Biochar – An Organic House for Soil Microbes

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Charred rice husk (photo by Bryan Hugill)

Rick Burnette wrote an article for Issue 6 (July 2010) of ECHO Asia Notes, titled "Charcoal Production in 200-Liter Horizontal Drum Kilns." My article takes the charring process a step further by exploring the rapidly re-emerging world of biochar. Biochar is a form of charcoal, produced through the process of pyrolysis from a wide range of feedstocks. Basically any organic matter can be charred, but agriculture and forestry wastes are most commonly used due to the available volume.

Biochar differs most significantly from charcoal in its primary use; rather than fuel, it is primarily used for the amendment of soils (enhancing their fertility) and sequestration of carbon (reducing the amount of CO_2 released into the atmosphere).

Biochar has received a lot of interest internationally over the last few years, especially in light of the rising demand for food and fuel crops, and of raging debates on how to radically slow down runaway climate change. With strong voices on both sides of the debate—that is, both in favor of and against the widespread production and application of biochar—I would like to step back to the beginning of the story, hopefully putting things into perspective again.

Terra preta ("black earth" in Portuguese), first noted by the explorer Charles Orton in 1870, is a type of very dark and fertile soil with a very high charcoal content found in the Amazon Basin. The soils were amended by local people between (roughly) 450 BC and 950 AD. *Terra preta* soils were re-discovered by Dutch soil scientist, Wim Sombroek, in 1966. This sparked intense research into the addition of charcoal to relatively infertile tropical soils with the express purpose of improving them for agriculture. Such charcoal can be made from a variety of organic matter (e.g. plant residues, animal manure, fish and animal bones). The practice of using charcoal to amend soil is not unique to the Amazon; it can safely be said that anywhere people have made fires to cook food or provide heat, or burned the land before planting (including natural fires), some amount of biochar has been produced. However, the aim of biochar is to produce the maximum amount of carbon and minimum amount of ash. This means that deliberate open burning of fields and forests is <u>not</u> the way to proceed, especially when the intended outcome is for agriculture. Slash-and-burn only leaves about 3% of the carbon from the burnt organic matter in the soil, with the rest literally going up in smoke.

Unlike the very hard charcoal used for cooking and heating, biochar is highly porous at the microscopic level due to its being made at relatively lower temperatures and has the unique ability to readily absorb moisture and certain nutrients. Herein lies one of its key strengths in the amendment of soils, and the basis for this article's title. From a soil perspective, biochar can be thought of as a microbial condominium. After it is initially made, biochar undergoes a maturation period during which it absorbs nitrogen (until saturation point) from the environment, usually from urine, composting, IMO teas, etc. After this period, the biochar becomes a stable environment for bacteria and fungi to take up residence. In poor and leached soils, microbial activity is often very low, especially during the dry season; the addition of biochar to these soils means that the soil microbes now have a stable and moist place to reside and prosper, even during the dry season. As a result, the need for additional fertilizer should decrease over time, as these now-resident microbes are able to break down organic matter in the soil, and even become food themselves for larger soil organisms, such as earthworms. Furthermore, nutrients stored in the pores are slow-released throughout the year as more and more microorganisms take up residence.

Climate change and carbon sequestration are currently big topics internationally. Biochar is one of the leading means for taking CO_2 out of the atmosphere and binding it up into soils as a stable form of carbon. Unless fires sweep through the area, biochar will remain in the soil for thousands of years. It has been estimated that some 15 to 35% of the carbon in plant biomass can be permanently captured as biochar during the pyrolysis process, putting it way ahead of many other leading technologies that are aimed solely at carbon capture. The ability to "capture" carbon makes biochar a subject of much debate and speculation in international discussions on carbon credits.

