Amazonians' black magic has multiple benefits

Sample biochar produced by BEST Energies – the company is producing commercial quantities from a range of feedstock. BEST Energies

Biochar, similar to the charcoal used by Amazonian cultures to invigorate their crops, is receiving attention as a potential solution for sequestration of significant amounts of carbon. Employing it in agriculture may also increase crop production and reduce emissions of carbon dioxide and other potent greenhouse gases, such as nitrous oxide. So what is this stuff?

In the search for ways to generate green energy from renewable sources, researchers have been perfecting the heating of biomass – ideally waste biomass (woody, cellulosic material) – in closed, oxygen-free conditions (known as pyrolysis) to make an efficient, gaseous fuel. The resulting bioenergy, or synthesis gas ('syn-gas'), is rich in hydrogen, methane and carbon monoxide, and can in turn produce useful heat and power, or be further converted to liquid fuels.

The question, however, was what to do with the substantial amounts of the solid waste product ('char') that was left over after the conversion. The pyrolysis process results in a significant amount of the carbon in the original biomass being converted into a highly stable chemical structure.

Inspiration came from the dark *terra preta* soils of the Amazon basin. Created by pre-Columbian indigenous farmers through the constant addition of charcoal, food scraps and waste materials to boost crop production, these soils supported a vast population. The high fertility and high carbon content of this dark earth, compared with adjacent charcoal-free soils, stimulated study and inspired researchers to look at the potential of biochar to be applied in modern agriculture.

The result is increasing understanding that biochar has the potential not only to boost crop production, but also to help sequester atmospheric carbon due to its highly stable nature and reduce the emission from soil of other gases.

The International Biochar Initiative (IBI) has been subsequently established and represents today's efforts to research and harness this by-product's potential. In an open letter to the IBI, Professor Tim Flannery advocated the great potential of biochar's multiple benefits.

'The biochar approach provides a unique powerful solution, for it allows us to address food security, the fuel crisis and the climate problem, and all in an immensely practical manner.'

'With the appropriate political and technical recognition, promotion and adoption, it will change our world forever, and very much for the better,' he wrote.

The structure matters

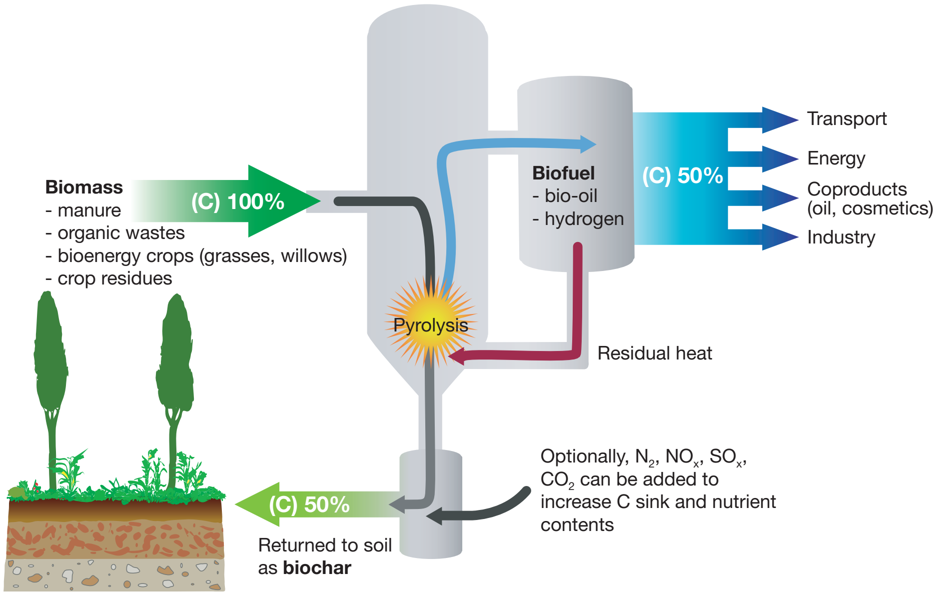
Biochar is essentially the same as fire-derived charcoal. It has a similar chemical structure that is highly aromatic[2] and this makes it difficult for microbes to break down. It can therefore remain in soil or sediments for much longer than most other organic materials – in some cases for up to 5000 years – with its properties

1 Lehmann J *et al.* (2006) Bio-char sequestration in terrestrial ecosystems – a review. *Mitigation and Adaptation Strategies for Climate Change* **11**, 403–427.
2 'Aromatic' refers to the chemical ring structure of the substance.

improving over time. The stability of both biochar and regular charcoal exceeds that of the starting biological material more than 10-fold.

