E-Workshop
Biochar; the potential in Asia Pacific?

Organised by the UK Biochar Research Centre, University of Edinburgh and Appropriate Rural Technology Institute-India

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UKBRC

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Proceedings:
Full proceedings from the conference can be found here:
http://biocharm.wordpress.com/eworkshop/
Online documents are available for download from: http://hedon.info/BiocharUKBRC
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By: Sarah Carter, Priyadarshini Karve & Simon Shackley

Contributors: Chris Adam, Stuart Brown, Annette Cowie, Gerbe Dellava, Karabi Dutta, Mamadou Fall, John Field, John Gaunt, Wim Getkate, Stephan Haefele, Bryan Hugill, Graham Knight, Sieng Huat Kong, Prakash Jha, James Joyce, Ron Larson, Lucy Lu, Luca De Moses, Lewis Peake, Sai Bhaskar Reddy Nakka, Ruy Korscha De La Rosa, Trevor Richards, Paal Wendelbo, Kelpie Wilson, Dominic Woolf.

Contact: Sarah Carter, University of Edinburgh, sarah.carter@ed.ac.uk

About the partners

The **University of Edinburgh** is one of the world's top 22 universities, and the School of GeoSciences is a leading interdisciplinary group, which has over 100 academic and research specialists, over 1100 undergraduate and 250 postgraduate students, and has some of the best scientific infrastructure in the UK (www.ed.ac.uk).

The **UK Biochar Research Centre** is an alliance that connects research organizations with significant biochar research activity in the UK. The UKBRC aims to serve as a source of robust data and informed objective analysis on this subject to all stakeholders (www.biochar.org.uk).

The UKBRC is also working on the Biochar Innovation project focussing on the application of gasification cook stoves in Cambodia and India (http://biocharinnovation.wordpress.com/)

Appropriate Rural Technology Institute (ARTI) is a renowned NGO in the field of biomass energy and sustainable agriculture. Two time winner of the prestigious Ashden Awards, ARTI is one of the pioneers in the area of RD&D on biochar production and use in India (www.arti-india.org).

The Household Energy Network (HEDON) (http://hedon.info/) is an online Global Sustainable Energy community.

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Discussion

What is biochar & what is charcoal?

Biochar is a charred substance which is thermochemically treated in a zero or low oxygen environment and is intended to be applied to soils. Charcoal generally refers to wood char, but biochar can also be produced from other biomass, and even processed biomass (e.g. paper mill waste). Generally biochar refers to those substances which are prepared, or have properties suitable for either as an agricultural soil amendment or for carbon storage. Biochar is not the same as ash – a product of full combustion of biomass, including combustion (with air) of biochar. Ash contains next to no stabilized carbon although is likely to have more available nutrients and is frequently alkaline. Learn more about biochar through Hedon here

Some definitions of biochar are presented below.

Biochar has been defined as “the porous carbonaceous solid produced by thermochemical conversion of organic materials in an oxygen depleted atmosphere which has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and, potentially, soil improvement” (Shackley & Sohi 2010)

“Biochar is commonly defined as charred organic matter, produced with the intent to deliberately apply to soils to sequester carbon and improve soil properties (based on: Lehmann and Joseph, 2009). The only difference between biochar and charcoal is in its utilitarian intention; charcoal is produced for other reasons (e.g. heating, barbeque, etc.) than biochar.” (Verheijen et al 2009).

”Biochar is a fine-grained, highly porous charcoal that helps soils retain nutrients and water. The carbon in biochar resists degradation and can sequester carbon in soils for hundreds to thousands of years, providing a potentially powerful tool for mitigating anthropogenic climate change.” (IBI 2010).

”Charcoal and Biochar are similar, but not the same. They share raw materials and production techniques, but they have different end uses and those end uses utilize different properties in the chars.” (Shields & McLaughlin 2010).

Charcoal can be produced from any biomass, and the best economic return is using a Heat Treatment Temperature (HTT) of 300-350ºC. Preferred biochar production range, based on optimized 'Adsorption Capacity', is shown to be 450-700ºC peaking at 600 ºC. (Shields & McLaughlin 2010). See charcoal for more information about their relative properties including heating value on Hedon.

IIt should be noted, though, that since the underlying physio-chemical and biological properties of biochar which may help to account for its positive impacts in soils are not fully understood, a definition based on biochar properties may be premature.

The origin of “biochar”

The term biochar originated in the bioenergy literature in the late 90's to distinguish grain-derived activated-carbon from similar coal-derived materials. The two concepts of using charcoal as a soil improver and as a GHG mitigation strategy arose separately in the early '90s.

The matching of the term “biochar” with the climate-change mitigation concept did not occur until 2005 in a presentation by Johannes Lehmann entitled “Bio-char sequestration in soil: A new frontier”. Lehmann relates that the term stemmed from a discussion he had with the late Peter Read who coined the phrase in this context (Guardian 2009) while working on the revisions to one of these publications and preparing the 2005 presentation. See http://www.nature.com/ncomms/journal/v1/n5/extref/ncomms1053-s1.pdf for the references behind this timeline.

