers are looking at the possibility of producing 'designer biochars' for different conditions, the large variation in impacts compared to the small amount of field data makes it difficult to see how this would be possible or practical, at least in the foreseeable future. Given how inconsistent biochar impacts on yields are and how little is known about their longer-term impacts, farmers who are to use biochar on their fields are taking considerable risks, even more so if they have to invest in producing or purchasing the biochar, rather than taking part in a trial in which biochar was supplied for free.

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Chapter 4: Biochar – The Policy Context

The push for commercial scale biochar production focuses largely on 1) securing funding via carbon markets and 2) securing subsidies for biochar research, development and deployment, including as a by-product of pyrolysis for bioenergy.

The main lobbying force is the International Biochar Initiative (IBI), which has been effective in promoting biochar at international, regional and national levels worldwide. The IBI is complemented by a number of regional biochar initiatives, including Australia and New Zealand, Canada, China, Europe, India, Japan Mongolia, Thailand and the US. Some of these are rather small, but others more active and growing. These initiatives are comprised largely of academic researchers, business entrepreneurs (including those developing biochar- producing stoves) start-up companies, bioenergy companies with interest in pyrolysis and gasification and carbon offset and other consultancy firms. A small number of NGO groups, including the French NGO Pro-Natura and the US-based Clean Air Task Force are also instrumental. The well-connected but low-profile US bioenergy lobby group Renew the Earth regards itself as the founder of the IBI in 2007, under its previous name, International Agrichar Initiative. Two leading IBI members are on Renew the Earth's Board of Directors.

Finally, several representatives of industrial agriculture and tree plantation interests have expressed an interest in biochar, amongst them the former executive director of the Indonesian Palm Oil Association (GAPKI), Didiek Goenadi, who presented at the IBI's 2008 Conference. In Indonesia, at least three pulp and paper companies, PT Musi Hutan Persada and PT Tanujngenim Lestari Pulp and Paper have taken part in studies looking at the potential of biochar for carbon offsets[78]. Malaysian researchers looking at biochar production from oil palm plantation residues and the manager of the Norwegian company Green Resources, who are investing in monoculture tree plantations for 'carbon offsets' in East Africa, has publicly supported biochar[79]

What does the biochar lobby seek?

Fundamental to who, what and how biochar advocacy is carried out is the fact that there are very divergent approaches to the issue of scale. On the one hand, visions for different biochar systems differ according to project scale, ranging from cookstoves to large pyrolysis plants, which are not mutually exclusive. On the other hand, different biochar advocates have different ideas about the scale of global use. Where biochar has been promoted to organic farmers in North America or Europe, for example, the emphasis has been on its use as a small scale, supposedly farmer friendly technology. On the other hand, the IBI foresees very large scale biochar use, sufficient to offset or sequester a sizeable proportion of annual carbon emissions. Some IBI members have openly spoken about using biochar for geo-engineering, whilst others have talked about converting hundreds of millions of hectares to biochar plantations. For example, IBI Advisory Committee Member and Founder of the Society of Biochar Initiatives, India describes himself as a "geo-engineering initiator"[80], while former IBI Advisory Committee member, the late Peter Read, called for the conversion of up to 1 billion hectares of land to produce biochar[81]. Outside the IBI, Tim Lenton and Nem Vaughan from the University of East Anglia described biochar as the most promising geo-engineering strategy in a peer-reviewed article[82] and the head of the climate unit at the European Commission's Joint Research Centre, Frank Raes, has described it as 'geo-renovating' or 'soft geo-engineering'[83]. However, it appears that IBI members have been increasingly reluctant to use the term geo-engineering or to publicly advocate large-scale land conversion for biochar production, even if this is what they promote – likely in response to the growing criticism of such plans. The most high-profile example of this was an article about the potential for 'sustainable biochar' to mitigate climate change, published in Nature Communications in August 2010 to which senior IBI members had contributed[84]. The study was widely reported in the media as having shown that biochar from waste and residues alone could 'offset' 12% of global greenhouse gas emissions every year. For example, BBC News reported that: "*The vision put forward is of a world where waste is burned, where some of the heat from that burning is used to transform waste to* *charcoal, and where the charcoal is ploughed into soil, increasing its capacity to support crops and locking up carbon for centuries, possibly millennia."*[85] Neither the authors nor the IBI appear to have challenged or corrected this interpretation. Instead it was left to 21 civil society groups to point out that the data which the authors used for calculating the presumed 12% greenhouse gas offset potential included the conversion of hundreds of millions of hectares of land to produce biochar feedstock[86]. One of the authors of the original article later clarified the data on which their figure actually was based, which was significantly larger than what the civil societies had assumed[87] – 566 million hectares in total. Those land figures were published neither in the article nor in the supplementary data but could only be deduced from references. It appears that for some biochar advocates the decision to refrain from speaking about large-scale land conversion and geo-engineering in public appears to merely be a tactical decision about communication. As discussed in chapter 3. The basic premise of climate change mitigation through biochar is by its nature based on a large-scale geo-engineering vision.

Biochar and Poverty

Biochar and the "Evergreen Revolution":

Much biochar advocacy is focused on promoting biochar as a means of addressing poverty and/or reducing deforestation. According to the French NGO Pro Natura, biochar could lead the way towards a 'Third Green Revolution': "*The Green Revolution...was instrumental in greatly increasing the agricultural output of the lucky minority of farmers throughout the world who had enough money to buy seeds, fertilisers, and access to water for irrigation. Hence the importance of the second wave 'Evergreen Revolution'...directed at the needs of the masses of small farmers...With biochar we now find ourselves on the threshold of a third wave, even more universal in its application.*"88 In chapter 3, we show that claims about long-term reliably higher yields with biochar production are not backed by the existing science. What is of interest here is the policy context and the assumption made by IBI member Pro-Natura. Behind the claim that biochar can reduce malnutrition and hunger are two assumption: First, that biochar will reliably increase crop yields. This is explored in chapter 3, where we show that those claims are not backed by findings from field trials. Secondly, that current practices by small farmers are commonly associated with low crop yields and soil depletion and that this is a significant cause of malnutrition/hunger. This second assumption ignores the political, social and economic context behind large-scale and increasing hunger and malnutrition as well as soil depletion and other environmental degradation. It runs counter to the realities expressed by La Via Campesina: "*The contemporary food crisis is not really a crisis of our ability to produce. It is more due to factors like the food speculation and hoarding that transnational food corporations and investment funds engage in, the global injustices that mean some eat too much while many others don't have money to buy adequate food, and/or lack land on which to grow it, and misguided policies like the promotion agrofuels that devote farm land to feeding cars instead of feeding people."*[89] Yet the policy context defined by Pro-Natura is not simply one in which international trade and the role of transnational food corporations and agribusiness are ignored: By linking their vision of a biochar 'Third Green Revolution' to the so-called 'Evergreen Revolution', they are linking it to policies which involve more trade liberalisation and more agricultural policies which seek to replace traditional knowledge and practices by small farmers (including, by implication, agro-biodiversity) with agricultural 'techno-fixes', including GMOs[90], to be transferred by Governments such as the US, academic 'experts', many of them trained at or supported by US universities, and undoubtedly, agribusiness. This is illustrated in a recent "Evergreen Revolution Partnership" agreement between the US and Indian Governments[91]. The 'Evergreen Revolution' association chosen by Pro-Natura is particularly interesting because of the crucial role played by Cornell University both in biochar advocacy and the Green Revolution. Not only did Cornell University provide much of the training and 'expertise' for the original Green Revolution in South Asia, but they have been given a key role in training for and implementing A Green Revolution for Africa (AGRA), with the new Chair of the Alliance for a Green Revolution for Africa, Kofi Annan, linking this to the "Evergreen Revolution" blueprint[92]. Cornell University are, at the same time, a leading centre for biochar research and development, with the Chair of the IBI, Johannes Lehmann an Associate Professor at Cornell's Department of Crop and Soil Science, and they have been awarded funds for deployment-oriented biochar work for example by the Gates Foundation[93] , also major funders of AGRA. Biochar as one part of this "Evergreen Revolution" model may well be a more likely prospect than the "Third Green Revolution" based primarily on biochar which Pro-Natura envision.

