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Biocharred Pathways to Sustainability? Triple Wins, Livelihoods and the Politics of Technological Promise

Melissa Leach, James Fairhead, James Fraser and Eliza Lehner

Biochar

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'Biochar' is currently the focus of extraordinary levels of both technological optimism and debate. As a substance, biochar refers quite simply to the carbon-rich product that results when biomass – from wood or leaves to manure or crop residues – is burned under oxygen-deprived conditions. But around the idea of biochar and the processes of generating and then burying it are emerging claims and hopes with far-reaching implications. The promise of biochar is generating a mass of research, imagination, and investment that for the moment far outpace actual practices, implementation and systems on the ground. Critique and counter-arguments are swirling too, in a mass of sometimes heated and polarized debate. This paper tracks key narratives and positions in this emerging 'politics of technological promise' around biochar, and thus reflects on the prospects of biochar becoming part of pathways to sustainability that also meet the livelihood priorities of small farmers in rural African settings and beyond.

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Biocharred pathways to sustainability?

Triple wins, livelihoods and the politics of technological promise

**Melissa Leach, James Fairhead,
James Fraser and Eliza Lehner**

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Introduction: Biochar and the 'triple win'

'Biochar' is currently the focus of extraordinary levels of both technological optimism and debate. As a substance, biochar refers quite simply to the carbon-rich product that results when biomass – from wood or leaves to manure or crop residues – is burned under oxygen-deprived conditions.[1] But around the idea of biochar and the processes of generating and then burying it are emerging claims and hopes with far-reaching implications. The promise of biochar is generating a mass of research, imagination, and investment that for the moment far outpace actual practices, implementation and systems on the ground. Critique and counter-arguments are swirling too, in a mass of sometimes heated and polarized debate. This paper tracks key contours and positions in this emerging 'politics of technological promise' around biochar. It makes no attempt to offer a comprehensive review of the science, technology or economics of biochar – deferring here to other valuable and authoritative sources (Lehmann and Joseph 2009). Nor does it attempt to adjudicate on biochar science and arguments about it. Rather, our aim is to consider biochar science in its social context, addressing how particular strands of scientific inquiry and evidence interlock with particular social and political positions. We offer a mapping of current actors, arguments, assumptions and interests in the biochar debate, considering what emergent pathways of biochar development they are shaping. By unpacking the assumptions and interests at play, we offer a particular set of reflections on the prospects of biochar becoming part of pathways to sustainability that also meet the livelihood priorities of small farmers in rural African settings and beyond.

At the same time, we expose and reflect on some of the striking dissonances that pervade the biochar debate: between advanced research and imagination and a paucity of practice; between global claims and local ones, and between future-oriented, technological modernity and an appeal to deep history and tradition. Furthermore, while replete with politics, biochar to date has been remarkably devoid of policy – and of state involvemententent. In biochar, we are seeing a bubble of promise inflated through sometimes incongruous alliances between 'fringe' soil science, and business. This perhaps makes it particularly susceptible to buffeting by opposing forces in a neo-liberal era. In this, biochar serves as a potent example of a peculiarly contemporary style of technological development that may be set to recur in other fields.

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[1] This is essentially the same process as used to produce charcoal and the terms are sometimes used interchangeably, although efforts to clarify terminology suggest that biochar is the correct term where charred organic matter is to be applied to soil (the term 'agrichar' is sometimes used for this) (Lehmann and Joseph 2009: 2).

Biochar, its proponents suggest, offers potent ways to meet pressing challenges across agriculture, climate change and energy – and moreover, to address all three domains simultaneously in an unprecedented 'triple win'. This is the 'magic' around which biochar's political economy of promise has emerged.

In relation to agriculture, it is argued and as we detail later, the burial of biochar provides a potentially powerful method for enhancing soils, helping them to retain nutrients and water, enabling increases in agricultural productivity without, or with much reduced, applications of inorganic fertilizer. Biochar-based strategies are thus being seen to offer valuable routes to building sustainable agricultural futures – not least for resource poor farmers for whom soil fertility and water availability are seen as key constraints on crop production and food security.

Second, biochar is attracting attention as a potentially powerful tool for mitigating anthropogenic climate change. The carbon in biochar, it is claimed, resists degradation and can sequester carbon in soils for hundreds to thousands of years. Offering massive carbon sequestration possibilities, biochar-based strategies are thus being seen by some scientists and policymakers as a promising route amidst the array of 'biogenic' and geo-engineering options for drawing down and locking up carbon dioxide from the atmosphere – at a time when geo-engineering is itself attracting growing interest and acceptability as a potentially valuable complement to emissions reductions.

Third, in the energy domain, biochar is being claimed to offer valuable ways forward in the challenge of building sustainable, low-carbon energy futures. Here the process of producing biochar is the focus, since the required burning of biomass, wastes or other feedstocks in a low- or zero-oxygen environment can be tuned, with the right technologies, also to release bioenergy/ biofuels in the form of syngas and bio-oil – as well as the biochar itself. So-called 'pyrolysis-biochar (PBS)' systems thus represent a way of 'decarbonising' biomass fuels, that parallels and could complement other low-carbon energy options (such as decarbonising fossil fuels through carbon capture and storage).

While there is policy and research excitement in each of these domains, it is the promise of biochar to link them in a triple win that makes it extraordinary. As Flannery (2009: 25) puts it: 'The biochar approach provides a uniquely powerful solution: it allows us to address food security, the fuel crisis and the climate problem, and all in an immensely practical manner'. Unlike other carbon-capture-and-storage techniques being explored to link energy production and climate change mitigation, biochar is not locked-up in a useless way, shoring up storage problems for the future, but harnessed for new productive possibilities in farming. The claim that the carbon buried as biochar stays in the soil through successive agricultural cycles, rather than being mobilized and re-released through crop growth, is key to this. Biochar thus seems to offer a way to mitigate climate change, produce energy and increase agricultural productivity through a single set of practices or technological applications that interact synergistically. Some add further value streams – such as the provision of a means to manage agricultural wastes (Lehmann and Joseph 2009), or even, as we shall see, poverty reduction – multiplying the triple win to quadruple or more. In this way, biochar offers a uniquely powerful pathway to meet multiple sustainability challenges.

In some of the more florid statements and claims, this becomes a pathway to reverse a history of environmental damage, and a magic key to a more sustainable future. For example:

> If you could continually turn a lot of organic material into biochar, you could, over time, reverse the history of the last two hundred years...We can, literally, start sucking some of the carbon that our predecessors have poured into the atmosphere down through our weeds and stalks and stick it back in the ground. We can run the movie backward. We can unmine some of the coal, undrill some of the oil. We can take at least pieces of the Earth and – this is something we haven't done for quite a while – leave them Better Than We Found Them (Bill McKibben, author, climate activist and founder of 350.org; McKibben 2009).

Or in the words of the US-based Huntsville Project:

> Biochar is the only true carbon "reductive" technology that exists… unique in its ability to help humanity solve the climate change problem by taking carbon "out" of the atmosphere. …But this just scratches the surface of what we know about what biochar can do. Biochar is the Swiss Army knife, or the "killer app" of climate solutions. It is the key to the New Carbon Economy (www.newcarboneconomy.info/page6.php).

… but for whom?

Biochar, it seems, has become a sustainability bandwagon for our times, fuelled by narratives of sector-specific and triple-win technological promise. But who is driving it forward and how, and who is jumping on board – which groups and networks of actors and interests? What evidence, arguments and assumptions are they mustering in support of their claims – and what uncertainties and ambiguities might they be overlooking, or conveniently downplaying? Who stands to gain from pursuing biocharred pathways to sustainability, and who might lose?

As with any arena of technological and policy promise, there is of course debate – and in the case of biochar this has strong momentum, within a vibrant research and policy field. Thus alongside positive narratives about the potential of biochar, an array of alternative narratives can also be discerned. These variously identify potentially negative outcomes of biochar investments, as well as trade-offs, uncertainties and ambiguities which qualify the overarching triple win story, and call for the bandwagon to be diverted – or in the extreme, halted. In a critical commentary in The Guardian newspaper in March 2009, the environmental journalist George Monbiot argued that 'the latest miracle mass fuel cure, biochar, does not stand up; yet many who should know better have been suckered into it' (Monbiot 2009a). At the very least, the so-called '"charleaders" need to cool their enthusiasm' (Monbiot 2009b). Biochar is thus becoming the focus of a – sometimes fraught and potentially high-stakes – political debate. Drawing on a pathways approach (Leach *et al* 2010) and through a review of the rapidly-burgeoning published, grey and electronic literature on biochar, this paper tracks these emerging narratives and counter-narratives, the actors and institutions involved, and their implications for building pathways to sustainability.

We are particularly concerned with the prospects for biochar to become part of 'pro-poor' pathways; those that meet the livelihood and sustainability goals valued by small farmers in resource poor settings in Africa and beyond. Here too there is much debate. For some, central amongst the positive attributes of biochar are its compatibility with small farmers' needs – in terms of attributes, potential, flexibility and scale. Yet others point out dangers, with the spectre of modern biochar-fuelled 'green grabs' of African lands central to the narratives of biochar's most vociferous opponents. Clearly, the political, institutional and knowledge relations through which biochar is developed and promoted will shape who gains or loses, and how. By exploring the dynamics of polarization that pervade so much of the current biochar debate – that the biochar approach is 'good' or 'bad' for the poor, or should be promoted 'at scale' or not – this paper aims to help open space for a more qualified, mid-range set of narratives that is just starting to emerge. These emphasise that biochar is not just one thing, and that diverse biochar systems will be appropriate to diverse contexts and goals (Lehmann and Joseph 2009). Amongst these, and as adapted to particular located settings, there is potential for small scale, locally appropriate biochar schemes using waste materials to meet local livelihood, agricultural and energy needs while contributing to climate change mitigation more modestly, as part of diverse portfolios. This in turn justifies research activities to explore and clarify the social and governance, as well as technical and economic, conditions for such promise to be realised.

While the biochar debate is quintessentially of our current and future times, turning on the promise of technologies and systems to address growing sustainability challenges, it also draws on deep history. The modern 'hype' over biochar has, in large part, been triggered by discoveries of 'anthropogenic dark earths' or terra preta in the Amazon as a legacy of pre-Hispanic settlement and farming – and now well-documented through two decades of research by soil scientists, historians and archaeologists there (Lehmann *et al* 2003; Woods *et al* 2009). Thus as Flannery (2009) puts it, 'Biochar is both an extremely ancient concept and one very new to our thinking' (2009: 25). As we shall see, narratives on all sides of the biochar debate invoke terra preta history in support of their claims – although in very different ways.

Although there are many overlaps, as we shall see, we group these narratives into two broad clusters: those taking ‘climate change mitigation’ as their key starting point, and those emphasizing ‘agricultural productivity through soil enhancement’. Neither cluster is homogeneous, and within each a variety of debates and sub-narratives – as well as counter-arguments – can be identified.

