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Biochar
The need for precaution?

By **Charles Merfield**

Five years ago biochar was almost unheard of, while today it appears in the mainstream press. The reason for this dramatic rise in awareness is that biochar is presented as a solution to two of the biggest issues facing humanity: climate change and agricultural production. Biochar achieves the apparently impossible by being both carbon negative and boosting crop yields. In a world with too much carbon in the atmosphere, too little in the soil and in many places sub-optimum crop yields, it sounds miraculous. At first blush it also appears compatible with organic philosophy and increasing numbers of people in organic agriculture are suggesting that we start using it. However, I'm not so sure that this is such a great idea. Let me explain.

The precautionary principle

This is not the first time that an apparently amazing agricultural technology has been promoted with a big heap of hubris and gung-ho attitudes. For example, Haber-Bosch nitrogen and pesticides, which were considered miraculous in their day, yet are now increasingly being found to be double edged swords.

A key 'antidote' to such gung-ho hubris is the precautionary principle. The organic movement has explicitly incorporated the precautionary principle as part of its fundamental world view within the IFOAM (International Federation of Organic Agriculture Movements) 'Principles of Organic Agriculture' and it has been a key foundation of organic philosophy since the earliest days.

Therefore, my humble recommendation is that the organic movement should be viewing biochar through the lens of the precautionary principle, and the other IFOAM principles, and giving it considerable and deep thought before it decides if it is compatible with organic/ecological/sustainable agriculture, or if it is more of a curse in disguise and we should restrict or prohibit its use.

To be totally clear, I am not saying we should permanently ban biochar right away, as I do not claim to know all the answers: that is the problem, no one knows the answers yet, because there is insufficient information. However, from what is known, I believe there is sufficient cause to proceed with precaution, and not rush in boots and all. The following is therefore a handful of points and questions for further discussion and scientific research; there are many, many more (see further reading). Only when we have good sound information, clothing a strong theoretical skeleton, can wise decisions be made on whether to allow biochar or not.

Terra preta

First a very quick recap: biochar was 'discovered' in Amazonian forest soils called terra preta do Indio (Amazonian dark earths). These soils were created thousands of years ago when neolithic farmers used a technique called 'slash and smoulder' to produce charcoal/biochar. Even after the passing of many millennia these soils still retain much of the original biochar, i.e., it has not decomposed back to the atmosphere, and the soils are often considerably more fertile than the same soil that has not had biochar additions. So biochar locks atmospheric carbon into soils for thousands of years that would otherwise of had a much shorter return time back to the atmosphere (where it helps warm the planet) while boosting crop yields. A pretty stunning result you would have to say.

The excitement is that if (a big if) this result can be replicated in current agricultural systems and get the same result, i.e., sequester carbon from the atmosphere into the soil and boost crop yields, we could make big

inroads into climate change and food production. However, not everything appears to stack up with biochar: it not only seems miraculous, it appears to need some 'real' miracles to square the circle.
The key reason we need to think and look very hard for possible pitfalls and proceed with precaution is that the use of biochar is irreversible. Once it has been applied to soil it is going to remain in the soil for thousands of years. If it is discovered after it has been applied that there are serious negative effects of adding biochar, then there is no known way to remove it, and there is nothing that can be done to mitigate the undesirable effects.
So what could possibly go wrong with biochar? Well, we simply don't know because we have not been looking hard or long enough. Like artificial nitrogen and pesticides, if you don't look for problems you won't find them. So what are some of these potential problems?
Terra preta are not representative of modern agricultural soils and ecosystems so extrapolating from them is speculative at best, probably foolhardy at worst. We have very little knowledge of the actual practices that made these soils. However, it's a fair assumption that neolithic farming systems were probably closed cycles for nutrients and its likely that biochar was not the only material going onto the treated plots, i.e. it is likely that there were significant nutrients flows from the surrounding forest into these plots, both directly, e.g., with the biochar and indirectly, e.g., via human and livestock manure. To put it scientifically, biochar is not the only variable/factor in this experiment. If large amounts of nutrients were also imported into the biochar-treated plots, it is little wonder that they are more fertile and the biochar may have nothing to do with it.

More than just carbon

It is commonly believed that biochar is just carbon, however, that is not the case. All the lithospheric nutrients (phosphorus, potassium, magnesium, etc.,) contained in the source material can't escape during production so they remain in the char and co-products. Therefore, a significant amount of the yield boost from biochar may well be due to the nutrients it contains rather than its physical properties. Clearly the amount of nutrients in the char is finite so these amounts will decrease with time and therefore so will any yield increase they create.
There is a rule of thumb for experiments looking at changes in soil function: a minimum of five years' data is required as it takes at least that long for a soil to change from one state to another. Ten years is a better timescale to ensure you are approaching the soil's new steady state. Most experiments looking at the yield effect of biochar are pot experiments, of a few months duration, or plot experiments of one or a few years at best. In short, I would not trust the results of short term biochar crop yield experiments to inform the long term effects on soil and crop yields, one iota.

Yield increase or decrease?