Biochar trials and projects

A large number of trials are supported by northern biochar interests, and implemented in Southern countries. A small number of those trials are scientific field trials which look at different biochar impacts. The greater number of the so-called 'trials' in Africa, Latin America and Asia, however, have been initiated by companies, biochar organisations and NGOs, not as scientific field-trials with results to be published as peer-reviewed articles, but as projects to prepare for larger-scale commercialization.

For example, the IBI and various companies, have initiated projects in Latin America. A biochar "feasibility" project involving Carbon Gold and the Toledo Cacao Growers Association in Belize is said to have had initial support from the Cadbury Foundation. Also a project in Costa Rica, with support from the IBI, is using a small pyrolysis facility to produce biochar from timber and oil palm plantations with the hopes of a "possibility of eventual carbon credits."94 Embrapa, the state-owned Brazilian Agricultural Research Corporation (affiliated with the Brazilian Ministry of Agriculture), is represented on the IBI science advisory board, and has supported trials through a biochar research program, a "terra preta" conference in 2002, and, as partner with IBI, hosted the 2010 International Biochar conference in Rio de Janeiro.

At least 28 projects and project plans have been announced in 13 African countries.[95] The largest are projects initiated by the (Belgian) Biochar Fund in Cameroon and DR Congo and another project by the (French) Centre for Rural innovations in Cote D'Ivoire. Many others are projects initiated by foreign biochar interests, and some with connections to the IBI.

The questions which must be asked are: do these projects actually benefit the mostly subsistence farmers who are brought into the trials? What impact does their participation in an experimental study of biochar have on their lives? Is land and labor diverted taking an overall toll on their productivity? Are they fully informed not only about the purported benefits but also about the potential risks? Are they properly instructed with regards to how to safely handle biochar to avoid breathing dust or otherwise avoid being exposed to risks? Are they fully informed about the results of previous studies? Or are they told biochar is likely or even guaranteed to improve crop yields? As we have seen in chapter 2, the results of field tests suggest that is very unlikely that the results of all or most of the trials would have been a net benefit for participants.

In several cases, very favourable images – smiling farmers with healthy crops etc - are offered with optimistic claims about the successes of these projects initially. But no independent assessments are available. In many cases, no updated information has been published, raising the question whether the projects have been abandoned. In one case, an NGO has announced that their initial biochar project in southern Ghana resulted in failure, despite technical support from three universities but states that a second trial, in northern Ghana has been successful and that they are optimistic that a larger trial will succeed based on "chemical soil analysis"[96]. However, no data from either of those trials has been published, the 'lessons' learned by the NGOs can thus be neither evaluated nor transferred and it is not clear how farmers were affected by those projects.

Of concern is the potential that subsistence farmers will be pulled into these projects on the basis of hyped claims about the benefits of biochar – and then will be disadvantaged by their participation when the claims prove unwarranted.

Biochar cook stoves

Another form of biochar promotion to "benefit the poor" involves biochar cookstoves. According to the World Health Organization, indoors pollution from biomass and other solid fuel cookstoves is responsible for 1.5 million deaths a year, over two-thirds of them in South-east Asia and sub-Saharan Africa[97]. Clean-burning stoves thus need to be a high public health priority. In recent years, clean biomass cook stoves have been increasingly promoted for climate change mitigation as well, because the soot emitted from open cooking fires contributes to global warming. While soot undoubtedly contributes the climate change, the contribution from cook fires in Southern countries remains highly uncertain. Fossil fuel burning as well as destructive fires, such as those set by plantation companies for large-scale forest and land clearance are major contributors to soot globally[98]. However, there is no doubt that clean and fuel-efficient cookstoves are vital for people's health, for reducing the time and impact of collecting wood and other biomass and that reducing all forms of soot emissions is important for reducing the speed and level of climate

Biochar cook stoves

Biochar-producing stoves are a type of stove commonly called 'micro-gasifiers' or 'wood gas stoves'. These stoves expose biomass in various forms (depending on design), to very high temperatures such that gases are released and these are then burned in a separate part of the stove for cooking. This reduces (indoor) air pollution, and compared to open cook fires, is a cleaner and more efficient method. Most micro-gasifiers currently gasify all of the biomass except for the ash that is left behind. Those are also called 'char-gasifiers' because the char is used to provide more heat for cooking. Biochar-producing stoves are adapted from this general design and allow the char to be retained and removed instead. No recent independent audit or comparative study of different modern biomass stoves, including micro-gasifiers has been undertaken, which makes it difficult to assess the performance of these different stoves. A recent German report reviewing 'micro-gasifers' summarizes based on the claims made by manufacturers. All are promoted as clean and efficient, but there is no independent data and no assessment of how practical they are for use. For example, some can only burn pelletized biomass, which may not be easily accessible. The German review was produced in collaboration with the IBI, however the data published (largely taken from developers) suggests that char-gasifying stoves provide more heat for cooking from the same volume of biomass compared to stoves that produce biochar. This makes sense given that more of the biomass is converted to useable energy rather than retained as char residue. Biochar producing stove efficiency should best be compared to other efficient biomass stoves, not to open fires. Their relative inefficiency has also been confirmed in a recent study about biochar stoves published by the UK Biochar Research Centre. They state: "More biomass ends up being used where biochar is produced and this additional collection costs time and removes more biomass. In order to counter these very real disadvantages, the benefits of applying biochar to soil would need to be very evident to the stove user and her household". The UKBRC research included pot trials using biochar from stoves the results of which described as 'somewhat mixed'. In some, though not all, cases crop yields improved when such biochar was applied at a rate of 20 tonnes per hectare. Producing this amount of biochar, not for a pot but for a one hectare field, would require a family to save up biochar from a stove over many decades (by which time, of course, it would not longer be fresh biochar and might not have the same impacts on crops). WorldStove for example, reports that a family cooking on one of their stoves three times daily for a year would produce about 438 kg of biochar over the course of the year . Therefore it would take about 46 years to produce enough biochar to treat a hectare of land with 20 tonnes of biochar. However, efficiency is not the only concern. As the UK Biochar Research Centre's stove study confirms, there are also questions whether different micro-gasifiers meet women's practical needs for cooking. For example, once a such a stove has been lit, the cooking temperature cannot generally be turned up or down and it is difficult or impossible to add more biomass or to switch the stove off early, making cooking more difficult and inflexible. Char removal can also be problematic in some designs, which require it to be either removed hot, risking accidental fires or burns, or to be quenched with water, causing the metal of the stove to corrode.