What is Terra Preta?

Terra preta refers to anthrosols (human modified soils), examples of which were first investigated in the Brazilian Amazon. Biochar, charcoal, ash and other substances were incorporated into the soil to make these dark earths. This happened over a long time period, and the methods and additions are unknown, which makes it not completely comparable to modern biochar addition, although lessons can be learned, and they can try to be recreated to realise the same benefits to plant growth which they show.

Biochar characteristics / characterisation

Biochar may be produced for different reasons, e.g. for carbon management, or as a soil amendment, to reduce leaching, to adsorb contaminants such as heavy metals, to filter dirty water, and so on. It is possible to produce biochar with different characteristics by using different feedstocks, but also through modifying the production process conditions. IIt may not be practical in small scale / low tech approaches, however, to exert much control over the production process. Stephen Joseph’s presentation covers the aspects that should be assessed in characterising biochar, from health and safety to effectiveness as a soil amendment http://www.ibi2010.org/wp-content/uploads/Joseph_characterization.pdf. Analytical techniques for characterising biochar and presentation of data for a range of chars can be found here http://www.publish.csiro.au/nid/84/paper/SR10058.htm.

Production risks

Silica
The IBI advised that when using high silica feedstocks such as rice husks, “it is important to keep the temperature of pyrolysis low (below 550 degrees C for high silica feedstocks such as rice husks) to reduce likelihood of forming crystalline silica”. However, specifying temperature alone can be misleading, because crystal formation is a function of temperature and time. Silica will be produced at temperatures below 1200 deg C and in time periods of the order of minutes. Crystalline silica formation may be less concern with slow pyrolysis than with fast pyrolysis. The presence of iron and other

similar metals is useful in encouraging the formation of low melting point silicates (especially under reducing conditions), which tend to be less crystalline because they melt and often solidify as amorphous silicates (depending on the cooling rate). For feedstocks including rice husk the intentional addition of colloidal iron to the feed *may* help in reducing formation of crystalline silica. Carbon traps in the pores of plant derived silicate structures during gasification. This *may* make it less of a health risk by making it easier to assimilate by the body. More research is required on this important issue.

"There is sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources. There is inadequate evidence in humans for the carcinogenicity of amorphous silica", page 210 (IARC, 1997).

Dioxins
Adriana Downie's presentation for the IBI has dioxin data. http://www.ibi2010.org/wp-content/uploads/Downie_-_ibi_2010_-risk.pdf

Feedstock availability

Malaysia & Indonesia – POI (Palm Oil Industry)
Biochar can potentially benefit fertiliser efficiency, crop enhancement, biomass waste management, Combined Heat and Power (CHP) and Waste to Energy (WtE), greenhouse gas emission management, river eutrophication management and provide an environmental 'spin' for the industry. The POI has readily available feedstocks in large quantities which could be used to make biochar, and the POI is likely to continue, so efforts can be made to make it more sustainable through biochar.

India - agriculture biomass
Between 600 - 800 million tons of all agri-waste and residues is produced in India (http://www.nariphaltan.org/gujarat.pdf), though much is already used. Another source suggests available crop residues are almost 140 million tons per year. (http://mnre.gov.in/biomass-atlas.htm). This is excluding forestry and animal wastes.

Asia Pacific - Rice
Residues (straw and rice husks) from rice are an interesting option to look at, since it is plentiful and available, in many cases it is not used, and its use does not interfere with food production (one competing use is that charred husks can be mixed with fresh husk to produce fuel briquettes). However findings from the Philippines showed:

- Rice husk char (RHC) contains little nutrients and because the biochar is hardly decomposed, most of the nutrients are not available to plants.
- lack of evidence that RCH has potential for poverty alleviation for use by small farmers
- husk char has good physical characteristics like water holding capacity but that is not very important in irrigated rice soils.
- husk char does not decompose well, which allows carbon sequestration in soils
- husks belong to millers not farmers
- drive could be carbon sequestration rather than soil improvement?

Asia Pacific - Forestry

Eucalyptus spp. has a very high productivity, and *Moringa spp*. and *Jatropha curcas* are potential tree crops with residues (competition is biofuels).

Biochar policy and carbon finance

An extended abstract from IBI focuses on learning from the experience of the bioenergy industry
Small scale biochar production is efficient and cost effective compared to other means of carbon sequestration. But because of the urgency of carbon abatement, both large and small scale options are required.

An overall assessment is that the prospect of creating C offsets from biochar projects is positive - see www.biocharprotocol.org. These are from:
1. Avoided emissions that arise from changes in the management of feedstock that reduce CH_4 or N_2O emissions.
2. Carbon stabilised in biochar
3. Fossil fuel offsets from energy produced.
It is much more difficult is to claim avoided emissions and C sequestration due to the benefits that arise where biochar is added to soil in agricultural settings. The mechanisms are clear but currently biochar specific evidence at the field scale is lacking (albeit increasing).