Biochar for climate change mitigation

Amidst unprecedented policy and public concern with climate change, it is not surprising that biochar's most prominent advocates – and the most publicized and heavily-invested narratives about it – emphasise its climatic benefits. Some treat biochar as one of an array of options for geo-engineering the climate (Royal Society 2009); others distinguish it from industrial engineering-based carbon capture and storage approaches, treating biochar instead as a 'biogenic' technique. The overarching argument that biochar buried in soil offers large potential for sequestering carbon, and thus a promising approach to mitigating climate change, has been forwarded by – and has served to draw together – a large array of actors. These range from researchers – mainly in the environment, energy, and earth departments of large universities in the United States (with Cornell University notably prominent) the United Kingdom, and Australia – and governments – mainly in Europe, Australia and the United States – to NGOs, private companies seeking to benefit from carbon markets, and the venture capital, clean energy investment firms and consultancy services that support them. What draws them together is both the high promise of biochar, and the research and action needed to 'prove it' and make it real – to provide a knowledge base linked to expanding practice.

Several prominent individuals have played key roles in the public promotion of a dramatic pro-biochar for carbon sequestration narrative. Amongst them are James Hansen, head of the NASA Goddard Institute for Space Studies, who has argued that 'Replacing slash-and-burn agriculture with slash-and-char and use of agricultural and forestry wastes for biochar production would provide a CO2 drawdown of ~8 ppm or more in half a century.'[2]. James Lovelock, originator of the Gaia theory, claims that 'There is one way we could save ourselves and that is through the massive burial of charcoal…. Then you can start shifting really hefty quantities of carbon out of the system and pull the CO2 down quite fast.' The late Peter Read of the Centre for Energy Research in New Zealand warned of dangerous climatic tipping points so:

> …it is necessary to go beyond what can be achieved through emissions reductions. This entails large-scale carbon removals from the atmosphere and stocking it somewhere safer. Thus… the threat of abrupt climate change thrusts negative emissions systems, including, most promisingly, biochar, into a key role in climate change mitigation (Read 2009: 395).

[2] James Hansen, http://www.columbia.edu/~jeh1/.

Tim Lenton, Professor in Earth System Science at University of East Anglia, suggests that biochar is one of the best technological solutions to reducing CO2 levels,[3] arguing that 'Biochar has the potential to sequester almost 400 billion tonnes of carbon by 2100 and to lower atmospheric carbon dioxide concentrations by 37 parts per million.'[4] Johannes Lehmann of Cornell University, a longstanding expert in the field, was in this context named by social enterprise Re:char as the 'biochar hero.'[5] Although often more nuanced and equivocal in their own research and contributions, these – along with a few other – individuals are widely associated by publics, activists, companies and the media with strongly pro 'biochar for climate change mitigation' stances.

In some versions of the narrative, this call to unity is supported by powerful metaphors. Thus the Carbon War Room (CWR), a U.S. based organization established by business entrepreneur Richard Branson, to harness 'the power of entrepreneurs to implement market-driven solutions to climate change', enlists biochar as one of its key 'battles' in its 'war' against planet-destroying 'business as usual'. It claims that 'early research has established biochar's potential to scale up to remove several billion tons of CO2e per year by 2054'.[6]

Tight networks link these actors and institutions. Many university researchers are on the boards of biochar organizations or companies, or offer biochar consulting services. The biochar community is also drawn together around the few large projects, with academics often focusing their research on schemes that companies have instituted for profit. In these ways, it is reasonable to speak of a veritable biochar-for-carbon-sequestration community or 'industry'. Some commentators have gone further to characterise a community of 'biochar worshippers' amongst whom there is corruption and nepotism (Smolker 2010; TNI 2009), suggesting that many researchers also have financial interests in the uptake of biochar – although it is questionable whether there is evidence to support these claims.

Networks are also facilitated through overarching international organizations and initiatives. Central amongst these is the International Biochar Initiative (IBI) (www.biochar-international.org/) established at the first international conference dedicated to biochar in Australia in 2007. The IBI is a 'non-profit organization that supports researchers, commercial entities, policy makers, development agents, farmers and gardeners, and others committed to sustainable biochar production

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[3] http://climatechangepsychology.blogspot.com/2009/03/chris-goodall-johannes-lehmann-tim.html

[4] "The Biochar Debate," Physics World, http://environmentalresearchweb.org/blog/2009/10/the-biochar-debate.html.

[5] "Biochar Hero, Johannes Lehmann, Testifies before 111th Congress," 9 July 2009, http://www.re-char.com/2009/07/09/biochar-hero-johannes-lehmann-testifies-before-the-111th-congress/.

[6] http://www.carbonwarroom.com/battle/biochar.

and use'. Its Board is chaired by Johannes Lehmann, and has members from key research and commercial organizations. Paid subscriptions entitle members to, inter alia, 'contribute to a global community seeking to advance biochar, enhance the earth's soils, and combat climate change', and 'Support IBI's work to commercialize biochar systems globally at various scales'. The IBI sees itself as 'providing a face for biochar research and outreach efforts as the authoritative organization with respect to information and policy on biochar' (Lehmann and Joseph 2009: 24); not surprisingly given this self-proclaimed leading public face, it is also a key target of biochar's critics.

Many other smaller pro-biochar networks are also emerging, with diverse interests and emphases within a climate change focus. There are now national and regional 'biochar networks' and online discussion fora in China, Mongolia, Hawaii, New Zealand, Japan, and elsewhere. They range from networks such as Biochar Europe, which unites companies and researchers in its aim 'to promote the development of a large-scale biochar industry within Europe', through research and development and by seeking carbon offsets through biochar to be recognised in emissions trading (www.biochar-europe.org/), to the Indian-based TSBI (The Society of Biochar initiatives) which was founded in 2010, claiming that 'sustainable biochar is a powerfully simple tool to fight global warming'. The claimed identity of TSBI's founder, as 'a passionate earth child and geo-engineering initiator' exemplifies the bizarre range of subjectivities that the promise of biochar seems able to unite and reconcile (www.biocharsoc.org/).

These organisations emphasise agricultural as well as climate change goals – but it is often the latter that are paramount in their optimistic, inclusive statements and climate change mitigation would appear to be a core raison-d'etre; whether agricultural concerns alone would have been sufficient to bring these organisations into being is questionable.

Biochar's potential for carbon sequestration

Key strands within the biochar for climate change mitigation narrative have focused on exploring and substantiating this claimed climate change mitigation potential of biochar. Carbon savings potentially come both from carbon sequestered in soils for the long term, and from avoided emissions (from substituting fossil fuels and fertilizer, and through suppression of methane and nitrous oxide emissions that would otherwise occur as biomass decomposes) (Shackley *et al* 2009; Gaunt and Cowie 2009). First, soil scientists are examining the stability of biochar in soils, finding that pyrolysed organic material has a much greater average stability than uncharred organic matter – suggesting a difference in decomposition rates of at least an order of magnitude, creating a long-term carbon sink that can last from hundreds to thousands of years (Cheng *et al* 2008; Lehmann *et al* 2009). Evidence of Amazonian terra preta soils that have retained their carbon since pre-Hispanic times is sometimes adduced to support these claims (e.g. Lehmann *et al* 2009: 184). Yet uncertainties remain, and long-term stability may depend on the conditions of pyrolysis (e.g. Shackley *et al* 2009), on the nature of 'background' soils and other factors (Lehmann *et al* 2009).

A second and related strand considers the size of contribution to greenhouse gas reductions that carbon sequestered in soils through biochar could make. As Smolker (2010) notes, pro-biochar organizations such as the IBI have created their platforms around highly ambitious-soundbites: that as a 'climate geoengineering technology' biochar can sequester 'gigatons' of carbon out of the atmosphere, or even 'absorb all of the carbon emissions from fossil fuel burning that has occurred in the past 50 years'. Researchers have variously substantiated and qualified such claims. Worldwide, total soil organic carbon is about twice the size of the global atmospheric carbon pool (Denman *et al* 2007). Most soils already contain char generated through vegetation fires and settlement practices during the last few thousand years, and these are estimated to make up several percent of total soil organic carbon worldwide (e.g. González-Pérez *et al* 2004). Biochar soil management offers the potential to add significantly to these pre-existing chars. However, there is uncertainty and debate over size of this potential impact. Proponents have argued that very large rates of carbon sequestration through biochar are in principle achievable. For example Lehmann *et al* (2006) quote a potential global carbon sink of 5.5 to 9.5 GtC/year by 2100, larger than the annual quantity of carbon currently produced by fossil fuels. Such figures presuppose an enormous growth in the resources and land areas devoted to the production of biochar feedstocks (biofuels), as well as that a very large fraction of this carbon would be converted to biochar. Narratives in support of such large-scale carbon capture therefore incorporate propositions about how this might be achieved. For example Goodall (2008), for whom biochar is one of his 'Ten Technologies to Save the Planet', proposes that 200 million hectares of 'forests, savannah and croplands' could be turned into biochar plantations, replacing slow-growing species with fast-growing ones that enable an increased rate of carbon capture. The late economist Peter Read, a high-profile biochar advocate and member of the IBI advocates establishing up to 1 billion hectares of new tree plantations for biochar (Read 2009). Carbonscape, a company that hopes to be among the first to commercialise the technique, talks of planting 930 million hectares (Monbiot 2009a).

The promise of such large scale carbon sequestration and the assumed availability of biochar feedstocks have, however, been strongly questioned, on grounds of both technical feasibility and sustainability. The Royal Society (2009) in a report on prospects for 'geo-engineering the climate' informed by expert consultations in the UK and beyond concluded that sequestration rates sufficient for biochar to make a significant contribution to enhancing the global terrestrial carbon sink would likely be infeasible and unsustainable given competing land uses; at best biochar could make only a small-scale contribution. Such questioning of large scale approaches – linked with concerns about their social and environmental impacts, discussed further below – have become a lynchpin of 'anti-biochar' counter-narratives. Yet these land, biomass and related economic constraints on large-scale biochar production are acknowledged – in their more nuanced research and communications – by some of the same researchers who have been associated with an uncritical 'pro-biochar' stance (e.g. Goodall 2009; Lehmann and Joseph 2009). These groups of researchers have also built more conservative models. Considering only limited biomass feedstock availability, Amonette *et al* (2007) found biochar able to remove around 1 GtC/year by 2050 (see also Shackley *et al* 2009). A recent study (Woolf *et al* 2010) incorporating a set of aggregate sustainability criteria estimates the 'maximum sustainable technical potential' of biochar to mitigate climate change as a maximum of 1.8 Gt of CO2 equivalent (incorporating also methane and nitrous oxide) per year without endangering food security, habitat or soil conservation. This is equivalent to 12% of current anthropogenic CO2 emissions annually. 1 GtC/year has been deemed a cut-off point for approaches to greenhouse gas abatement to be taken seriously. Biochar methods, as indicated above, are theoretically able to achieve this sustainably – even if they do not offer the overall carbon sequestration potential of some other geo-engineering techniques, such as chemical air capture (Royal Society 2009).