change.

Slash and Char: Another "pro-poor" biochar promotion involves efforts to encourage the use of "slash and char" over slash and burn (swidden) agriculture. This is based on the highly questionable assumption that swidden agriculture is a leading cause of deforestation, and that using biochar will reduce the need to burn off new plots of forested land periodically, enabling subsistence farmers to build and maintain soil fertility in plots that have already been cleared, with increased crop yields.

Slash and char

A 2006 article by soil scientist Johannes Lehmann, Chair of the International Biochar Initiative claims: "Existing slash-and-burn systems cause significant degradation of soil and release of greenhouse gases...Our global analysis revealed that up to 12% of the total anthropogenic C emissions by land use change (0.21 Pg C) can be off-set annually in soil, if slash-and-burn is replaced by slash-and-char." Yet, to date there are no medium- or long-term trials to compare slash and char with traditional swidden cultivation. As discussed in Chapter 2, estimates of how much carbon is converted to charcoal during wildfires vary significantly and, furthermore, there is so far no evidence that biochar will maintain soil fertility for longer periods than swidden agriculture.

A project by the Belgium-based Biochar Fund and the Congolese NGO ADAPEL in DR Congo was the first biochar project to attract funding linked to Reduced Emissions from Deforestation and Degradation (REDD), through the Congo Basin Forest Fund. That project was funded as a forest conservation project that would "avoid slash and burn farming." In fact, at least eight national REDD plans have been submitted to the World Bank proposing to effectively ban slash and burn, based on the assumption that it is a leading cause of deforestation. The underlying premises are questionable: Growing international demand for and trade in agricultural products and wood, as well as urbanisation are the leading causes of deforestation, not swidden agriculture practised by small farmers, which in some cases helps conserve rather than destroy forests and their biodiversity. Measures proposed under REDD to halt the practice of swidden agriculture will help destroy the livelihoods of Indigenous Peoples and other forest-dependent communities who have protected and defended their forests from destruction.

The push to replace swidden agriculture with slash and char in the context of REDD and the emerging forest and agricultural carbon markets, is of great interest to the International Biochar Initiative and many of their members, since it appears to offer another way to attract carbon credits and other supports for biochar projects.

The friendly sounding rhetoric surrounding the small scale farmer friendly, poverty alleviation projects - even when these projects often fail to deliver promised benefits - is used to lend support to advocacy for the much larger scale forms of implementation (i.e. it "works wonders for these farmers and therefore will work on a very large scale to address climate change"). This leap of faith is made without any independent audit to assess whether the claims about different projects and acceptance amongst farmers are even justified. The strategy of using small scale projects in developing countries to make biochar more "politically acceptable" is quite explicit in some cases. For example, biochar marketing company Genesis Industries used to describe a "guerilla marketing" strategy with a focus on small farmers as a key marketing slogan for helping owners of pyrolysis units to market their products. Although they have removed this controversial reference from their website, their close links to the film industry together with a 'farmer-friendly' web image suggest that they continue pursuing this strategy. Several biochar projects involving or aiming to involve farmers cite the development of carbon offset projects and methodologies as an aim. Will villagers enrolled in a biochar stove project in Western Kenya, for example, have been told that the project and their participation are to be used for "application for the project to be recognised for carbon trading under the Clean Development Mechanism or other schemes including the voluntary market"[99]?

For the most part, it appears unlikely that the small scale farmers are aware even, that biochar is being promoted on a very large scale and especially that their own experiences are being used to promote something much larger and far less benign – the scaling up of commercial biochar production, and global deployment under the guise of climate geoengineering, and the inclusion of soils into carbon markets.

Biochar advocates' commercial and policy setbacks

In spite of efforts at all levels to promote biochar, so far visions for scaling up production of biochar have not been fulfilled. In 2008, the IBI had a realistic hope that biochar support would be written into a UN climate agreement. Today, such a prospect appears very remote, although, as discussed below, biochar could still be boosted significantly if soil carbon is included into larger carbon markets. Some significant investors in biochar have gone into receivership or had to downsize their operations, such as Best Energies Inc. in the U.S. (now in receivership, although their biochar and pyrolysis business has been taken over by Pacific Pyrolysis in Australia), Dynamotive in Canada and Carbon Gold in the UK both have had to downsize significantly; some biochar firms are increasingly looking for non-biochar markets and uses of char, as in the case of Carbonscape in New Zealand who are now looking at the 'activated carbon' market in the chemical industry. ConocoPhillips remains the only multi-national corporation to have endorsed biochar and offer support (except for some very limited research funding for example by Shell). Many biochar advocates are now hoping to develop small niche markets rather than envisioning exponential global growth of biochar production and use. For example, in a recent article entitled "Getting The Biochar Industry Up to Speed: What Can We Learn From the Pellet Business",100(illustrating the synergies with bioenergy in general), the author poses the question: "…Given this background and an abundance of good press, why is so little biochar being produced, sold and used?" The advice offered: serve niche markets, requiring "designer" biochars, and develop small scale affordable pyrolysis units".

Very little commercial production of biochar is currently underway. According to a survey by the Irish consultancy firm C.A.R.E., 20 companies worldwide claim to be commercially producing biochar but only 10 would give a quote[101]. The fact that most biochar research, including field studies has so far relied on traditional charcoal, not pyrolysis biochar, indicates how difficult it is even for researchers to obtain modern biochar for trials.