Biochar has many other fascinating properties:

- Field trials involving biochar have shown crop yields to increase significantly, especially when used in conjunction with other good agricultural regimes. Increased yields have been obtained with rice, maize, wheat, corn, tea, coffee, legumes, tomatoes, flowers, etc.
- The pH of acidic soil can be increased / optimized through the application of biochar.
- The micro-porous structure of biochar is highly variable, depending on the way in which it is produced (for example, highly porous activated charcoal is made by injecting steam into the oven after the carbonization stage) and the type of feedstock used.
- The micro-porous structure provides a habitat for the proliferation of beneficial soil biota.
- The micro-porous structure of biochar benefits water retention in the soil.
- The surface area of biochar has been demonstrated to be anywhere from 10 to 300 m^2/g (activated charcoal has a surface area of up to 2,000 m^2/g!), most of which is found internally and provides ample area for microbial habitat.
- The large surface area of biochar can attract and hold all mineral ions - not only cations (+) such as ammonium, calcium, magnesium and potassium, but also anions (-) such as nitrogen, phosphorus, sulfur, and boron. By attracting and holding both positive and negative nutrient ions in the soil, biochar can reduce both leaching (into groundwater) and out-gassing (into the atmosphere). These loosely-held nutrients are bio-available to microbes and plant roots in the complex root zone.
- Biochar can improve soil texture and workability, particularly heavy clay soils, although it has shown great promise in all soil types.

- Recent studies have shown that plants grown in biochar as a growth medium (at concentrations as low as 1 to 5% of the total soil mixture) tend to have a higher resistance to pests and diseases (i.e., systemic resistance) (Elad et al., 2010).
- Biochar's natural affinity for nitrogen allows it to arrest the flow of the nitrogen cycle. It tends to only release as much nitrogen into the surrounding soil as is needed by microbes and plants to maintain healthy growth (*ScienceDaily*, 2010).

The policy debate – Should we promote biochar or not?

We must reduce the levels of CO_2 in the atmosphere through substantial changes in our "use as much as we can" lifestyles if we hope to have any chance of bringing global temperatures back down to what we consider as "normal." At an international level, several organizations are actively promoting the production and use of biochar in a responsible manner, particularly in terms of its ability to function as a soil amendment and as one of the most valuable tools in the climate change mitigation "toolbox."

Spearheading this charge is the International Biochar Initiative (http://www.biochar-international.org), with a rapidly growing member organization base and 30 regional biochar groups around the world. Biochar has even been adopted at the UN level as a tool demanding serious consideration in the global "runaway climate change" debate. While finding a "new" way to process organic "wastes" that results in significant crop yield increases and sequesters carbon at the same time may seem fantastical, therein also lies the curse… On the other side of the political fence are organizations that are calling for extreme caution in the widespread development of a formal biochar sector for fear that it will lead to increased land-grabbing and deforestation.

Often, though, we find that real people living in real conditions do things that run counter to or far ahead of the prevailing policy debate, both as a matter of survival and "because this is the way we have always done it". Thailand is a classic example: *glab pao* (แกลบเผา) or burned rice husk is a common by-product of village-level charcoal production and is for all intents and purposes, the precursor to biochar. This char is bought in large volumes, left to sit in piles in the corner of the land (i.e., undergoing a "maturation" period, to be explained in more detail below), and eventually used as a growing medium for such plants as coconuts and bananas. In other words, it's the same product as raw biochar (i.e., biochar that has not undergone the maturation period), has the same use, but a different name so it's not on the biochar radar screen. I don't doubt that similar activities are happening all around the world as I write this and I feel should be supported, when used in conjunction with other forms of environmentally-friendly soil amendments.

Making your own biochar

One of the easiest ways to begin making biochar in Thailand, considering the available feedstocks, is using rice husks resulting in *glab pao* (แกลบเผา). Short of making charcoal and using rice hulls as a filler material in the ovens, the PhilRice Open Type Carbonizer is the simplest option, as outlined in an excellent booklet available online. Other options for such feedstocks as maize cobs and stover, coconut shells, sugar cane bagasse, etc. could include the top-lit updraft (TLUD) kilns and stoves, drum retorts, brick and Magh biochar retorts, earth pit kilns, inverted downdraft gasifiers, and so on [*Editor: Links to websites containing diagrams, photos, plans and* *other information related to these biochar-production technologies are available at the end of this article*].