Modelling has been the core route to assessing biochar potentials in relation to climate change – in part because too few biochar systems have yet been implemented to enable the tracking of actual impacts. A few researchers have built more detailed models drawing on 'cradle to grave' lifecycle assessments of biochar systems. These early studies quantify the potential greenhouse gas benefits of biochar (in some cases along with other benefits in bioenergy production, agricultural production and economy), and generally find that biochar results in a net reduction in greenhouse gas emissions, as well as being an energetically-efficient use of biomass (Gaunt and Lehmann 2008; Lehmann and Joseph 2009). However they also underline that the climate change mitigation benefits depend on the specific methods of biochar production and use (Schahczenski 2010). At stake are both the specific methods of pyrolysis and, crucially, the feedstock. As Gaunt and Cowie (2009) point out, this is a fundamental issue: for additions to the soil carbon pool to result in a net reduction in carbon released to the atmosphere, then the buried organic matter needs to be the result of increased production – otherwise apparent increases in soil carbon stocks might simply reflect the movement of organic matter from one site to another (termed 'leakage' in the language of emissions trading). If the source is virgin material grown for biochar production, this can be less efficient in overall climate change mitigation, as the carbon sequestration capacity of that vegetation is lost when harvested for biochar. Roberts *et al* (2010) compared biochar systems based on corn stalks, yard waste and a switchgrass biofuel crop, finding that the first two contributed net greenhouse gas emission reductions (of 864 and 885 kg CO2 equivalent per tonne of dry feedstock respectively, of which 62 – 68% was realized from carbon sequestration in the biochar), but the switchgrass system could be a net greenhouse gas emitter, given indirect land use change impacts. If high carbon-sequestering vegetation such as old-growth forest is cleared to plant biochar feedstock, for instance, then the overall effect on carbon sequestration could be even more negative. In general, the limited range of studies so far seem to point to the advantages of waste-based systems on both technical and sustainability grounds.

A further stream of work assesses the economic potential of climate change mitigation through biochar. Thus Pratt and Moran (2010) use Marginal Abatement Cost Curves in scenarios to 2030 to compare biochar strategies with a range of other carbon abatement strategies, including those based on fossil fuels with carbon capture and storage, renewable energy technologies, and efficiencies in transport and electricity use. They find that even the most expensive biochar projects rival the cost-effectiveness and efficiency of other abatement strategies (although not overall abatement potential). Again, though, economic potential depends on the conditions of biochar production. Comparison of a range of biochar strategies, from small-scale stove and kiln projects in developing countries to large-scale processing plants in Europe and North America, concludes that while most are cost-effective, low-tech projects in developing countries offer the greatest potentials, because a large number can be set up within each region without heavy start-up and running costs. They also note, crucially, that the cost-effectiveness of any of these climate change mitigation projects depends on the price of carbon that can be negotiated through carbon markets – an issue we discuss further below. Assessments of the economic as well as technical potential of biochar to contribute to climate change mitigation thus depend heavily on the way that biochar is produced and used.

Risks and uncertainties

A further strand in narratives about biochar compare it with other techniques for 'geo- engineering the climate' in terms of risks and uncertainties. As The Royal Society (2009) inquiry concluded, biochar systems (like other related ways of using biomass to sequester carbon, including direct biomass burial and biomass energy production with carbon capture and storage) 'appear to have …. moderate and predictable environmental impacts and low to medium risk of unanticipated effects' (2009: 19). In these respects, they compare favourably with techniques such as ocean fertilization, deemed to have 'high potential for unintended and undesirable side-effects' (Royal Society 2009: 18), as well as with solar radiation management approaches for which the potential environmental impacts are potentially large but also deeply uncertain, and replete with 'unknown unknowns'.

However, this does not mean that biochar systems and their effects are known or risk-free. As researchers emphasise, the field is new, fast-moving and replete with uncertainties, and more science is badly needed to explore and reduce these. Uncertainties about biochar as a carbon abatement method include the relationships between different kinds of biochar systems, and greenhouse gas emissions: how long carbon is stored in the soil with biochar produced from modern methods (Collison *et al* 2009; Shackley and Sohi 2010), how much black carbon is lost during transport and application, with what effect on the climate (Shrestha *et al* 2010); and what land-use changes will result from increased production of biochar and how will those land changes feed back to affect lifecycle assessments of biochar (Shackley and Sohi 2010; Roberts *et al* 2010; African Biodiversity Network, Biofuelwatch and the Gaia Foundation 2009; Paul *et al* 2009). Many of these uncertainties arise from the lack of large-scale, long-term biochar experiments in which to study its effects in real contexts. Resolving such uncertainties thus becomes a justification for the setting-up of biochar projects 'on the ground' that can simultaneously operate as real-time experiments – and indeed as discussed below, many projects are functioning in just this way.

Moreover, both researchers and activists identify a range of potential social and environmental risks, impacts and trade-offs from biochar developments. To fulfill a 1 GtC/year carbon abatement threshold or beyond, biochar systems would need to be implemented at significant scale, raising questions about competition with land for food production and other uses. While many researchers acknowledge such limits on any endless capacity of biochar strategies to expand, and have incorporated these for instance in recent assessments of 'sustainable technical potential', such aggregate notions of limits overlook questions about whose land, where, will feed the biochar industry. Meanwhile, other pro-biochar advocates envisage grand visions and mega-schemes that either pay no heed to any such limits, or make assumptions that assume them to be very large. It is such grand visions, in particular, that are targeted in a growing body of critical counter-narrative that, in the words of the Biofuelwatch Declaration (TNI 2009) considers biochar 'a big new threat to people, land and ecosystems'. In particular, biochar is linked with 'land grabs' in developing countries.

Biochar, 'green grabs' and livelihoods

Concern about biochar land-grabbing unites a range of international NGOs, networks and researchers. Prominent amongst these are Biofuelwatch, the Gaia Foundation, the African Biodiversity Network, Friends of the Earth, the Transnational institute (TNI) and GRAIN, who in turn draw on the contributions of a small number of researchers, activists and critical journalists. Since 2009, NGOs such as Biofuelwatch have been raising concerns about biochar, especially that 'big new demands for biomass are a threat to farms and forests already suffering from soil degradation and deforestation'. Biochar concerns draw on (and link with) those raised about biofuels in general from the mid 1990s, and the 'Biofuels vs. food' debate, and discussions of 'biochar land grabbing' look set to repeat, with specific nuances, arguments rehearsed in relation to biofuels (Borras *et al* 2010). Biochar, in this way, has very rapidly become embroiled in potent discussions about 'green grabbing', where the lands and resources of the poor are seized to assuage the emergent concerns of global environmentalism (Fairhead and Leach 2010).

Thus a report on ‘Biochar land grabbing: the impacts on Africa’ (African Biodiversity Network, Biofuelwatch and Gaia Foundation 2009) claims that ‘the negative impacts of large-scale biochar development in Africa are likely to be dramatic, including exacerbating land-grabbing in Africa’. They point to the claims of some biochar advocates that biochar production on a scale large enough to impact climate will require up to a billion hectares of plantations, and that much of this will be in Africa. This, it is argued, will add to the ‘massive land grabbing’ that is already taking place for biofuels and foreign agricultural investment geared to food security elsewhere in the world, with major impacts on indigenous communities and their access to land and resources – so exacerbating evictions, food insecurity and conflict. Land grabs in Africa and elsewhere – driven by global food, fuel and financial crises – have already been highlighted including large foreign take-over deals having been concluded in Mali and Ethiopia and proposed for Madagascar, for example (Cotula *et al* 2009). Detailed analysis and documentation of cases of biofuels-related land grabs (e.g. Borras *et al* 2010) present many nuances and qualifications to this dramatic picture, showing that the extent and ways in which grabs play out, and their impacts, depends greatly on prior institutional and governance, as well as environmental, conditions. Nonetheless, it is the more dramatic instances and threats around food and biofuel land grabs that are called up to warn of the consequences of large scale biochar development. This is coupled with the assumption that biochar production will be on a large scale – drawing on the claims and visions of some of the biochar industry’s most extreme advocates.

So, for example, the Biofuelwatch report raises alarm about the proposals of the late Peter Read to establish up to 1 billion hectares of plantations for biochar. Read expected sub-Saharan Africa to contribute 893 million hectares of this land; land which, while he acknowledged is not unoccupied, is not deemed to be under economic activity ‘as reported to the FAO’. Lack of formally recorded production is thus seen as justification for taking over lands – regardless of the myriad agricultural, pastoralist, collecting, and other livelihood activities carried out by communities living on and accessing these lands. The journalist Monbiot (2009b), following up his attack on the ‘charleaders’, puts it thus:

> I wasn’t harsh enough about Peter Read. In his response column today he uses the kind of development rhetoric that I thought had died out with the Indonesian transmigration programme. To him, people and land appear to be as fungible as counters in a board game. He makes the extraordinary assertion that “degraded land” – which he wants to cover with plantations – is uninhabited by subsistence farmers, pastoralists or hunters and gatherers. That must be news to all the subsistence farmers, pastoralists and hunters and gatherers I’ve met in such places (Monbiot 2009b).

In some of his later writings – and presumably in response to critics – Read rephrased his argument as for ‘improved’ land use over large areas, with this defined as ‘sustainable production of the biomass raw material, co-produced with food and fibre' (e.g. 2009: 401). Yet how this balance is to be struck in multi-use lands is not addressed, nor is there any retraction from the assumption that large scale transformations of land use are required – now also justified by the argument that this will be 'good for rural development' by putting unproductive land to productive use. Read draws on the distinction between 'bad' and 'good' biofuels with respect to socio-economic and biodiversity impacts proposed by the Sustainable Biofuels Consensus (Trindade *et al* 2008). 'Biochar land-use improvement' is assumed to be 'good', likened to Brazilian sugar cane-ethanol management systems, 'the main good biofuel that is currently available' and where 'sugar cane expansion occurs on cerrado land (miombo land in sub-Saharan Africa) that is not used for food production and that is plentifully available' (2009: 400). Villagers whose livelihoods depend on miombo woodlands might argue otherwise.

Paul *et al* (2009) in a report from the NGOs Econexus, Biofuelwatch, Grupo de Reflexion Rural and Friends of the Earth Denmark, raise similar alarm at the 1 billion tonnes of carbon sequestration per year quoted as a lower range to address climate change, arguing that this would make further pressure on ecosystems and land inevitable. They point to a discussion at the 2008 IBI conference in which it was suggested that plantations would be required for scaling-up biochar. For instance the IBI partnered with the CWR, founded by entrepreneur Richard Branson, to promote 'Operation Black Gold'. Smolker (2010) suggests that the CWR seeks to set up a biochar trade association with the goal of removing a billion tonnes of carbon from the atmosphere – an experiment that, as Biofuelwatch points out, would require a billion tonnes of wood to be burned. Biofuelwatch also raise alarm about proposed commercial developments, including proposals included in the US Senate Climate Bill for up to 60 pyrolysis plants producing biochar. They argue that such commercial developments rarely make explicit where their raw materials would come from, and they suggest that land grabs in developing countries might be part of the source.