There are multiple reasons for this, including the fact that experimentation has not verified claims made about biochar, and that biochar thus has no proven benefit, especially to farmers - (although clearly this lack of support has not stopped advocates from continuing to advocate based on these same claims). Another factor that has kept biochar marginal is that the pyrolysis equipment required to produce biochars with consistent qualities has proven costly and difficult to maintain. According to the C.A.R.E. Ltd survey, prices for biochar currently range from £100.- £16,000 per tonne. Even the lowest figure is considerably more than what farmers would expect to pay for organic fertilisers, including manure or compost.

Biochar has won over many "converts", but it has also been met with considerable skepticism. This is in part due to growing awareness of the disastrous consequences of biofuels policies. As evidence has mounted demonstrating that biofuels (ethanol and biodiesel) are driving increased demand for crops, water, soil and land, contributing to rising food prices and hunger, and all the while failing to actually reduce emissions, public opinion has soured. Further initiatives such as biochar, requiring large amounts of plant biomass are increasingly viewed with suspicious reserve. In March 2009, over 147 groups worldwide signed a declaration urging caution against large-scale biochar use and opposing the inclusion of biochar and soils in general into carbon trading[102]. Some of those organizations have continued to actively oppose the IBI's efforts and claims and some have published critical analyses.[103]

Finally, and key to the failure of commercial development, is that high hopes were pinned on gaining supports from carbon markets. Those hopes have not so far been realized. The IBI initially focused primarily on the Clean Development Mechanism (CDM), but the future of the CDM is uncertain given that a post-2012 UN climate agreement appears increasingly unlikely to be reached in the foreseeable future. Moreover, far from expanding, the volume of carbon offsets traded through the CDM has fallen for the third year running, by nearly 50% since 2009[104]. Other markets have failed to materialize: For example, in the U.S., the IBI lobbied for the inclusion of biochar into cap and trade legislation, but that legislation failed to pass. The Chicago Climate Exchange, the longest-standing carbon market trading in agricultural and soil carbon offsets folded at the end of 2010. The European Emissions Trading Scheme, by far the largest carbon trading system worldwide, continues to exclude soil carbon and other so-called 'carbon sinks'.

Carbon trading in soils

As global greenhouse gas emissions continue to soar , and evidence of fraud and scams in carbon markets mounts , doubts about and opposition to carbon trading has been growing. Carbon offsetting is at best a 'zero sum game', which allows polluting companies in the North to emit more greenhouse gases as long as they pay for projects which 'save' 'equivalent amounts' of emissions in the South. In reality, however, carbon offset projects tend to benefit those who can afford the specialist carbon consultants and navigate the system, and those who can offer projects large enough to offer 'economies of scale'. That generally means larger companies, including polluting industries, industrial livestock and plantation companies. The European Emissions Trading System (EU ETS) and the Clean Development Mechanism (CDM) combined account for more than 90% of carbon trading worldwide. So far, carbon in soils, farmlands and existing forests has been specifically excluded from trade under both of those schemes, although, large-scale carbon credits are already going to agribusiness companies, mainly for projects related to bioenergy from 'residues'. In recent years, there has been growing policy momentum for broadening the scope and availability of carbon offsets from the 'land use' sector, including forests, forestry, farmlands, grasslands, wetlands and soil carbon, both within the existing carbon markets and new emerging ones. There is also a drive, particularly by the World Bank, to create a plethora of (at best lightly regulated) new carbon markets in which the land use sector, including soils, is to play a major role, with the ultimate aim of trading carbon credits freely between different schemes.

The IBI's new strategy

The IBI and biochar enthusiasts have recently been shifting away from a near exclusive focus on marketing the carbon sequestration “potential” of biochar, to a broader approach that would facilitate the inclusion of biochar on the basis of “multiple ancillary benefits” for agriculture (for example “improving yields”, reducing nitrous oxide emissions, minimizing fertilizer runoff, retaining water etc. – all claims that have been made, even if the evidence is scant.)

Debbie Reed, a founder of the IBI and Executive Director of Renew The Earth, has been particularly active in promoting biochar in the UN climate negotiations. Her recent presentation on biochar policy developments[105] advocates for this “landscape based approach: “*Such landscape-based approaches will also allow for the multiple ancillary benefits of biochar systems to be considered and acknowledged.*” This appears to be a strategic response to developments within the UN climate negotiations and the World Bank. It embraces the potentials to profit from the strengthening calls within the UN Framework Convention on Climate Change and the World Bank to go beyond individual project-based offset schemes and instead to include soil carbon, agriculture and forestry practices into overarching 'sectoral mechanisms', still based on market mechanisms, most likely carbon markets.

In spite of the evident problems with carbon trading and growing civil society opposition to it, the push to include soils and agriculture and forestry practices into carbon and other emerging 'environmental services' markets, is proceeding, and biochar advocates consider this a most promising direction for channelling their lobby efforts with the expectation that biochar will end up prominently featured – if not only for its proclaimed ability to sequester carbon, then for other reasons.

Developing Standards

A top priority for the IBI is the development of industry standards and certification, a pre-requisite for commercializing biochar as well as appealing to carbon market developers and participants. Standards and certification in this context mean industry specifications, not a 'sustainability certification scheme'. The idea is, above all, to allow investors and customers to have some idea what they are buying when they purchase 'biochar', which is not currently clear at all. The IBI has appointed Keith Driver, one of the architects of the Alberta Offset System (discussed below), to draft this standard. The IBI website reports on the process: "*IBI's initiative to create transparent, globally-developed and accepted standards for biochar characterization, production, and utilization has completed the most recent round of working group discussions focusing on testing and assessment methods*"[106]. They also mention the need to develop a Materials Safety Data Sheet for addressing concerns about handling biochar, and indicate that there are ongoing concerns about "*accessibility of tests to biochar producers of all operational sizes and world locations (cost and facilities locations), and the applicability of soil-type-specific criteria to create a globally-enforceable product standard*." This last point is especially important given that experimentation increasingly indicates that the wide range of variation in soils and biochar properties, makes it very unlikely that any effective widely applicable "standard" can be achieved.