The key feature of biochar, compared with char produced by wildfires or burning associated with agriculture or land clearing, is its specific production under pyrolysis conditions with partial or complete exclusion of oxygen – a so-called 'C-negative' process, making biochar a carbon 'sink'. That is, a net amount of CO_2 is withdrawn from the atmosphere through the combined pyrolytic process of energy production from renewable (biological) materials and generation of a very stable form of carbon, which can be added to soil as a carbon sequestration and soil conditioning material.[1]

The best feedstocks for biochar production are derived from uncontaminated and non-compostable waste materials that aren't useful elsewhere (therefore helping waste disposal efforts), rather than from substances that contain a significant amount of readily available nutrients, such as compostable wastes – these are likely to provide better soil-health benefits when left un-charred.



Concept of low-temperature pyrolysis bioenergy with biochar sequestration. Typically, about 50% of the pyrolysed biomass is converted into biochar and can be returned to soil. Johannes Lehmann

Biochar's potential

The recently released Garnaut Report recognises biochar as part of a 'negative emissions' process and suggests that biochar production may be economically competitive under a carbon emissions trading price of US$37 per tonne. However, in many circumstances where these organics are attracting a waste management fee, the process is already economically feasible.

While the stable properties of charcoal, which underpin its use in carbon sequestration, have been confirmed for some time, the use of biochar as a beneficial soil amendment to aid crop production is less well researched and understood.

Several studies have observed significant changes after the application of biochar to crop soils, including increased crop yields, reduced need for fertiliser and increased water-holding capacity. In addition, emissions of nitrous oxide (a greenhouse gas 310 times more potent than CO_2) from soils were reduced by several times the usual levels in some trials.

Dr Lukas van Zwieten, Senior Research Scientist with the NSW Department of Primary Industries, has been running trials to study the effect of biochar on soil properties. He has shown that biochar addition can reduce nitrous oxide emission five-fold.

Other research has indicated that plants grown in contaminated soils respond positively to biochar applications, suggesting that biochar may aid in rehabilitation of contaminated soils and waterways. Exactly how biochar achieves these improvements is the subject of ongoing research.

These observations of biochar's benefits are not universally true and there are issues that complicate the use of biochar as a beneficial soil amendment.

First, the effects of biochar on soil properties depend to a large degree on the type of feedstock used, and on the temperature and time of reaction. Biochars produced under certain conditions have been shown to have a detrimental effect on plant growth.

Second, not all soils respond positively to biochar applications. Most studies reporting positive effects have been on

A trial garden plot at BEST Energies, showing comparative productivity results under biochar application (left) and natural conditions (right). BEST Energies highly degraded and nutrient-poor soils, whereas application of biochar to fertile and healthy soils often yielded no changes in the short term.

National research efforts

Biochar research in Australia is carried out in several universities and research organisations in partnership with biochar producers. BEST Energies, one of these partners, is working with the NSW Department of Primary Industries (DPI) on field trials that deploy their commercial biochar, which they aim to make in a sustainable way.

A recent meeting at the University of New South Wales, jointly organised by NSW DPI and CSIRO Land and Water, brought together Australian and New Zealand biochar researchers. The Network of Australian and New Zealand Biochar Researchers was formed as a result and it will ensure better dissemination of information about biochar and its benefits. Members of the network will coordinate the first Asia-Pacific Biochar Conference, to take place on the Gold Coast from 17–19 May 2009.

The network's researchers are focusing on the use of biochar for carbon sequestration and soil amelioration. While most studies focus on biochar application in agriculture, future work will examine other beneficial uses including its capacity to adsorb organic and inorganic contaminants, and its role in the rehabilitation of degraded soil and waterways.

Dr Neil McKenzie, Chief of CSIRO Land and Water, said CSIRO had an outstanding record of research into the dynamics of soil carbon. 'Our work on the age, chemistry and abundance of char in soil has provided the foundation for our new studies into the potential of biochar. This research is essential for developing one of our most promising mitigation strategies against climate change.'

'Biochar also provides a real bonus by improving the fertility of our naturally depleted and ancient soils. CSIRO is playing a key role in meeting this important national challenge,' he said.

It will also be necessary to understand risks associated with biochar: for example, identifying safe feedstocks; defining sustainable and appropriate rates of application; and documenting responses of different soil types to biochar. A concerted research effort is needed to properly understand the 'black magic' of biochar so we can fully reap the benefits.

Johannes Lehmann, Associate Professor of soil fertility management and soil biogeochemistry at Cornell University, USA, has probed the mystery mechanisms of the Amazon's *terra preta* soils and he is emphatic about the scale of this task: 'We need a research effort, comparable to the development of fertilisers over the past century, to provide the underlying scientific information for the development of biochar in this century.'

● **Evelyn Krull**

More information:
International Biochar Initiative, www.biochar-international.org
BEST Energies, www.bestenergies.com