Some of this spectre of large scale 'land grabbing' for biochar is mitigated by the convergence of recent research, as described above, on the view that small-scale approaches using crop wastes as feedstocks actually perform better for climate mitigation in both technical and economic terms. In this view, large scale, monocultural biochar feedstock plantations are a red herring, as they would not be economically viable anyway (David Wayne, pers. comm.). Thus increasingly, a narrative is emerging that links certain types of biochar system positively with the livelihood needs and conditions of people in rural areas of developing countries – as illustrated below. However, it should be noted that if such small-scale schemes are to add up to the aggregate levels of carbon sequestration promised by 'biochar for climate mitigation' narratives, there will have to be a very great many of them. On the one hand, the spectre looms thus not of large-scale land grabs, but of replicated small-scale 'project grabs', which, to be implemented in the number required, will acquire a degree of standardization that rides roughshod over the diversity of local priorities, livelihoods and landscapes. On the other hand, if biochar systems that genuinely work for small farmers emerge, an alternative scenario might see rapid, spontaneous spread from community to community, with farmers adapting technologies and practices to suit their diverse contexts. This would be analogous to the way that other initially marginal innovations – including the System of Rice Intensification (SRI) (Uphoff 2009), and Community-Led Total Sanitation (CLTS) approaches – have spread, now right across the globe (Kar and Pasteur 2005).

A variety of case studies of model, hypothetical biochar systems suited to the conditions of farm households in developing countries have been proposed, and their particular goals, inputs and benefits described and quantified (Lehmann and Joseph 2009; Joseph 2009). These range from a Kenyan household scale bioenergy/biochar system linking crop wastes with improved pyrolising cooking stoves, to a Brazilian system involving the conversion of slash-and-burn farming to slash-and-char, and a model village-level multi-purpose biochar project in an Asian setting. Although the specific benefits vary in these different model scenarios, on balance they are argued to be positive. Hypothetical models (of both small-scale approaches and large scale, industrial ones – see Lehmann and Joseph 2009 and McCarl *et al* 2009) are an important stock-in-trade of current debate about the socio-economic as well as environmental promises of biochar, given the paucity of ‘systems in practice’ on the ground.

Nevertheless, there are also a growing number of practical examples of small-scale biochar projects in developing countries These are all at an early stage, having started in the years since 2005. Most describe themselves as ‘trials’, illustrating both the novelty/unproven character of biochar applications, and the status of many as simultaneous research sites for the development of biochar science. In African settings, for instance, African Biodiversity Network, Biofuelwatch and Gaia Foundation (2009) list 19 projects. These range from a project by the French Centre for Rural Innovations in Cote d’Ivoire (with an extension to Burkina Faso), involving biofuel (Jatropha, moringa) and biochar trials on 2,500 hectares involving farmers and projects in Cameroon (‘field trials’ involving 1,500 farmers) and DR Congo (a ten year project in ten villages) run by the Biochar Fund (Belgium); to research projects/trials in Western Kenya linked to Cornell University, targeting 20 households with cookstoves and carrying out biomass assessments on 50 households; small pilot pyrolysis plants and biochar trials in Mali, Niger and Senegal supported by the NGO Pro-Natura, and a study in West-central Ghana aiming to develop ‘biochar-based soil management strategies for smallholder agriculture’ run by Rothamsted Research (UK) and the Soil Research Institute in Kumasi. In South Africa, several energy and mining companies have started biochar projects: for example Alterna Energy, a subsidiary of a Canadian company, has started a small pyrolysis plant in Mpumalanga Province, with the charcoal sold as fuel and for biochar trials, and Delta Mining is said to be looking for biochar projects. Several of these African projects (including those in Cameroon and Western Kenya) are included amongst the nine country projects worldwide that the IBI selected for evaluation in 2008, partly to ‘evaluate cost effective approaches for the widespread introduction of biochar'. The IBI promotes a database and forum for the burgeoning number of small projects and trials around the world to post information and share findings, contributing to a growing global community of experimental practice around biochar.

A number of these projects, as well as the organizations promoting them, claim explicitly to link climate change and energy benefits (and soil benefits, as the next section will explore) with farmers' livelihood needs. Indeed several of the international networks and non-profit organisations discussed above claim to have poverty alleviation and support to small farmers as amongst their goals – although often mixed with potentially contradictory aims geared to large scale commercial biochar systems. Thus for instance the IBI invites members to support its work both to commercialise biochar, and to 'support IBI's work with community-based local and regional biochar groups'.

For organizations with a biochar focus, meeting farmers' needs and priorities is cast as one amongst the multiple 'value streams' generated by biochar projects. Thus the strapline of The Biochar Fund is 'fighting hunger, energy poverty, deforestation and climate change – simultaneously' (http://biocharfund.org/index.php?option=com_content&task=view&id=14&Itemid=37). The Fund claims its impact – such as in projects like those in Cameroon and DR Congo – as creating 'a synergy that radically changes the livelihoods of some of the world's poorest communities in multiple ways'.

In other cases, organizations with a broader-based development/environment focus take farmers' livelihoods and 'community empowerment' as an entry point, with biochar-related activities cast as a way to address these. An example is Pro-Natura, whose topline concern is 'fighting rural poverty':

> Pro-Natura is tackling the social, economic and environmental problems that face rural communities in the Developing World. The aim is to provide viable economic alternatives to those people struggling to make a living from imperilled environments. This is achieved by building local capacity and establishing participative governance, so that the preservation and restoration of natural resources can be linked to local economic success.

But which has added a series of activities and communications that include biochar, green energy and accessing carbon markets:

> Pro-Natura decided to encourage the use of its green charcoal as a biochar and has launched pilot projects on its intervention sites. The environmental benefits of this innovative application add to the advantages already recognised of the substitution of green charcoal for wood charcoal (deforestation avoided, no methane emissions, etc.). It is thus possible to render the carbon footprint globally negative (by taking more carbon from the atmosphere than is emitted), while fighting effectively against poverty

> and hunger ….(www.pronatura.org/index.php?lang=en&page=biochar).

Similarly, TerrAfrica casts its broad interest as in regional sustainable land management, through an approach emphasizing that 'small-scale subsistence farmers, agro-pastoralists and pastoralists of Sub-Saharan Africa must be acknowledged as important custodians of the environment'. It has joined the biochar bandwagon from this position:

> Biochar technology appears promising, as it connects improving degraded soils, increasing crop yields, energy provision, climate change mitigation and rural development (Woodfine 2009).

In the justifications and descriptions for such rural development-focused projects, global/regional climate change mitigation rarely figures explicitly – not least because it would not be a convincing entry point for local communities faced by more pressing day-to-day challenges. Instead, broader climate concerns are translated into local challenges around deforestation and daily energy needs, as is the case for a variety of projects that link biochar to improved woodstoves. For example,

> The African Christians Organization Network (ACON) has been working in Western Kenya since 2000 to empower villagers by providing opportunities for development that are environmentally sustainable. Since 2004, they have been focusing their work on how to reduce deforestation while improving soils for local farmers in the area. Part of this solution is improved cookstoves and the use of biochar (www.biochar-international.org/profile/ACON/Kenya).

Further examples can be found in the work of WorldStove, an NGO 'committed to creating useful and innovative carbon negative products that increase quality of life for individuals and households around the globe' (http://worldstove.org/). They have developed and piloted (in Uganda, Kenya, Haiti, Malawi, Indonesia, Zaire, the Philippines, Burkina Faso, Congo and Niger) pyrolitic cooking stoves that produce biochar:

> ….. many of our intended end users live in extreme poverty and cannot afford the wood it costs to cook a single meal. All of our stoves are designed to function using waste agricultural products that cannot normally be used in a standard stove. Not only does this mean that the fuel cost becomes less, it also means that the end product, biochar, is of commercial value. Our stoves can therefore provide a new way to generate income for the end user in addition to being environmentally friendly on the global level.

What is on offer here is not just a triple win (climate change mitigation, appropriate energy, and agricultural benefits/income), but a fourth: improved health from reduced cooking smoke and indoor air pollution. Indeed as discussed above, the kind of small-scale, slow pyrolysis used in such cooking stoves projects is also being found more efficient and cost-effective for greenhouse gas emissions reductions than the fast pyrolysis that large plants favour (Pratt and Moran 2010).

In these versions of pro-biochar narratives, then, reduced poverty, wellbeing and livelihood benefits to rural people in developing countries go hand in hand with climate change mitigation. The nature of the technology and projects – locally appropriate and small-scale – are core to these co-benefits.

However, cynical critics dispute this promise. They argue that small projects are likely to be only a small part of the biochar picture. At the moment, they suggest, all biochar projects are small-scale simply because in the virtual absence of subsidies, there has been no opportunity to scale them up (African Biodiversity Network, Biofuelwatch and Gaia Foundation 2009). Indeed this network considers small-scale ‘sustainable’ biochar to be a ‘myth’, and current small-scale biochar ‘trials’, even those with farmer participatory claims and approaches, to be trials for the eventual implementation of schemes at large, commercial scale. Larger-scale deployment is the explicit aim of several projects, they argue, including those run by the Centre for Rural innovations in Cote D’Ivoire with farmers on 2,500 hectares. Moreover, ‘emphasis on small-scale biochar appears, at least in some cases, to be part of a marketing strategy to make biochar more politically acceptable’. They point, for example, to the way that biochar marketing company Genesis Industries openly speaks about its ‘guerilla marketing’ tactics, in which a focus on small farmers provides a key marketing slogan for the owners of pyrolysis machines. Biofuelwatch similarly suggests that commercial organizations and umbrella initiatives such as the IBI use images of small farmers, their fields and woodstoves to promote a ‘humanitarian’ image while actually seeking to implement the ‘grand visions’ and large scale commercial schemes that have been their interest from the outset (Smolker 2010). In this way, and as happened with biofuels, it is argued, small scale participatory schemes are both a smokescreen for and an opening to pave the way for large scale biochar monocultures that displace farmers from their land.

Carbon markets and commerce

Key to positive narratives is the idea that biochar projects – whether large or small – can tap into emerging carbon markets. Glover (2009) lists numerous opportunities for ‘taking biochar to market’, exploiting commercial demands across seemingly disparate areas from urban and rural waste management, agricultural input supply, livestock and industrial sectors, especially as these come under growing pressure from global climate change agendas to internalize environmental costs and use resources sustainably. In particular, it is argued that biochar offers high market potential ‘as a long-term and readily measurable sequestration product, [that] will provide additional revenue in any market or jurisdiction where C is traded or C sequestration outcomes are valued' (Glover 2009: 378). Funding from carbon trading is argued to be essential to finance the research and development necessary to discover and exploit the full potential of biochar to contribute to climate change mitigation, and to enable scale-up to sequester carbon at globally-significant levels. At the other end of the spectrum, those emphasizing small farmer livelihoods argue that if farmers receive payments for sequestered carbon, this can provide an income stream and justify the financial and time investment necessary to adopt biochar systems (Palmer 2009) – a model currently being tested by the Biochar Fund in Central Africa.