Recent international policy developments relating to biochar

UN treaties – UNCCD, UNFCCC

Around 2008/09, the IBI successfully lobbied parties of the UN Framework Convention on Climate Change to get biochar on the agenda for the post-Kyoto agreement text. Luc Gnacadja, Executive Secretary of the UN Convention to Combat Deforestation (UNCCD) has been a strong supporter of biochar. In 2009, UNCCD made a submission to UNFCCC entitled "Use of biochar (charcoal) to replenish soil carbon pools, restore soil fertility and sequester CO2". On the heels of the submission from UNCCD, lobbying efforts resulted in a wave of agenda submissions to the UNFCCC pushing for the inclusion of biochar in a Post-2012 climate agreement, from 20 mainly Southern countries, though many of these do not appear to have actively supported this demand either within UNFCCC or outside. A reference to biochar was briefly included in a UNFCCC draft text, but was subsequently removed. Since then, as indicated above, the debate has moved on towards 'landscape approaches' which would cover soil carbon, forests, tree and crop plantations of all types, agricultural practices, etc. Those are strongly promoted by the World Bank, who foresee a substantial proportion of funding for such an approach to come from carbon markets both inside and outside UNFCCC[107].

Market-based landscape approaches are being promoted through a variety of obscure and barely known acronyms, such as REDD-plus-plus, LULUCF (Land Use, Land Use Change and Forestry) carbon markets, AFOLU (Agriculture, Forestry and Land Use) or REALU (Reducing Emissions from ALL Land Uses), hiding a debate and policy drive which is hardly transparent even to UN delegates, let alone civil society. The more general trend to include soils and agriculture into a UNFCCC agreement and into other carbon markets is proceeding. At the recent UN Framework Convention on Climate Change COP 16 in Cancun in December 2010, negotiations under the title of 'Land Use, Land Use Change and Forestry' (LULUCF) sought to extend CDM funding for land sinks beyond the previously limited "1%, afforestation and reforestation only" to enable countries in the future to purchase a larger percentage of credits, for a much broader array of land use practices. These would expand supports for afforestation and reforestation (tree plantations), and also market carbon from soils, cropland management, 'revegetation' (any type of plantation), forest management (industrial logging) and grassland management. Though the specific text proposals were not adopted, they were resubmitted for negotiation at the UNFCCC SBSTA meeting in Bonn.

World Bank

The World Bank has long been a 'pioneer' of carbon trading. They set up the Prototype Carbon Fund in the late 1990s, which became operational in 2000 and served as a 'blueprint' for the Clean Development Mechanism (CDM). In 2002, they set up the BioCarbon Fund, which has been providing carbon finance to 'carbon sink' projects – initially only 'afforestation and reforestation' schemes, many involving monoculture tree plantations, which also fall under the CDM. In November 2010, the World Bank announced their first ever soil carbon offset project – not a biochar project but one which appears to involve a long-standing project in Western Kenya and which now forms part of the BioCarbon Fund. Shortly thereafter, at a side event held at the UNFCCC COP 16 in Cancun, World Bank President Robert Zoellick announced a multi-million dollar fund to help emerging market countries set up their own carbon markets, called 'Partnership for Market Readiness' and he included a strong statement for the inclusion of agricultural mitigation activities, including soil carbon sequestration, within these markets. The World Bank in general is playing an active role in shaping both agriculture and carbon markets. They have committed themselves to "expand carbon finance in areas such as soil conservation and work on standardized baselines"[108] Recently the World Bank has partnered with the IBI and Cornell University (where IBI Chair Johannes Lehmann is based) to conduct a survey of biochar projects in developing countries, and a detailed "lifecycle assessment" of their potential for greenhouse gas mitigation.

Unregulated international offset markets

While the CDM contracted by nearly 50% and total global carbon trade declined by 1.3% between 2009 and 2010, unregulated or voluntary carbon offsetting grew by 34% in the same year[109]. Yet compared to the regulated carbon markets (above all the EU Emissions Trading Scheme, followed by the CDM), the voluntary carbon market remains small. In 2010, it was estimated as being worth $424 million, out of a total global carbon market of around $142 billion[110]. Of particular interest to investors and to the IBI is the Verified Carbon Standard (formerly Voluntary Carbon Standard). Its aims include "establishing a global benchmark for quality offsets [and] providing a framework to bring coherence to the voluntary carbon market"[111], i.e. to serve as a 'certification system' for voluntary carbon offsets. Out of 25 methodologies adopted by the VCS, 9 fall into the "Agriculture, Forestry, Land Use Category", most of them related to forestry. In 2009, Carbon Gold submitted a proposed biochar methodology to the VCS. This received little support, with some of the details being criticized even by the IBI, and appears unlikely to be progressed further. However, the Carbon War Room, funded by Richard Branson, which has partnered with the IBI, as well as the Biochar Protocol, co-sponsored by ConocoPhillips and working closely with the IBI, both regard developing new biochar methodologies for the VCS as well as the Alberta Offset System (discussed below) as their top priorities.

Some recent key national and regional policy developments relating to biochar

Australia

Biochar has probably featured more highly on the political debate in Australia than in any other country. It formed a keystone of Malcolm Turnbull's policy on climate change as Leader of the Opposition and is being strongly advocated by Tim Flannery, head of the government's Climate Change Commission (and until recently board member of biochar company Carbonscape). Both the government and the main opposition support large-scale carbon offsets involving agriculture, forestry and soil carbon and successive governments have funded biochar research and development, the biggest grant having been for AUS$1.4 million (US$1.5 million) for biochar research made available to the Commonwealth Scientific and Industrial Research Organization (CSIRO)[112] . The proposed Carbon Farming Initiative, which will be voted on by the Australian Parliament in June, seeks to establish a publicly administered and regulated carbon market for Australia to utilize both domestic and international agriculture, forests and soils for emissions "offsets". It is a sectoral carbon market unrelated to any emissions cap. The Initiative would introduce soil carbon offsets with 'few strings attached', i.e. without any public consultations on projects and setting aside most of the remaining 'safeguards' of the CDM or European Emissions Trading Scheme (which exist at least on paper). For example proving that projects have to provide benefit additional to what would otherwise have happened, will likely not require much demonstrated proof. The consultation document specifically embraced biochar. Some, like the Organic Farmers Association, claimed enthusiastically "A Soil Carbon Offset Scheme has the potential to sequester all of the 537 million tonnes of CO2 that Australia emits and generate $70 billion in Carbon Credit payments to the Australian economy.[113]" claim that Australia will be able to (inexpensively) offset all of the country's emissions by shifting to more "climate friendly" agricultural and forestry practices, although in the absence of any emissions cap it is not clear who would want to buy the new offsets.