It is also recommended that you make biochar from materials that are locally available for environmental and economic reasons. The “200-Liter Horizontal Drum Kilns” in Rick Burnette’s article also function as fantastic ovens for making biochar from tree branches, bamboo, etc., with the simple addition of a grating to allow the even distribution of heat from the external fire through the biomass inside. Such technologies are simple to operate and maintain, effective, cost-effective, and readily adaptable to a variety of local needs.

Making IMO for maturing the biochar (photo by Khongchi Yiayang, GIZ CliPAD)

Making biochar in a modified PhilRice Open Type Carbonizer (photo by Bryan Hugill)

IMPORTANT: Before you begin using your biochar, remember that you need to “mature” it first. The addition of “fresh” biochar to soils often results in what is termed “nitrogen shock” whereby the biochar rapidly absorbs all the available nitrogen in the surrounding soils, thereby limiting its availability to plants (the nitrogen is eventually released, but very slowly). To prevent this from happening, biochar is commonly first treated with urine or mixed with compost and/or drenched with compost teas and IMO mixes and combined together with soil from the field to which the biochar will eventually be applied after having been left to sit quietly in the corner of the field or yard for a few months. During this period, the biochar absorbs all the available nitrogen to saturation point, as well as begins the process of microbial colonization. As a result, the biochar that you add to the soil will be able to begin working immediately.

Application rates for matured biochar typically vary from between 1–3 kg per m^2, depending on the condition of the soil. The biochar can be applied in a variety of ways, including: (a) simple broadcasting across a field, which is most useful in moist/wet soils, or where the soil will soon be plowed, although this runs the risk of being blown away by the wind if the biochar is too dry; (b) targeted application such as in a hole when you plant a tree; (c) mulching, both around a tree and along its lateral root system; (d) mulching on raised beds, preferably thereafter covered in straw, etc.; (e) mixed into composting systems; and (f) mixed into animal bedding, which is then applied to the field periodically.

It is best to start small and build up the concentration of biochar until the crop yield increases reach a plateau, and then stop adding biochar. After that point, short of a fire raging through your field and vaporizing everything or a flood washing your field away, the biochar should remain stable in your soil for thousands of years, quietly working its magic.

Final thoughts


Nearing the end of the charring process (note the wood vinegar collection) (photo by Bryan Hugill)

Biochar, while appearing on the surface to be a climate change and agricultural panacea, is not without very real dangers if the production and sourcing of feedstocks are unregulated, particularly at an industrial scale. To be cost effective, centralized industrial production requires enormous volumes of feedstocks. There are worries that such large-scale biochar production will be sourced primarily through land-grabbing, followed by tree plantations (such as *Eucalyptus*), resulting in an escalation of social and environmental conflicts. However, such concerns remain hindered for two key reasons. First of all, the biochar industry and market are still very young and at the experimental stage with regard to technology (much of which is extremely expensive at an industrial scale) as well as efficient production processes, biochar characterization and applications and market readiness. Second, many proponents of biochar production and use are acutely aware of the dangers and are actively campaigning to prevent the negative effects from industrial production from happening.

Biochar is also not an easy carbon-in-the-ground substitute for changing our oil-addicted "business as usual" behavior and, as noted above, should never be used as an argument for large-scale land-grabbing and the promotion of plantations for charring. Neither should the making of biochar mean abandoning other good agricultural practices. Rather, biochar should be used as yet another tool that every farmer has at his or her disposal for using agricultural wastes in innovative ways to improve soil fertility and productivity.

Finally, to quote Albert Bates, "… if it [biochar] fulfills its promise of taking us back from the brink of irreversible climate change, it may well be the most important discovery in human history."