Pro-biochar advocates across the spectrum of scale concerns have therefore been at pains to bring biochar into the UN Framework Convention on Climate Change (UNFCCC) process, and to argue the case for biochar to be included as an offset mechanism in formal carbon trading schemes under the Kyoto Protocol and in its Clean Development Mechanism. At the forefront of this lobbying have been international organisations and networks, notably the International Biochar initiative, as well as a range of NGOs and of agribusiness and other companies seeking opportunities to invest in the new carbon economy. Richard Branson's Carbon War Room has, through its 'Operation Black Gold', sought to 'apply overwhelming force' to ensure that biochar is included in carbon trading schemes and gains prominence on the agendas of large NGOs (Smolker 2010). But lobbyists also include developing country organizations and governments advocating for small farmer perspectives. Thus in the run-up to the 15th Conference of Parties to the UNFCCC in Copenhagen in December 2009, a group of African governments[7] forwarded a joint submission urging 'the importance and relevance of a decision for including the potential of soils in drylands in sequestering carbon. One such exponent is biochar…' (African Governments 2009). At Copenhagen, a range of specific proposals were made – including that biochar should be included as an allowable method for carbon sequestration within the soil carbon and land use change mitigation and adaptation category, and that biochar should acquire status in the Clean Development Mechanism as a mechanism for carbon offsets. Lal (2010) notes further that payments to land managers for sequestering carbon in agricultural soils was a logical issue for discussions at Copenhagen, not just as sink projects under the CDM but also for enhancing ecosystem services. Through 'farming carbon' – sequestering carbon in soils, including those that are desertified or degraded – and selling carbon credits just like any other farm produced commodity, carbon trading could contribute to poverty reduction.

In the end, these attempts failed. Many scientists, policy makers, NGOs and land managers were disappointed by the discussions at Copenhagen which did not fully address biochar and related land/forest strategies offering multiple benefits (Lal 2010). The post-2012 framework agreement negotiated at Copenhagen

[7] The Gambia, Ghana, Lesotho, Mozambique, Niger, Senegal, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

included no specific mention of carbon sequestration in soils or of biochar. Yet proponents continue to argue hard for their inclusion as the post-Copenhagen process moves forward. Meanwhile, biochar advocates have achieved notable successes at national policy levels. For instance in the United States, the IBI succeeded in getting biochar R&D included in the 2008 United States Farm Bill while the 2009 US Senate climate bill features biochar prominently. The convincing testimony of prominent scientists and advocates (e.g. Lehmann 2009) has been key in these policy changes, and these advocates continue to argue that at international level, mechanisms for carbon trading that recognize soil carbon sequestration need to be put in place.

At the same time, some advocates recognize that the inclusion of biochar in formal carbon trading will face significant challenges. These echo those common to many CDM/offset mechanisms – they have arisen repeatedly for REDD (Reduced Emissions from Deforestation and Degradation), for instance – but in the case of biochar have a particularly acute complexion. These include establishing a system for quantifying the carbon benefits – a particular challenge given how different these may be for different biochar feedstocks and lifecycle assumptions, and given uncertainties about permanence of sequestration and 'leakage' from projects (Gaunt and Cowie 2009). They also include developing a robust certification system – another particular challenge given that biochar projects are so often small-scale, geographically dispersed, and both difficult and expensive to monitor – not least for small farmers (Palmer 2009). As Lehmann argues, 'the distributed nature of biochar systems and the potential for variability between systems create significant opportunities for sustainability, but also hurdles to widespread adoption, regulation and financial viability' (Lehmann 2009). Such views support arguments for research to explore and establish appropriate regulation for biochar application and crediting (Collison *et al* 2009; Lal 2010), and to establish whether the monitoring and verification of smaller scale biochar products can be economically feasible (Lehmann 2009). They also highlight potential trade-offs: between large, industrial-scale, uniform biofuel-biochar applications that may be more commercially viable and amenable to the international carbon trade, and smaller scale, diverse applications that might deliver greater social and environmental benefits, but are less amenable to carbon trading mechanisms.

For now, such debates rage in an implementation vacuum, while the post-Copenhagen climate change policy machinery rolls slowly on. Nevertheless, even in the absence of this formal carbon market recognition for biochar, opportunities already exist for carbon financing: first through voluntary carbon markets and a variety of available schemes not linked to the Kyoto Protocol and UNFCCC (Gaunt and Cowie 2009) and second through the practice and possibility of aggregating biochar projects with other kinds of small offset project to (legitimately and cost-effectively) sell them in formal global markets (Palmer 2009). These – together with the high promise of big carbon trading gains to come – have been sufficient to entice many small companies and commercial initiatives onto the biochar scene. There they form a subset of the dizzying array of commercial ventures forming around the new carbon economy in general. The website statement of one of the latter, the investment advice firm Green Chip Stocks (strapline: ‘a new way of life, a new generation of wealth’) encapsulates the immense imagined profits enwrapped with the promise of carbon-trading futures:

> *Carbon Trading: The World’s Next Biggest Market. Here’s how to get your piece of the profits in the early going*.
> The New York Times recently ran an article claiming that “carbon will be the world’s biggest commodity market, and it could become the world’s biggest market overall”. Rest assured, it will be. Currently valued at over $30 billion, the carbon trading market is set to skyrocket to over $1 trillion as the price of carbon becomes more and more valuable. And it’s possible to get a piece of this infant industry right now. Early investors can play the burgeoning carbon market by 1. Investing in carbon credits themselves, or 2. Investing in companies that are making extra cash by reducing their emissions. There’s no telling just how lucrative this market will become. Why else would huge companies like GE, DuPont, and Johnson and Johnson be racing to reduce their emissions? It’s because of the huge profits that stand to be made.

Commercial ventures specializing in or including biochar are many and varied, but are united in the imagined promise of profit- generating technological solutions to a collective global environmental problem. As the venture capital firm VenEarth Group put it:

> Biochar can be produced from agricultural and forest wastes sustainably worldwide. Large scale deployment of biochar in agriculture can deliver gigatons of annual carbon sequestration while improving farm productivity, making us all healthier and wealthier (www.venearth.com/).

Among the many companies – and the list is too long to repeat – forming or shaping their activities and claims around the promise of biochar, are first, those producing biochar or biochar technology. These include for example BioChar Products: ‘a start up company dedicated to the demonstrating and testing of the fast pyrolysis concept for use in small communities near forested landscapes’ (www.biocharproducts.com); Carbon Gold, a UK-based company that manufactures biochar-based products for gardening and has a portfolio of projects in developing countries (www.carbongold.com); BiG – Black is Green, an Australian company that designs and produces fast pyrolysis plants (www.bigchar.com), and the aptly-named Dare to Imagine (DTI) Strategy and Marketing Consulting (www.daretoimagine.com/projects.html) that among other activities has a renewable energy project of commercially producing biochar from waste. Another – the Pennsylvania-based Mantria Industries opened the ‘world’s first commercial scale BioChar facility’ in August 2009 to great fanfare but no longer exists, having been charged for fraud by the US government regulators for using ‘exaggerated claims and aggressive marketing to con people into investing in biochar sequestration’ (Inman 2010). In this fast-moving world of promise, it seems that biochar companies come and go.

Others that have come, for now, include, second, many consultant groups that help firms set up biochar production. For example Biochar Consulting (www.biochar-consulting.com) is a Canadian based company offering ‘comprehensive technical services to clients who wish to undertake projects or produce or utilize Biocarbon or Biochar.’ CarbonZero (www.carbonzero.ch/) focuses specifically on biochar as ‘a team of agricultural consultants who can help firms interested in reaping the multiple benefits of utilizing biochar in their operations’, and lists seven reasons why biochar is such a good investment/product. A third kind of company are consultancy (or finance) groups offering carbon offsets through biochar, sometimes alongside biochar production. For example Crucible Carbon (http://cruciblecarbon.com/consulting.php) includes biochar amongst the options it advises for how companies can go carbon neutral based on existing technology, while doing research on ‘next generation pyrolysis’ and regenerative land practices. Outback Biochar (www.outbackbiochar.com) produces biochar mobile technology, sells biochar in small quantities, and provides consultancy services to assess biochar sites, feedstocks, carbon potential, and financing and profit options. Similarly, Re:char: (www.re-char.com/about/) is ‘part technology company and part information source, providing up-to-date information and commentary on the nascent world of biochar’.

These examples are only a small handful amongst many. In short, there is a vibrant world of ‘start-up’ commercial activity that seeks to profit from biochar technologies, to profit from helping others set up and manage profit-making initiatives, and to profit from advising others about the potentials. These are layers of hope built upon, and in turn supporting, the narrative of biochar as a solution to climate change. The fragmented nature of this multitude of initiatives reflect the bubble-like character of this investment in promise, as well as the absence of any regulatory framework. Whether investment in biochar approaches for the long-term can be sustained through this style of market growth is questionable (Glover 2009).

Yet these pro carbon funding narratives also meet counter-narratives. More nuanced research and commentary casts the future of global carbon markets as more uncertain. It suggests that the future profitability – and economic efficiency – of biochar as a climate change mitigation approach will depend heavily on future carbon prices and the many factors shaping these in a complex global economic system. Others critique carbon trading and geo-engineering together in more general terms. They argue that this represents an economic and techno-fix that distracts from the more pressing need for systemic changes in economies, production systems and lifestyles. As the People’s Declaration from Klimaforum09, the large alternative meeting at the Copenhagen Summit, put it:

> Environmental and climate debts must be paid. No false, dangerous, and short term solutions should be promoted and adopted, such as nuclear power, agro-fuels, offsetting, carbon capture and storage (CCS), biochar, geo-engineering and carbon trading…. (Klimaforum 2009).

In this view, biochar is grouped with other geo-engineering methods as part of top-down, centralized approaches promoted by a techno-capitalist industrial complex. This is contrasted with a quite different bottom-up vision in which, as the People's Declaration argues:

> We want to take the future into our own hands by building a strong and popular movement of youth, women, men, workers, peasants, fisher folks, indigenous peoples, people of colour, urban, and rural social groups, which is able to act on and deal with environmental degradation and climate change (ibid).

More specific public and activist concerns turn on whether geo-engineering is a distraction from the more pressing need to cut carbon emissions at source. This is despite the fact that most proponents of carbon sequestration methods and geo-engineering themselves acknowledge that this does not reduce the need for cutting emissions now. As the President of the Royal Society put it in introducing the Society's report, 'nothing should divert us from the main priority of reducing global greenhouse gas emissions. But if such reductions achieve too little, too late, there will surely be pressure to consider a "plan B" – to seek ways to counteract the climatic effects of greenhouse gas emissions by "geo-engineering"' (Royal Society 2009: 5). Prominent biochar researchers and advocates (e.g. Lehmann and Joseph 2009) also see this as a complement, not a substitute, for emissions reductions through transformations in economies, energy and transport systems. Moreover biochar offers the double prospect both of carbon sequestration and of emissions reductions through pyrolysis-bioenergy production, and the latter's replacement of more carbon-emitting energy sources.

Narratives critical of carbon trading and geo-engineering also invoke global injustice. CDM and carbon offsets, they suggest, offer the developed world an excuse for not cutting their own emissions – rather than as a tool to use in addition to cutting emissions (TNI 2009). This is especially likely for biochar, given that most land for biochar production will be in developing countries. Some groups therefore suggest banning any carbon sequestration or geo-engineering options, while others recommend leaving such methods out of the Clean Development Mechanism and carbon trading, in order to reduce the funding towards them (e.g. African Biodiversity Network, Biofuelwatch and The Gaia Foundation 2009).