Canada/Alberta

In 2007, the government of Alberta introduced a mandatory Greenhouse Gas Reduction Programme. The programme's name is misleading in that it does not mandate any greenhouse gas reductions. Instead, it requires a small number of large polluters to reduce their carbon intensity or, if they fail to do so, to purchase carbon offsets through the Alberta Offset System, or to pay into a Climate Change and Emissions Management Fund set up by the provincial government. Reducing carbon intensity means reducing emissions per 'production unit' – even if greater production will mean overall more carbon emissions. The legislation and the Alberta Offsets Scheme are closely linked to the government's policy on tar sands expansion, with carbon offsets being of particular interest to investors in tar sands extraction megaprojects, considered to be among the most destructive projects on earth in terms of their impacts on the environment, public health and the climate. At a meeting of climate activists in 2010, IBI Advisory Committee Member Lloyd Helferty announced that "Biochar could offset Canada's tar sands industry for 14.5 years."[114] Development of a biochar carbon offset methodology for the Alberta Offset System, together with the Verified Carbon Standard, has been identified as a top priority by the Biochar Protocol, founded by ConocoPhillips Canada and the Carbon War Room to develop such methodologies. A biochar methodology appears to have been submitted to the Alberta Offset System, but has not yet been published for consultation. There is, however, a significant chance that such a proposal would effectively be rubber stamped, much to the delight of tar sands investors who are eager to have access to unlimited quantities of inexpensive offsets. ConocoPhillips, one of the lead investors in tar sands, previously provided $22.5 million in funding for bioenergy and biochar research at Iowa State University[115]. Furthermore, the IBI has hired one of the architects of the Alberta Offset System, Keith Driver, to develop biochar standards, as mentioned above.

China

The **Panda Standard** is being set up as China's first voluntary carbon offset standard. According to its website: "The China Beijing Environment Exchange (CBEEX) and BlueNext founded the Panda Standard, as the first Chinese domestic voluntary carbon standard, designed to provide transparency and credibility in the nascent Chinese carbon market and to advance the People's Republic of China (PRC) Government's poverty alleviation objectives by encouraging investments in China's rural economy"[116]. The land use sector is to play a key role in the Panda Standard, with a specification for Agriculture, Forestry and Other Land Use having been developed, and consultations invited. Biochar was specifically mentioned. So far, the Panda Standard has launched a first pilot project, involving 'bamboo reforestation', with financial support from the French Development Agency AFD and the French Global Environment Fund (FFEM)[117]

European Union

The EU has taken on binding emissions reduction targets, which have translated to an alarming degree, into subsidies and mandates for bioenergy, including biofuels. Biochar advocates recognize that these mandates and subsidies, especially pyrolysis and gasification, are one of their most promising avenues for achieving supports for biochar in Europe. The development of second-generation (solid-to-liquids) biofuels is being strongly promoted, including through the EU's Renewable Energy Directive. Pyrolysis and gasification research and development attracts public support through the EU and member states in this context, although the bio-oil and syngas produced through pyrolysis and most types of gasification need to be refined further before they can be used as transport biofuels. In the UK, the UK Biochar Research Centre (members of the IBI) received core funding of £2 million ($3.26 million) from a government research council[118], as well as additional funds from another UK government research council, the European Regional Development Fund, a Canadian Crown Corporation and Shell Global Solutions[119].

The European Commission's Joint Research Commission, which provides scientific and technical advice to the European Commissions and EU member states, has advocated for biochar, organizing side events at the UN Framework Convention on Climate Change COP 15 with IBI member participation[120]. They published a research paper on biochar[121]. Alarming, the head of the Commission's climate change unit has openly advocated for biochar as viable climate geo-engineering technique – referring to it as 'geo-renovating' or 'soft geo-engineering'[122] The EU's North Sea Region Programme includes a "Biochar: climate changing soils" project to "*raise awareness and build confidence in black carbon as a way of capturing carbon and increasing soil quality and stability*". They also seek to establish "biochar competence centers" in countries in the region, supporting biochar research at research institutes in seven EU member states. [123] Furthermore, the EU's 7th Framework Programme includes funding for biochar research and some funds for biochar commercialization have been made available by member states under the European Rural Development Programme[124].

Although the EU Emissions Trading System does not permit 'land based' carbon credits, including those from soil carbon, there are some indications that this position might be reviewed in the future, depending on international developments[125].

New Zealand

The NZ Government, through the Ministry for Agriculture and Forestry (MAF) has invested substantial funding into biochar research with a clear mandate to further commercialisation. This includes a grant of NZ$3.13 million ($2.56 million) to the NZ Biochar Research Center. Several NZ universities, especially Massey University, as well as different Crown Research Institutes are involved. The 'biochar model' promoted in New Zealand primarily seeks to use residues from tree plantations, i.e. additional finance for plantation companies, possibly new tree plantations for biochar production, and also biochar use aimed at reducing methane and nitrous oxide emissions from pasture. Landcare Research has been particularly active in developing proposals and support for agricultural and soil carbon offsets more generally. Agriculture will likely be fully incorporated into the NZ Emissions Trading Scheme (NZ ETS) in 2015 and a proposal for a biochar methodology can be expected.

United States

Cap and trade legislation: Climate legislation passed in the House of Representatives, but failed to pass in the Senate in 2010. These bills sought to enact cap and trade, and to provide large quantities of offsets (2 billion tons) with the bulk to be derived from (mostly domestic) agriculture and forestry, (which were in turn exempted from any cap on emissions). The Senate version of the climate bill specified biochar among eligible offset technologies. In addition, it offered finance for research and development on biochar and even included a separate title on "rapid mitigation" featuring biochar. Those proposals were actively supported by the IBI, with their Chair, Johannes Lehmann testifying to a House Select Committee in 2009[126]. None of these proposals however were passed into law.

In general, the U.S. Government has been, and continues to be, a major proponent of marketing soil, agriculture and forest carbon, advocating for this in national and international policies and investing considerable sums in research and development to facilitate the measurement of carbon fluxes. The Chicago Climate Exchange had taken the lead in trading offset credits for agriculture (especially for industrial no-till practice[f]) within the voluntary markets, with the expectation that experience would then carry over to mandated markets – which have subsequently largely failed to materialize. The Chicago Climate Exchange itself closed and was sold off. Several regional trade schemes have emerged or are in planning stages however. The US Department of Agriculture has recently sought consultation on "Quantifying greenhouse gas emissions and carbon sequestration for agricultural and forestry activities", including soil carbon[127]. During a speech at the UN Climate Conference in Cancun in December 2010, U.S. Department of Agriculture Secretary, Tom Vilsack, promised an 'aggressive agenda' to "*provide American farmers and landowners with information on how protecting the environment through actions such as carbon sequestration...can also bring economic savings*", including an evaluation of "*how emerging voluntary and state greenhouse gas markets and USDA conservation programs can work in concert*"[128] Tom Vilsack previously expressed support for biochar as a speaker at the North American Biochar Conference in 2009 and USDA issued a press release for the occasion expressing strong support for biochar research and development[129].