Further information

Below are a few websites that provide solid evidence for the value of using biochar in various soil types and climatic conditions. The sites also include discussions on matters such as policy, remediation, production, field trials, and external funding sources:

- The Thai Biochar Initiative: http://www.biochar-international.org/regional/thailand
- Japan Biochar Association (been studying biochar for almost 30 years): http://www.geocities.jp/yasizato/JBA.htm
- Bioenergy Terra Preta Discussion List (the most up-to-date discussion list covering a wide range of biochar-related topics, including production and field trials): http://terrapreta.bioenergylists.org/
- Yahoo Group mailing lists:
  - Biochar (http://tech.groups.yahoo.com/group/biochar/)
  - Biochar in Soils (http://tech.groups.yahoo.com/group/biochar-soils/)
  - Biochar Production (http://tech.groups.yahoo.com/group/biochar-production/)
  - Biochar Policy (http://tech.groups.yahoo.com/group/biochar-policy/)

- Biochar Funding (http://tech.groups.yahoo.com/group/biochar-funding/)
    - Biochar Remediation (http://ca.groups.yahoo.com/group/Biochar-Remediation/)
- South East Asian Biochar Interest Group: http://sea-biochar.blogspot.com/
- GEK Gasification (an open-source resource for engineers and DIY-ers): http://www.gekgasifier.com/
- Understanding micro-gasification in stoves and why it works: http://www.hedon.info/Micro-gasificationWhatItIsAndWhyItWorks
- PhilRice Open Type Carbonizer: http://terrapreta.bioenergylists.org/philricecarbhull. The main challenge with producing rice husk char is the potential for the high levels of silica in the husk to vitrify due to excess heating. The PhilRice Open Type Carbonizer limits this effect, but may result in excessive amounts of ash if allowed to burn too long.
- Top-lit updraft (TLUD) kilns and stoves: http://terrapreta.bioenergylists.org/files/1G%20Toucan%20TLUD%20for%20Biochar%20Jan%202010%20-%20final_0.pdf and http://www.arti-india.org/content/view/80/52/
- Magh biochar retorts: http://maghbiocharretort.blogspot.com/
- Earth pit kilns: http://www.pacificviews.org/weblog/archives/002103.html
- Inverted downdraft gasifiers: http://transectpoints.blogspot.com/2007/02/pyrolysis.html

Here are a few books worth finding and reading:

- Bates, Albert (2010) *The Biochar Solution: Carbon Farming and Climate Change*. New Society Publishers. ISBN: 9780865716773.
- Bruges, James (2010) *The Biochar Debate: Charcoal's Potential to Reverse Climate Change and Build Soil Fertility (The Schumacher Briefings)*. Chelsea Green Publishing. ISBN-10: 160358255X, ISBN-13: 978-1603582551.
- Lehmann, Johannes and Stephen Joseph (eds.) (2009) *Biochar for Environmental Management: Science and Technology*. Earthscan Publications Ltd. ISBN-10: 184407658X, ISBN-13: 978-1844076581.
- Steiner, Christoph (2007) *Slash and Char: An Alternative to Slash and Burn*. Cuvillier Verlag Göttingen. ISBN-10: 3867274444, ISBN-13: 9783867274449.

References

Elad, Yigal, Dalia Rav David, Yael Meller Harel, Menahem Borenshtein, Hananel Ben Kalifa, Avner Silber, and Ellen R. Graber (2010) "Induction of Systemic Resistance in Plants by Biochar, a Soil-Applied Carbon Sequestering Agent". *Phytopathology* 100(9): 913-921. Available at: http://apsjournals.apsnet.org/doi/abs/10.1094/PHYTO-100-9-0913.

ScienceDaily (2010) "Is Biochar the Answer for Agriculture? Long-Term Study Digs Up New Information on Biochar's Ability to Reduce Nitrous Oxide Emissions from Soils". 9 August 2010. Available at: http://www.sciencedaily.com/releases/2010/08/100802073945.htm.

Woolf, Dominic, James E. Amonette, F. Alayne Street-Perrott, Johannes Lehmann and Stephen Joseph (2010) Sustainable biochar to mitigate global climate change: Supplementary information. Section 2.6.8. Available at: http://www.nature.com/ncomms/journal/v1/n5/extref/ncomms1053-s1.pdf.