The governance implications of biochar, along with other forms of geo-engineering the climate, are only just beginning to be raised (Royal Society 2009, Rayner, pers. comm.). Most governments have yet to engage in the debate, let alone establish specific policy positions and frameworks – while global policy frameworks through the UNFCCC are, as we have seen, remarkably non-specific when it comes to biochar. In this governance and policy vacuum, businesses and NGOs alike are pursuing their biochar interests, leaving biochar-for-climate-change-mitigation remarkably vulnerable to the unregulated interplay of private hopes and fears.

Finally, critics of carbon economy-funded approaches argue that these falsely promise a simple solution to far more complex problems. Thus as part of his attack on biochar, Monbiot (2009a) wrote that 'The idea that biochar is a universal solution that can be safely deployed on a vast scale is as misguided as Mao Zedong's Great Leap Backwards… We clutch at straws (and other biomass) in our desperation to believe there is an easy way out.' Biochar and other geo-engineering approaches play into what Hulme (2009) has characterized as a misguided view that 'climate change' is a problem to be solved – rather than a discursive phenomenon that will inevitably be disagreed over and debated, and that implicates multiple smaller, more diverse problems. In this respect, the very 'universal' promise of biochar – the triple win – is also its Achilles heel, leaving positive claims and hopes about it very open to accusations and counter-narratives that these claims are over-reaching, over-universalist, and thus hubristic.

Dynamics of polarization

Thus in relation to climate change mitigation, biochar has become the subject of a range of competing narratives and counter-narratives. At the extreme, the debate has become highly polarized, with advocates and critics taking a pro or anti-biochar stance. Yet what also emerges is that biochar can be (in practice, and in imaginations) many different things, depending on how it is produced and applied, by whom, and through what systems. These implicate technical questions (of feedstock, pyrolysis, scale and land use practices), as well as interlocked questions of social goals and those of finance, governance and control. In this respect, and at the extreme, recent debate has often pitched two contrasting positions and sets of assumptions that speak both at and past each other. Thus one broad narrative centres on the promise of large scale, commercially-viable, biochar production to sequester gigatons of carbon per year and thus contribute significantly to climate change mitigation. It is this large-scale narrative that is the main target of critics, with their counter-narratives that label this as a commercially-driven, infeasible, attempt at a technical fix that will lead to 'green grabs', dispossession and poverty. Amidst such polarization, the myriad more nuanced views and lines of research in the middle can fall out of view. Yet a more qualified, mid-range set of narratives centre on the potential for small scale, diverse, locally appropriate biochar schemes using waste materials to contribute to climate change mitigation more modestly, as part of diverse portfolios of climate change mitigation and adaptation strategies, while generating livelihood benefits at the same time. This in turn justifies research and governance activities to explore and clarify the ecological, technical, social, financial and governance conditions for such promise to be made real.

This middle range set of narratives also opens the way and offers a potent field for research and advocacy around the soil benefits of biochar, to which the next section turns.

Biochar for agricultural productivity through soil enhancement

When added to soils, biochar has been found to bring about enduring improvements in productivity. The actors and networks forwarding arguments and evidence around this second major biochar 'win' overlap strongly with those promoting biochar for climate change mitigation. Indeed for most pro-biochar researchers and advocates, it is the combination of climate and soil (and energy, and waste) benefits that make biochar systems so promising. Networks and organizations such as the IBI and Biochar Fund thus emphasise both. However, a range of further actors is attracted by, and involved in exploring and promoting, the soil benefits of biochar. These include a (relatively small and tight) community of soil scientists and agronomists; development organizations seeking to improve rural livelihoods, who see value in soil benefits (which they might not find in climate change mitigation arguments); a small number of companies specializing in biochar (which they sometimes term 'agrichar'), and governments and policymakers concerned with food security and agricultural sustainability – especially in developing countries.

Thus as Hansen *et al* (2008) argue, 'Carbon sequestration in soil also has significant potential. Biochar, produced in pyrolysis of residues from crops, forestry, and animal wastes, can be used to restore soil fertility while storing carbon for centuries to millennia. Biochar helps soil retain nutrients and fertilizers….'. This is an attractive promise given current policy concerns about impending global food crises, the need for expanded agricultural production, and the key limits that soil fertility is thought to place. For instance agriculture in Sub-Saharan Africa is argued to need a 'green revolution' (AGRA 2009). The continent, it is claimed, faces a growing soil productivity crisis (Abuja Declaration 2006; Sanchez 2002; FAO 2003) which will in turn undermine the region's vital need to sustain and expand food production. Biochar, it is argued, 'provides a unique opportunity to improve soil fertility and nutrient-use efficiency using locally available and renewable materials in a sustainable way' (Lehmann and Joseph 2009: 6). This offers the prospects of increasing incomes and food security for farmers (Schazenski 2010), and contributing to national, regional and even global food security goals. Rattan Lal, Director of the Carbon Management and Sequestration Centre at Ohio State University, argues for attention to biochar from a starting point that 'there are more than 1 billion food-insecure people in the world… the gap in cereal requirement in Sub-Saharan Africa … was about 16 million tonne in 2001 and is projected to increase to 52 million tonne in 2015'. Increasing the amount and quality of the soil organic carbon pool offers a key route to addressing what Lal casts as 'the trilemma of food insecurity, climate change and soil/environmental degradation' (2010: 13).

Of course there is much debate about how to address the presumed global – and African – soil productivity crisis (Scoones 2008). Many organizations favour an increased role for organic, biomass-based pathways, and biochar strategies offer one route of this kind (e.g. TerrAfrica; Woodfine 2009). Yet others see increased chemical fertilizer use as essential to the required new generation of 'green revolutions' in Africa and beyond, citing Africa's low levels of fertilizer use as a central problem to be tackled. Advocates of a fertilizer-led revolution, supported by widespread subsidies, range from the World Bank (Agwe *et al* 2007), the Bill and Melinda Gates Foundation, certain governments and powerful actors within the Alliance for a Green Revolution in Africa (AGRA 2009) – as well as many fertilizer companies and their lobbying organizations. These debates are manifold and heated, and involve complex scientific and policy processes[8]. Biochar is potentially interesting for all 'sides' because its advocates do not offer it as an alternative to inorganic fertilizers, but rather a complement – enhancing fertilizer uptake and efficiency of use (Lehmann and Joseph 2009). This is potentially an attractive scenario for companies and organizations that profit from fertilizer production and distribution, who can expect greater demand for fertilizers from farmers who see their application resulting in larger crop productivity gains.

Some versions of 'biochar for soil enhancement' narratives emphasise not just food production goals, but also the promise of greater resilience and adaptive capacity to climate change – especially for vulnerable people and areas in developing countries. As the submission of African governments to the UNFCCC meeting in Bonn, 2009 put it:

> Today the world faces a situation of growing urgency given the combined consequences of and the intricate linkages between climate change and severe droughts, land degradation and desertification. The effects of these phenomena are most severe in the villages and in the countryside of developing countries, with negative impacts on the ability of the inhabitants to cope with and adapt to climate change…. The resilience of the dryland populations can be brought about with innovative and proven technologies such as biochar… (African Governments 2009)

In this view, biochar strategies offer an appropriate 'synergistic response' to land degradation, desertification, and drought – to climate change adaptation – as well as mitigation.

In helping plants to grow better, some pro-biochar advocates have made the point that biochar's effects on soils also boost its capacity to contribute to climate change mitigation, making larger-scale systems more feasible. For instance as Goodall (2009) responded to Monbiot's (2009) critique in The Guardian:

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[8] See for example http://www.future-agricultures.org/EN/e-debates/Soil_Fertility/soilfertility_main.html.

> We will have to take the organic outputs of large areas of land in order to achieve this [significant greenhouse gas reductions] and Monbiot is right to express horrified disbelief at some of the figures that we have suggested. Here we depart from the path of agreement. Monbiot mentions but then ignores the other benefits of biochar. These are at least as important as direct climate change mitigation. First, soil dosed with charcoal can substantially improve agricultural productivity. Food crops grow better. Trees planted in biochar often have better root systems. Crop yields are improved. This means that we can provide food supplies for more people from a smaller area of land. Growing bigger plants and trees, which are largely made from carbon, hydrogen and oxygen has a secondary effect of holding back CO2 that would otherwise be in the air. It is another form of useful carbon sequestration, albeit a once-only gain, adding to the primary effect of storing charcoal in the soil.

Biochar, soils and historic anthropogenic dark earths

Key to narratives concerning biochar as a soil enhancer is the evidence of pre-Hispanic terra preta soils in the Amazon. Indeed it was initially the soil science, historical and archaeological work around terra preta that kick-started early interest by researchers in anthropogenically-enriched ‘dark earths’. Recent research on the Amazon basin has led to a fundamental reappraisal of its social and natural history. Earlier arguments that the poor soils of the region had restricted pre-Hispanic social formations to the small, semi permanent settlements similar to those found among Amerindian people today (Meggers 1971), have been undermined by archaeological evidence of large sedentary settlements throughout the Amazon basin (Mann 2008; Schaan *et al* 2008; Heckenberger *et al* 2008). Areas of dark and highly fertile soils that can support intensive farming have been found to cover 1.2 - 1.8 million hectares of forested lowland Amazonia, undermining earlier interpretations that its infertile soils could not support large settled populations (e.g. Woods *et al* 2009). Pre-Hispanic populations are now known to have been far greater than earlier thought, their decline far more precipitous, and their impact on modern Amazonian forests far more significant (Woods *et al* 2009; Balée and Erikson 2006; Clement 1999; Lehmann *et al* 2003; Denevan 2001). Amazonian archaeologists, historians, anthropologists and ecologists now form an epistemic community (e.g. The Terra Preta Network) exploring the mix of timescales, sequences of practices and social/historical factors involved in their formation. The mixes suggest a family of dark earth types, produced through various pathways (Kampf *et al* 2003) although evidence of their modern formation remains limited (Schmidt and Heckenberger 2008; Steiner *et al* 2009).

In contemporary narratives around the soil enhancing effects of biochar, direct links between the existence of terra preta and modern biochar management are made. Lehmann and Joseph (2009: 4) describe how biochar has ‘been frequently connected to soil management practised by Amerindian populations before the arrival of Europeans… this proposed association has found widespread support through the appealing notion of indigenous wisdom rediscovered'. While leaving open whether such links are justifiable or not, Lehmann (2009) notes the equivalences when arguing that: 'biochar soil management increases the amount of such naturally existing chars, which have been found to provide beneficial health and productivity properties to soil'. A review for the European Commission (Verheijen *et al* 2010) based on a meta-analysis of biochar/soil studies sees terra preta (as well as other carbon-enriched anthrosols in other parts of the world where they have been identified, such as Japan) as analogues for modern biochar, and a positive in its favour, in showing that the principle of improving soils through carbon enrichment has been tried successfully in the past. Modern Amazonian farmers value these soils, and many have developed distinct agricultural practices on them that contribute to more sustainable livelihoods (German 2003; Fraser 2009). Soil scientists are therefore researching ways to mimic their establishment (e.g. Uphoff *et al* 2006; Lehmann 2009). Some have suggested that research on Amazonian terra preta might offer a useful technology to transfer elsewhere – such as to Africa (e.g. Sillitoe 2006).