Other legislation: A stand-alone biochar bill (Water Efficiency via Carbon Harvesting and Restoration [*WECHAR]* Act of 2009) which focusses on subsidies rather than carbon offsets was put forward but has not been progressed,

Regional carbon market initiatives: The West Coast Regional Carbon Sequestration Partnership (WESTCARB) describes itself as "*a collaborative research project bringing together dedicated scientists and engineers from more than 90 public agencies, private companies, and nonprofits, co-funded by the US Department of Energy to characterize regional carbon sequestration opportunities and conduct technology validation projects*". It is managed by the California Energy Commission and covers seven US states as well as British Colombia in Canada. WESTCARB does not administer carbon offsets, but helps to develop the policy drive and methodologies for introducing them, with 'terrestrial carbon storage' as a key priority. The California Energy Commission recently commissioned the Climate Trust (who describe themselves as an "innovator and quality leader in the carbon offset market"[130]) to write a report for WESTCARB about "Carbon Market Investment Criteria for Biochar Projects". This is currently available in draft form[131], with a published factsheet that states enthusiastically: "…*Given these and other pathways for reducing emissions, at its maximum sustainable potential, biochar could annually reduce 1.8 Gigatons of carbon dioxide equivalents emissions or 12% of the worlds GHG emissions. This, is based on the assumption that one metric ton of biochar contains .8 metric tons of carbon and 80% of this carbon will remain sequestered in biochar after 100 years*"[132].

Government funding for biochar research and development: The U.S. Department for Agriculture and the U.S. Department for Energy, as well as some state governments have been funding biochar as well as broader pyrolysis research and development through various initiatives, including through the Biomass Research and Development Initiative which, amongst other biochar funding, has provided $5 million to use beetle-damaged trees for biochar and energy[133]

Synergies with coal and biofuels

Many companies involved with biochar are essentially bioenergy companies, or industrial forest/agribusiness companies, with biochar being just one facet of a broader portfolio of interests. These companies are simply looking for means to profit from char residues that might otherwise languish – or even pose a messy disposal problem. A look at some of the startup companies that have arisen (and in some cases, subsequently failed) is revealing (see table). Equally revealing is a look at attempts to capitalize on synergies between biochar and the coal industry. Although the

f Industrial no-till agriculture has been introduced across millions of hectares, particularly in North and South America and especially to grow corn and soya. It is claimed that soil carbon is protected and increased by not tilling soil, although scientific findings about this are far from consistent. Tillage is replaced with increased use of herbicide, with weeds being poisoned, not ploughed. Herbicide-resistant GM crops are commonly grown and the practice has been advocated by Monsanto for several decades.

IBI's definition of biochar is strictly limited to biomass sources of black carbon, various companies, including ones linked to the IBI are seeking to combine biochar with the agricultural use of coal power station residues.

ICM Inc. (www.icminc.com)

U.S.-based ICM Inc is mainly an ethanol company seeking to diversify into other forms of bioenergy, including gasification. They installed a pilot gasification plant at a landfill site in North Dakota and are now advertising similar gasification units for sale. They promote, amongst other things, a 'char byproduct' for carbon sequestration and as soil amendment.

Best Energies (www.bestenergies.com)

Best Energies Inc. were based in the U.S. with a subsidiary in Australia. They began as one of the primary startups promoting biochar, but are now in receivership. A look at their approach, claims, and portfolio of interests and marketing is illustrative however. Best Energies invested mainly in biodiesel but also in biochar and 'green charcoal', i.e. charcoal as fuel and they claimed to provide carbon offsets[134]. Several of their directors came from Union Carbide and Dow Chemical. The Best Energies website stated: "*We are well positioned to win the current land grab in next-generation fuels.*" Their biochar and pyrolysis business has been taken over by Pacific Pyrolysis in Australia.

Alterna Biocarbon (www.alternaenergy.ca)

Based in Canada with a subsidiary in South Africa, Alterna owns and uses a technology called "Enviro Carbonizer" in a small industrial facility in South Africa and another demonstration facility in B.C., Canada. Their website claims: "*Alterna Biocarbon is a company focused on the manufacturing of biocarbon from products, such as wood, municipal and agricultural waste and tires. Biocarbon, also called biochar or charcoal, is a renewable replacement for coal manufactured for industrial markets...There are many markets for the product including biochar (agricultural applications), activated biocarbon, and energy pellets.*" The company is owned in partnership with "All Wood Fibre", which procures and markets woodchips, stating "*Our services are utilized by the major forest products, logging, lumber, pulp and paper, and bioenergy companies*." Alterna Biocarbon have not yet produced biochar commercially, only for research purposes.

Eprida (www.eprida.com)

Founded in 2002 as a Delaware Corporation in Colorado, they were the first ever biochar company. Eprida has been involved in different biochar research collaborations and has so far produced biochar for research only. According to their website, they have developed a so-called ECOSS technology, which involves combining pyrolysis biochar with chemicals scrubbed from coal power station flue gases to produce an ammonium bicarbonate fertiliser. Genesis Industries hold the license for Eprida's pyrolysis system.

CoolPlanet Biofuels (www.coolplanetbiofuels.com)

CooPlanet are a California-based biofuel company developing biofuels from biomass fractionation (related to gasification). They state on their website: "*Imagine driving high performance cars and large family safe SUV's while actually reversing global warming*". GE, NRG Energy, ConocoPhillips and Google Ventures are investing in CoolPlanet Biofuels. Their technical advisory board is made up of Leio Manzer (DuPont Fellow), David Austgen (formerly with Shell), Raymond Hobbs, Cliff Detz (formerly with Chevron) and Ron Sills (formerly with BP and Mobil). Cool Planet produces small amounts of biochar in their process, but they use that to argue the claim that their fuels are "carbon negative".

Mantria Industries LLC

Mantria Industries LLC, a subsidiary of Mantria Corporation, claimed in 2009 that they had opened the world's first commercial-scale biochar production facility[135] and they advertised 'EternaGreen' biochar for sale. Mantria Corporation was set up as a partnership with Speed of Wealth LLC and Mantria Industries claimed to invest in the BioRefinery industry and specifically in biofuels and biochar, focussed around carbon credits. There is no evidence that they ever sold or even produced biochar. In 2009, the Securities and Exchange Commission filed a court case against them for 'operating a Ponzi scheme' and the scale of the fraud allegations has since increased to $54.5 million. Following the announcement of this investigation in 2009, the IBI published a statement claiming that their knowledge about Mantria's biochar activities was limited to what was in the media, that they had not supported their projects and received no funding from them[136]. However, previous, uncontested, media articles had described the IBI as a supporter of Mantria's biochar activities[137] and the IBI website hosted a full 'project page' for Mantria. There are no reasons to believe that the IBI would have had any idea about the apparently fraudulent nature of the business. However this example shows the ease with which such a dubious company could take advantage of the positive image created around biochar and even be promoted by the IBI, without any checks on the nature of their business.