Biochar does not always increase yields, sometimes it decreases them. That is clearly a pretty undesirable effect so its essential that the cause is understood. Where biochar is increasing yields beyond that expected from its nutrient content what is causing that increase in yield and can it be sustained? There are plenty of techniques, e.g., cultivation/tillage, soluble nitrogen fertilisers, herbicide strips under perennial crops, that can cause a short-term (1–10 years) increase in yield from the decomposition of existing soil organic matter, but in the long term cause yield losses as organic matter levels bottom out and soil function grinds to a halt. Can we be certain that adding biochar to soils is not enhancing microbial activity which in turn is depleting 'normal' soil organic matter creating short-term yield boosts at the expense of long-term yield declines and impoverished soils? The answer is no, we can not even make an educated guess.

Natural is not necessarily safe

Current organic standards are chiefly concerned with the prohibition of xenobiotic materials especially biocides. At first blush biochar seems to pass this hurdle. The source material for biochar is eobiotic, the production process (burning) is also 'natural', therefore biochar appears to be eobiotic and therefore permissible under organic standards.

However, if you wanted a quick and easy recipe for making some pretty toxic compounds you would do well to start with a mix of biological material and burn it in a low oxygen environment. Some of the toxic compounds produced include volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). There is also an issue of heavy metal contamination, as these become concentrated in the biochar and may also have their chemical forms altered in the process. The assumption that because biochar is 'natural' does not mean it is non-toxic or safe.

Using 'agricultural wastes'?

The main materials that are lost from the source material during biochar during production are the atmospheric nutrients oxygen, hydrogen, carbon and some nitrogen, plus a lot of energy. Taking a holistic view, what are the opportunity costs of this process? The starting material for biochar is biological compounds, mostly plant remains. These are often called 'agricultural wastes'. There can be few things that more clearly demonstrate an ignorance of soil than the term 'agricultural wastes'. There are no wastes in agriculture, just as there is no waste in nature, everything is food for something else. 'Agricultural wastes' are in fact one of the most valuable resources on the planet: they are soil 'food'.

Soil is the most complex ecosystem on the planet and it needs a constant supply of food (energy and nutrients) to function properly, and that food is plant (crop) residues. As far as we know biochar is not soil food, and if it is, it's a poor comparison with the crop residues from which it is made, as much of the carbon, oxygen, hydrogen and a big chunk of energy have been removed. Biochar is likely to be a zero-sum game; if biological materials, especially 'agricultural wastes', are used to create biochar, that same material can not be used as soil food. This is not however an all-or-nothing situation, more a matter of balance.

Application of biochar

While biofuels create an ongoing loss of soil food, biochar application is mostly proposed as a one-off activity, i.e., the biochar is applied once to an area of soil and then no more is added, because biochar remains in the soil for a very long time. However, biochar application rates can be quite substantial. While 20–40 tonnes per hectare (t/ha) are typical, rates of up to 1,000 t/ha have been used. In comparison an application of 20–30 t/ha of compost is a substantial amount that will last several years. However, an application of 20–30 t/ha of biochar is equivalent to 60–120 t/ha of dry weight of plant residues as biochar has a typical conversion factor of 25–35%.

In a best case scenario, e.g., growing a strawy cereal, the amount of crop residues left to convert to biochar could reach 5 t/ha ('wet' weight). So to create a typical application of biochar would require the residues from 12–25 years of crop production, but in practice many more years, e.g., half a century, because only a few crops would produce a couple of tonnes of high carbon residue per hectare let alone five. Depriving soil of its main food source for that long is without doubt going to cause serious problems.

Holistic thinking

This issue of the source of the feedstock for biochar and its alternative uses is a classic illustration of the need for holistic/systems thinking and using well thought-out life cycle assessments (LCA). This is something the organic movement has been very good at in the past and it is essential that it continues to maintain this perspective (it has been slipping lately) as much of the rest of the agricultural world still have their reductionist blinkers firmly on.

Conclusion

In conclusion: the above are a small fraction of the many issues surrounding biochar. Only a handful of the issues are understood in any detail, most issues are known unknowns, and there are quite likely to be quite a few unknowns unknowns, just as there are new issues being found today for mineral fertilisers and pesticides, even a century after their discovery. If all of these issues with biochar are resolved and none turn

out to have harmful effects it will be quite amazing, which would be great, as we desperately need less carbon dioxide in the atmosphere and more organic matter in our soils.
However, the sheer number of issues surrounding biochar means the likelihood of all being without problems is pretty low. The question then is how bad are these problems likely to be, especially considering biochar application is irreversible as far as we know?
Any technique with the ability to alter the biogeochemical cycles is clearly pretty powerful. So, just as putting carbon dioxide and other green house gases into the atmosphere raised no concerns for a very long time, if biochar has large unknown negative effects that take many decades or longer to reveal themselves then humanity could be creating a bigger problem that the ones we are trying to fix. Hubris, as the saying goes, is inevitability and inexorably followed by nemesis.

Dr Charles 'Merf' Merfield is head of Science and Extension at the Biological Husbandry Unit Organic Trust – see www.bhu.co.nz for details. His personal website is www.merfield.com

Further reading and information sources

Caveat emptor! Finding good information on biochar is not simple. The best sources are mostly reviews commissioned by governments and large independent (research) organisations. The following are recommended and were used as source material for this article along with a range of other research articles.

- F Verheijen, S Jeffery, AC Bastos, M van der Velde, I Diafas, 'Biochar application to soils: A critical scientific review of effects on soil properties, processes and functions', 2010, http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR24099.pdf
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