However, others are sceptical about this linkage. They argue that there is a disconnect between ancient terra preta and modern soil management possibilities – as the people and knowledge involved in terra preta are no longer extant. In a tirade against what she terms the 'biochar worshippers', journalist and co-director of BiofuelWatch, Smolker (2010) argues that 'the biochar worshippers like to claim they are making something like terra preta when they pyrolize everything from wood to municipal solid waste, and that their biochar will similarly last for thousands of years. But there is little basis for comparison between modern biochar and ancient terra preta'. The UN FAO similarly asserts that 'the knowledge systems and culture linked to the Terra Preta management are unique but have unfortunately been lost' (Smolker 2010). Such views have become incorporated into counter-narratives that cast doubt on claims about biochar as a soil enhancer.

Soil science debates and uncertainties

Biochar is still an under-explored phenomenon for soil sciences and agronomy, but the number of researchers and universities interested in it is growing and proponents suggest that it is moving rapidly into the agronomic mainstream (Lehmann, pers. comm.). Networks centred on Cornell University in the US are key, extending to include researchers in Amazonia (e.g. at EMBRAPA in Brazil) and Europe (e.g. at the Rothamstead research station and the Edinburgh-based Biochar Research Centre in the UK) and more recently, Africa (e.g. at the Kumasi Institute of Science and Technology in Ghana). Compared with biochar's climatic impacts, which must largely be ascertained through modelling, there are a number of empirical studies; most are small scale experiments in controlled conditions, although the numbers of field studies – and their variety of geographical conditions and 'background' soils – is expanding. On the basis of these, research findings are both substantiating the promise of biochar as a soil enhancer, but also raising further uncertainties and issues requiring further study – uncertainties that critics have seized on.

A key line of study concerns how far, and through what mechanisms, the addition of char improves soil productivity (Blackwell *et al* 2009). Many studies have found plant production to increase significantly after biochar addition to soils (Verheijen *et al* 2010). A number of processes and factors are thought to be involved, including reduction in soil acidity, improvement in caption exchange capacity, improved habitat for soil micro-organisms and better water-holding capacity (Shackley *et al* 2009; Lehmann and Joseph 2009). Transformations in soil microbial activity, macro fauna (e.g. ants and earthworms), and soil bacteria are thought to be highly significant to the increases in soil productivity observed in biochar systems, as terra preta researchers have found (e.g. Ponge *et al* 2006; O'Neill *et al* 2006). In effect, char addition enables a 'ratcheting up' of the soil biology/soil ecosystem into a different, more productive state (Uphoff *et al* 2006). Yet uncertainties remain, for instance concerning how the degree of response is shaped by background soil nutrient availability, and other ecological and management conditions (Thies and Rillig 2009). Similarly while the addition of biochar to soils sometimes improves water retention capacity, there is some uncertainty as to whether this is a universal property. Other studies suggest that effects on soil water retention are more complex, and can be direct or indirect, short or long term, and even positive or negative depending on soil type and the quantity of biochar applied (Verheijen *et al* 2010; Shackley *et al* 2009). To date, trials have been conducted in controlled (greenhouse) conditions and in (mainly tropical) regions with particular environmental conditions, and even in these, responses have been variable. This leaves open questions about the effects amidst the diverse range of biochar sources, ecological and management conditions that biochar systems will involve. Such variability has caused critics to question the overall claims made about biochar's effects on soils. Thus Biofuelwatch (Smolker 2010) suggest that there is no 'proof' that biochar improves soil fertility. 'Nor is there any proof that it performs as well as compost, l*et al*one better!'

A second strand of research and debate addresses the longevity of biochar in soils. Pro-biochar advocates suggest that biochar is long-lasting in soil under agricultural management, with terra preta often invoked to justify this view. Carbon from forest fires has existed in some soils for 10,000 years, while radio carbon dating of Amazonian terra preta soils finds persistence of between 500 and 7,000 years (Lehmann and Joseph 2009). Based on studies of dryland Australia, conservative estimates of a Mean residence Time of 1,000 – 2,000 years have been made (Lehmann *et al* 2008). Yet other studies show a more rapid turnover time (Shackley *et al* 2009). Uncertainties remain over how far the type and extent of subsequent agricultural management might influence the decomposition of biochar in soil – with certain practices perhaps accelerating it (Verheijen *et al* 2010).

A further area of risk and uncertainty concern possible toxicity effects of biochar on soils. The existence of contaminants such as heavy metals within biochar has been raised as a possibility – although there is very little experimental evidence on this, on how levels and types of contaminants might relate to biomass feedstocks and pyrolysis conditions, or on the effects in different soil and ecological conditions (Verheijen *et al* 2010). Meanwhile, critics have raised concerns that toxins concentrated in char could end up in soils and enter the food chain.

Whereas critics have frequently seized on such areas of uncertainty and contradictory findings to undermine the case for biochar in soils, for biochar researchers, they underline the need for further research. Thus a review for the European Commission (Verheijen *et al* 2010) finds that 'meta-analysis of the effects of biochar application to soils and plant productivity … showed a small overall, but statistically significant, positive effect of biochar application to soils on plant productivity in the majority of cases,', but argued that 'before policy can be developed in detail, there is an urgent need for further experimental research with regard to long-term effects of biochar application on soil functions, as well as on the behaviour and fate in different soil types (e.g. disintegration, mobility, recalcitrance), and under different management practices'. Lehmann (2009) argues similarly that to promote implementation, more evidence is needed 'of best biochar practices at scale of implementation, including farm scale; and of demonstration of soil health benefits for the full spectrum of agroecosystems' (2009: 5). Indeed a vibrant research community is growing around biochar, animated by these and other questions, and often working on and through practical field-based biochar projects – such as those in Africa described in the last section. Researchers agree that long-term field experiments are important to understand the effects of biochar on soil and ecosystems (IBI 2009; Lehman and Joseph 2009). While urging governments to fund this research, there is also acknowledgement that big field trials may rely on partnerships with businesses to attract the necessary levels of resources.

Commercial promise of biochar for agriculture

A range of companies are interested in the agricultural promises of biochar, and their commercial potentials. The list overlaps heavily with the burgeoning field of commercial interest in biochar as a climate change mitigation method, and as the last section illustrated, many technology and consultancy companies are interested in both. However, further businesses interested in agricultural biochar include those that produce pyrolysis plants for farms, and those that create and sell biochar as fertilizer. The only consultancies in this field are those offering services to aid the construction of biochar plants; consultancies and venture capital firms interested in carbon offsets rarely focus on the agricultural impacts, other than to suggest that such an investment is socially conscious as well as environmental. As for climate mitigation-focused biochar commerce, a rapidly-expanding set of businesses is emerging around the agricultural promise of biochar technology. This explosion of interest, again, has a bubble-like character, inflated by an array of anticipated market opportunities – but potentially very fragile. Some argue that the variety of agriculturally-focused market opportunities for biochar now need broader evidence, frameworks and regulation to establish proven price structures and market volumes, and secure a sustainable climate for investment (Glover 2009).

Most of the companies producing biochar commercially for agriculture – sometimes calling this 'agrichar' – are small. They include, for instance, Carbon Gold, which is marketing its 'gro-char' range in UK garden centres; the Australia-based Outback Biochar (www.outbackbiochar.com/about-us/company-profile/), Eventix, and Eprida – which claims to have a patent pending for a new 'Eprida technology' that 'uses agricultural waste biomass to produce hydrogen-rich biofuels and a new restorative high-carbon fertilizer (ECOSS)' (www.eprida.com/invest/index.php4). Such companies see their markets primarily as in the gardens and farms of consumers able to purchase their fertilizer products, while their clients also include firms and governments keen to offload biomass waste to be processed in their pyrolysis plants. These ventures, in effect, turn biocharred soils into a commodity – and a valuable one at that – that can be bought and sold just like any other.

Yet these soil-enhancement focused commercial initiatives have strong distributional implications. TNI (2009) argues that 'turning soils into a commodity is profitable to industry but disastrous for the poor'. Noting that several patent applications have been made for charcoal use in soil (and pyrolysis with charcoal production), they argue that this will ensure that future profits from the technology will go to companies, not communities. Moreover, they raise concerns over intellectual property rights, alluding to terra preta arguments to do so: 'given that successful strategies for combining charcoal with diverse biomass in soils were developed by indigenous peoples, "biochar" patenting raises serious concerns over biopiracy'. Such arguments about biopiracy run somewhat counter to those – forwarded by the same organisations – that there is a disjuncture between the ancient) peoples and production techniques used to form terra preta, and today's farmers. Within their own framing, it is not clear quite whose extant intellectual property rights should be respected. Nevertheless, if – as we discuss below – evidence is found of contemporary farming communities producing terra preta analogues, it would give weight to such biopiracy concerns. At another level, some have suggested that small farmers too could profit from the production and sale of biocharred soils as a commodity. This is, in effect, what Lal (2010) recommends in his proposals for 'farming carbon' – although in this case profits would come indirectly through carbon credits, not from direct sales. The possibility that rural communities are already producing and selling biochar-enriched soils – to other farmers, or urban gardeners – has been overlooked within narratives that assume profits only to business, and which confine 'indigenous' agrichar production to the past. Yet this is quite plausible, and evidence that farmers in the Amazonian trade pre-Hispanically-created terra preta opens up tantalizing questions about whether such small-scale trade is also operating in other regions, overlooked, today.

Soil enhancement for small farmers

Some versions of narratives supporting biochar for soil enhancement emphasise the particular benefits for small farmers living in conditions of poverty. The individuals and organizations forwarding these arguments overlap strongly with those emphasizing poverty benefits from biochar for climate change mitigation. Indeed it is soil improvements that are often the key benefit to farmers identified in actual and promised 'multi-win' biochar projects, such as the African projects discussed in the last section. The benefits of agricultural improvement to small farmers are much closer at hand than payments for carbon offsets from biochar. Thus NGOs and development organizations promoting small-scale biochar woodstove projects, for instance, place greatest emphasis on their capacity to improve the productivity of crops and thus farmers' food security and incomes. Further, biochar is said to be particularly efficacious at restoring and improving degraded or poor lands – and these are the lands on which poorer farmers often live. TerrAfrica (Woodfine 2009), for instance, emphasise these rural development benefits. Since biochar as a soil enhancer reduces the need for other fertilizers (and makes small applications more efficacious), it is also appropriate for resource-poor farmers. Studies conducted with small farmers add weight to these claims. For example:

> Many field studies in the tropics carried out by academic researchers have shown that biochar improves soil productivity. Biochar Fund's research did more. It showed that poor farmers typically making less than $300 a year from their crops were able to improve their own yields using simple techniques both for making the char and adding it to the soil…. (Goodall 2009).