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Chapter 5: Discussion and Implications

The promotion of biochar bears troubling resemblance to the history of biofuels promotion. Biofuels in general were promoted as a “green” alternative to fossil fuels, based on unsubstantiated claims. Many in civil society and elsewhere repeatedly warned that they would result in escalating competition with food production, deforestation, expanding industrial monocultures, worsening hunger, depleting water resources, more rather than less greenhouse gas emissions, human rights violations and land grabs etc. Yet subsidies and supports were put in place, above all in North America and Europe, and still remain in spite of escalating evidence of the harms.

Especially similar to the push for biochar is that underway for jatropha. Jatropha has been strongly promoted as a 'miracle crop'. As Jatenergy Ltd, a company investing in jatropha as well as coal, claims: “Properly developed, it will not compete with land or water resources for food production. It is extremely hardy, and can survive long, dry periods in a wide range of soil conditions.”[138] Those claims have long been disproven. In fact, jatropha plantings have largely failed even on fertile soil with regular watering. A study in Kenya, published by the World Agroforestry Centre concluded: “*Based on our findings, jatropha currently does not appear to be economically viable for smallholder farming when grown either within a monoculture or intercrop plantation model.*”[139] No commercial quantities of jatropha have been sold, several years after the first plantations should have reached maturity. Nonetheless, large and growing numbers of communities have lost their land, livelihoods and food sovereignty to jatropha and forests and other ecosystems are being destroyed as a result of this land-grab. Jatropha continues to be promoted in a growing number of countries in Asia, Africa and Latin America, regardless of the lack of evidence that it 'works', let alone that it brings any wider benefits.

Biofuels, biochar and the other “green technologies” that employ use of biomass as a substitute for fossil fuels, all share a standard “blueprint” for underlying assumptions upon which advocacy is based. For example, a recent Nature Communications article on the “theoretical potential” of biochar, which claimed that 12% of global greenhouse gas emissions could be offset through 'sustainable biochar'[140] embraces this “blueprint”. The models used for this assessment were based on a study of the global potential for 'sustainable biomass', including biofuels, according to which 386 million hectares of 'abandoned cropland' exist[141] which are not forested and have not been built up, though they include non-forest ecosystems and pasture. This study is but one of many 'biomass potential' studies[142] which are the building blocks of the “blueprint”, based on the following assumptions:

a) The idea that large areas of land can be converted to biomass production without causing significant emissions from deforestation of other land-use change (lending biomass a 'positive carbon balance' or even carbon neutrality).

b) That there are hundreds of millions of hectares of “idle”, “marginal” and “degraded” lands available, especially in Africa, Asia and Latin America, that could be used to grow biomass crops.

c) That 'social impacts' (except for the overall amount of food production), for example the fact that so-called 'marginal or 'degraded' land provides the livelihood and home of hundreds of millions of pastoralists, indigenous peoples and other communities can be ignored when calculating the 'theoretical' biomass potential, (on which policies are then based).[143]

d) That “standards” can be developed, agreed and implemented that will ensure that the conversion of large areas of land to biomass crop production does not worsen biodiversity losses or interfere with food production.

e) That there are vast quantities of “wastes and residues” available from agriculture and forestry operations that could be used.[144]

In reality, crop producers and investors will seek not the most degraded and useless lands, but rather the best available soils – with access to water for irrigation – that their money can buy.

Peasant farmers and others without formal title to their lands increasingly find themselves pitted against wealthy foreign investors (and often, complicit governments within their own countries). The current trend in land grabbing, was spurred on by the food and financial crises – investors cognizant of the growing demand for food and bioenergy crops, and seeking secure investments - have brokered deals to purchase and lease hundreds of thousands of hectares of arable lands, particularly in Africa and Latin America.[145] This is in addition to already escalating conflicts over access to lands such as those happening as a result of industrial expansion of soya and palm oil. This trend is countered by, for example, the worldwide peasant farmers organization, La Via Campesina, among others, have called for a ban on land grabbing and continue to mobilize resistance.[146]

Biochar, particularly if it does succeed in gaining supports through carbon markets and/or as a climate geo-engineering strategy, could contribute further fuel to the land grab fires.[147] Concerns over the potential for biochar to contribute to the harms already underway as a result of biofuels policies, resulted in an international declaration of opposition “Biochar, a New Big Threat to People, Land and Ecosystems”, signed by 147 organizations in 44 countries.[148] While biochar advocates engage in discussions couched in terms of “sustainable harvests” and “sustainability standards”, there is little basis for confidence in these, which are ineffective, not least because they cannot address indirect impacts: Greater demand for crops, woods and land inevitably pushes the agricultural frontier further into forests and grasslands and no credible way of preventing this without curbing demand has ever been proposed. Furthermore, even very basic standards have been shown to be unenforceable and serve more to greenwash than to ensure protections.[149]

Ironically, as with biofuels, biochar is promoted largely as a “solution” to the problems of climate change and food crisis. Yet it is poised to work directly at odds with the known, proven effective and justice-based solutions that already exist: protecting biodiversity, preserving soils and water resources, and promoting diverse, locally adapted peasant farming and organic and agro-ecological practices.[150] Reducing demand for wood and other biomass is key. Creating large new demands based on unfounded claims, faulty assumptions and hype, only makes these real solutions less likely to be achieved.

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145 The World Bank has estimated that near 47 million hectares of land had been requested for purchase by foreign investors between October 2008 and June 2009 alone. (see: Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Benefits? World Bank, September 2010.) See also: www.farmlandgrab.org

146 It’s Time to Outlaw Land Grabbing, Not Make It “Responsible”. http://viacampesina.org/en/index.php?option=com_content&view=article&id=1076:its-time-to-outlaw-land-grabbing-not-to-make-it-qresponsibleq&catid=23:agrarian-reform&Itemid=36 see also the Dakar Appeal Against Land Grabbing: http://www.petitiononline.com/dakar/petition.html

147 Ironically, Best Energies had for some time proudly proclaimed on their website that they were “well placed to win the global land grab” www.bestenergies.com/downloads/BEST_BioEnergyProducts.pdf

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149 The longest-standing international certification scheme, the Forest Stewardship Council, for example, still regularly supplies wood from illegal logging and plantations, from legal but highly destructive plantations, from old-growth forest logging, etc. The Roundtable on Responsible Soya, and the Roundtable on Responsible Palmoil – have been soundly rejected by civil society for greenwashing what are fundamentally unsustainable practices. See for example www.fsc-watch.org, http://www.biofuelwatch.org.uk/docs/17-11-2008-ENGLISH-RSPOInternational-Declaration.pdf and http://lasojamata.iskra.net/node/110

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