Those advocating biochar for soil improvements for small farmers and poverty reduction emphasise that small-scale biochar approaches should become the main type of biochar used globally (e.g. Pratt and Moran 2010; Lal 2010). A variety of hypothetical biochar systems geared primarily to soil enhancements for small farmers have been proposed (Lehmann and Joseph 2009).

However, organizations against biochar, including Biofuelwatch, use a similar rhetoric of concern for small farmers when they warn that the biochar's productivity gains are not proven and its health risks under-studied. Uncertainties about the possible toxicity of biochar in soils, and about effects on ground water (Shackley *et al* 2009) are cast by some organizations as posing high potential risks to vulnerable small farmers. They therefore suggest that encouraging small farmers to use biochar before such uncertainties are fully resolved is tantamount to using them as guinea pigs in dangerous trials (Smolker 2010).

Any debate over one use of biochar overlaps with debates about its other uses, so those advocating biochar's agricultural benefits have, like proponents of biochar for climate change mitigation, met worries about land-grabs. Critics are concerned that the large-scale production, transportation, and application of biochar for soil enhancement made from first generation biomass could – like the large scale application of biochar for climate change mitigation – encourage land-grabs and commercial profits over local benefits to small farmers. Furthermore they suggest that even when such 'grabs' do not involve land per se – or a transfer of property rights in it – they might be 'biomass grabs'. Thus as Paul *et al* (2009) argue, if biowaste is removed from a farm to be made into biochar and then not returned to that land, the soil there will be depleted so instead of improving the soil for local farmers, the biochar industry will undermine it. Such arguments suggest that the challenge with large-scale production of biochar for agriculture is producing and then distributing it in a way that does not undermine the soils of small farms. For this reason, many argue that small-scale biochar production should be favored. To make biochar most beneficial for small, rural farmers, the production and application of biochar on a small, local scale, from local biowaste, should be encouraged (Pratt and Moran 2010; Roberts *et al* 2010; Lehmann and Joseph 2009).

To date, literature and debate is largely silent on the possible impacts on small farmers of encouraging them dramatically to shift their existing farming practices. Yet arguments for 'transfer of biochar technology' suggest precisely this. Biochar projects and trials – most, as we have seen, at an early stage and too soon to be evaluated – emphasise technical aspects, within overall assumptions about the suitability of the techniques proposed for farmers' needs and livelihoods. The interactions of biochar with farmers' practices are occasionally alluded to (e.g. Woodfine 2010) but hardly studied, as compared with the detailed attention given to interactions with soils, ecology and crops. Yet the history of 'transfer of technology' approaches in agriculture more generally shows that suitability, adoption and uptake frequently stands or falls on socio-technical questions – around the implications for farm labour, tenure, gender and crop control issues, as well as the dynamics of farming within a broader social setting. So far, such questions are hardly on the agenda for biochar-related agricultural developments. In a rare exception, Joseph (2009) argues that 'biochar technology transfer programmes' might learn lessons from experiences in related fields – from the introduction of improved cooking stoves more generally, to renewable, energy, agriculture and forestry projects. These underline the importance of socio-economic, as well as technical appraisal, and it is suggested that the Sustainable Livelihoods Framework (Carney 1999) offers an appropriate basis for a biochar socio-economic assessment methodology – drawing attention to the importance of gender and other social relations, and local power dynamics (Joseph 2009: 361).

Again almost uniquely in the biochar field, Joseph also emphasizes the need to ‘develop programmes that are people centred, responsive and participatory’ (2009: 360), drawing lessons from experiences with participation in development more broadly. The picture painted is thus of community members, researchers and project implementers jointly analyzing local needs, resources, social and cultural strengths; developing and implementing project plans, and evaluating – and if necessary adaptively adjusting – strategies. This model scenario of a biochar project process – as well as of a technical system – is nicely described through a hypothetical village-level project in an Asian setting. How and how far such ‘ideal type’ participatory planning might actually proceed in practice, especially given the many conflicting goals, interests and uncertainties that pervade the field, remains to be seen.

A further notable silence in current biochar debates – and despite these general arguments about ‘participation’ – concerns the potential for working with and seeking to build on farmers’ existing knowledge and practices. With a few notable exceptions – such as the broad arguments of TerrAfrica, and the BioChar Fund’s work in Cameroon and Central Africa, which is led by a social anthropologist – the dominant modus operandi is of introducing biochar strategies from outside, as a new, transformative approach. This presumed gap between farmers’ existing practices and biochar strategies seems, at first sight, to jar with the origins of biochar interest in work on Amazonian terra preta. The latter is, par excellence, an example of ‘indigenous’ knowledge and practice – although many uncertainties remain about precisely what practices were entailed, and how intentional they were. Yet there is a presumed disjuncture between terra preta creation – part of a pre-Hispanic past – and today’s farming. This narrative of disjuncture deters interest in the implications of today’s farming systems for the implantation of biochar practices. More significantly, it also deters interest in the possibility that today’s farmers might themselves be creating anthropogenic dark earths; that recent, extant indigenous knowledge might include acknowledgement, value and use of – or even practices to create – char-enriched soils. Yet research led by social scientists in Africa is now exploring just this possibility (Fairhead and Leach 2009; www.steps-centre.org/ourresearch/biochar.html), seeking to investigate more widely and systematically practices that have so far been reported only as isolated cases and anecdotes (e.g. Sohi and Yeboah 2009; Zech *et al* 1990; Leach and Fairhead 1995). If evidence builds, it may lend support to those arguing for small-scale, locally appropriate approaches to biochar strategies for soil enhancement. But it will undoubtedly also open up new lines of inquiry and narrative possibility around the conditions required for small farmers, in all their diversity of social as well as ecological circumstances, to gain.

Conclusions

Biochar and its promises are therefore matters for heated debate. This is fast-moving and multi-dimensional, with narratives and counter-narratives swirling amongst and between advocates and critics, researchers and activists, governments and NGOs, businesses and farmers – and those who claim to speak for each. There is truly a politics of biochar at work – and this is, as we have argued, in many respects a politics of promise, around a substance, technology and set of ideas that have yet to make much impact on the ground.

More polarized aspects of the debate have treated biochar as if it were a silver bullet – for the challenges of climate change mitigation, soil fertility, sustainable energy production, or all three together. This is the triple win – and in some versions, waste management, poverty reduction and health are added in as well. It is this claimed promise as a universal 'fix' that has been at the forefront of the positive hype about biochar – but which has also attracted its most vociferous critiques. This pro and anti-character has certainly brought high profile to the biochar debate, across scientific, policy, activist, media and public circles. This has helped drive interest and attention forward, in a self-fulfilling feedback that keeps heated debate about biochar's promise running ahead of practice in research, implementation, funding and regulation.

Yet as this paper has shown, positions and sub-narratives in today's debates about biochar are far more nuanced and varied than their more polarized versions suggest. Even biochar's strongest advocates – who in some contexts do make universalistic, 'triple win' claims, or are represented by others as doing so – prove on further interrogation to be more nuanced, reflective and qualified in their approaches. Thus the so-called 'biochar hero' Johannes Lehmann states clearly that 'biochar is not a silver bullet' (e.g. Kleiner 2009) and is seeking through research to clarify the conditions in which it may realize benefits – and for whom (Lehmann and Joseph 2009). The journalist Monbiot (2009b), who initially painted biochar champions James Hansen, Chris Goodall and James Lovelock as single-minded biochar zealots, on further reflection was forced to retract this view and admit that their positions were more nuanced.

A key emphasis of these more qualified positions is to portray biochar not as a universalistic silver bullet, but a valuable contributor within necessarily diverse approaches to meeting global challenges – 'an important "wedge", contributing to an overall portfolio of strategies' (Lehmann and Joseph 2009: 9). Thus biochar has a potential role in climate change mitigation, but needs to be considered alongside and in relation to a diverse portfolio of mitigation strategies – including reducing emissions in the first place. Similarly, 'from a soil conservation perspective, biochar may be part of a wider practical package of established strategies and if so, needs to be considered in combination with other techniques'

(Verheijen *et al* 2010). Rather than turning whole landscapes and livelihoods over to biochar, it might have value for some people and places within diverse, context-specific ways of managing environments and making a living. In this respect, an overarching biochar narrative may be emerging that emphasizes diversity and context specificity. The nascent lines of research that are exploring how biochar performs, according to different criteria and under different agro-ecological and economic conditions, are both justified by such a narrative and likely to generate findings that support it.

Nonetheless, the play of narratives and counter-narratives also reveal some strong tensions, dilemmas and trade-offs around biochar. One is around spatial scale, with large scale schemes (promising globally-significant climate change impacts) pitted against small ones (promising more efficient and effective systems, and livelihood gains rather than land grabs and losses). Another is around benefits, and whether these are to accrue in commercial profits or improved small farm livelihoods. A third is around history, and whether – and in what ways – historical experiences around terra preta should be invoked in assessments of biochar's future promise. Narratives and potential biocharred development pathways vary in how they align themselves in relation to these tensions, which are linked to different framings of biochar systems and goals. Meanwhile the more polarized aspects of debate have sometimes involved instances where framings 'speak past' each other, as in relation to the spectre of biochar 'green grabs' where accusations target large scale schemes, and defendants retort that (small scale) biochar developments can benefit small farmers.

Interplaying with these tensions and debates are a range of uncertainties. Many of these involve technical and ecological issues, and vibrant, multi-stranded research is seeking to address these, in studies ranging from soil science and agronomy to interdisciplinary systems and lifecycle assessments. Other uncertainties involve questions of economy and policy, which are starting to attract attention, given impetus by the promise of big profits from the new carbon economy. Questions of governance, deeply interlocked with issues of scientific uncertainty and of who will gain or lose from biochar developments, are only just starting to be addressed (Royal Society 2009). Most notably absent from the current biochar field are social science inquiries: both studies of biochar as a phenomenon with social as well as technical meanings, and the interactive social science, with farmers, land users and project implementers, that will be needed to explore its interactions with diverse local social, as well as physical, environments. Opening up a space for such inquiry has been one of the aims of this paper. In a field where the politics of promise are running ahead of practice, there are gaps that research can help to fill, but this will need to be social as much as technical. The exploration of existing narratives around biochar such as we have attempted here is part of this social science inquiry. By clarifying current actors, arguments, assumptions and political interests, along with the emergent pathways they are shaping, we have tried to open up space to consider what narratives would help biochar to become part of pathways to sustainability that also build social justice.

A set of promises that are running ahead of practice and implementation offers the advantage that socio-technical regimes are not yet established and cemented, locked-in through investment and practice. Opportunities to destabilise more problematic narratives may therefore be greater than in more practically-embedded fields of science and technology. Biochar has been deemed a disruptive technology to incumbent political-economic regimes locked into unsustainable pathways – of high carbon emission-fuelled economies and unsustainable, inorganic fertilizer-fuelled agriculture. Perhaps it is time to disrupt the disruptive, and ensure that biocharred pathways themselves do not lock-in to routes and styles that favour scale and profit at the expense of local livelihoods and landscapes.

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