In terms of project development, barriers will include the complexities and costs of setting up systems and claiming the credits due to the monitoring, reporting and verification requirements.

There is considerable scope for innovation in incorporating biochar into a. REDD+ scheme, e.g. multi-species, managed forests. Management can double annual output of biomass production in forests and therefore one logical place for REDD+ output would seem to be biochar (for waste management).

Biochar crop trials

India

The Appropriate Rural Technology Institue - India (ARTI) are managing the Biocharm project: Biocharm Project: Biochar for Carbon Reduction, Soil Management and Sustainable Agriculture. Biocharm.pdf (other conference documents from the workshop September 2010 are available at http://biocharinnovation.wordpress.com/workshop-india/), which discuss other field trials in India.

Geoecology Energy Organisation (GEO) are undertaking tree crop trials, http://www.e-geo.org, soil is added to pit where mango saplings are planted, and also a biochar-compost is being used as a mulch. GEO are also undertaking vegetable trials: biomass of a variety of crops generally improves with biochar. More nitrogen is required initially with biochar addition to the soil http://biocharindia.com.

Cambodia

Under the above project, trials in Cambodia are being undertaken http://biocharinnovation.wordpress.com/.

Philippines

Also in the Biocharm project (above) research is being done in the Philippines by the International Rice Research Institute (IRRI) Biochar article 01-1.pdf

Australia

Field trials are being conducted in soils ranging from tropical oxisols to sands, with a range of biochars (different feedstocks and process temperatures). The project also includes characterisation of biochars, and studies on carbon turnover and nitrous oxide impacts, and herbicide retention. This national project and other work is listed at http://www.anzbiochar.org/projects.html

Generally, they have seen very positive effects on plant growth from manure-based and paper sludge chars, especially in acid soil, and less response to wood waste chars. But the wood-based chars have much slower carbon turnover, and give greater reduction in nitrous oxide emissions.

Older published work is listed at http://www.anzbiochar.org/links.html#publications. The most recent volume of the Australian Journal of soil research is a special issue from the 1st Asia-Pacific biochar conference, held in May 2009 http://www.publish.csiro.au/issue/5422.htm.

Indonesia

Biochar is being tested in rice systems BiocharRiceKalimantan.pdf.

Malaysia

Maize Biochar Maize Study UMS.pdf

Oil Palm waste, is being investigated by the National University of Malaysia (UKM) and Malaysia Palm Oil Board (MPOB) Malaysia, which they suggest is suitable for orchids, palms, trees, shrubs, flowers and vegetables. Producers of biochar include BEK from ALL Power Labs, BEC from Biochar Engineering, UPM-Nasmech Carbonator Pilot Plant in Malaysia. The following components can be used to produce biochar: empty fruit branches (EFB), fronds, trunks and shells.

Lao & Vietnam

Lao & Vietnam - rice husk biochar trials http://www.mekarn.org

Japan

Tokai University are testing bamboo charcoal for tea trees.

China

Rice hull biochar trials have been undertaken in Hangzhao
http://www.airpollutionfacts.net/2010/10/17/rice-hull-biochar-trial-hangzhou-2007/

Nepal

Trials are underway using biochar produced in stoves
http://picasaweb.google.com/jhapchandra/Biochar#

USA

Work at University of Colorado (on alkaline soils).
http://www.biocharengineering.com/about_us/index.html.
University of Colorado at Boulder - North American Biochar Conference
http://cees.colorado.edu/biochar_soils.html

Biochar in use

Some examples of existing biochar use within the region include:

Waste charcoal (rice husk which is used as a packing material in clay/earth charcoal kilns) in Thailand is being applied to coconut palms. It is sold for plant propagation. There is no evidence of this being briquetted as a fuel.

Charcoal / activated charcoal can be used in nurseries, as a plant and tissue culture medium (it absorbs secondary metabolites - which are growth inhibitors), as a "soil and mulch sweetener", and as a fertiliser and insecticide. This practice has been carried out in many areas around the world.

Small-scale farmers in India commonly add char and ash. Some investigation has been carried out on these historic practices http://biocharindia.com.

GEO, in India have designed simple Biochar Urinals http://e-biocharurinals.blogspot.com/. These provide smell absorption benefits. As part of an integrated farming and wastewater management, human urine can be added to biochar for the production of maize http://conference2005.ecosan.org/presentations/tidaker.pdf. Recently GEO have encouraged farmers to spread biochar in their cattle sheds to keep them dry and clean as well to absorb the urine of the cattle - which is then included in the soil additive when the biochar is replaced and added to the soil. This technique has been used historically in Europe and USA where char and ash from stoves or charcoal in the 1800s, was mixed with "nightsoil" and sold to farmers as "poudrette" http://timespanner.blogspot.com/2009/08/new-lynn-poudrette-factory.html.

Waterless cleaning of utensils using biochar, the oil and other substances attached to Biochar adds value and serves the purpose of cleaning too. http://e-biocharclean.blogspot.com/.

In Nepal biochar has integrated eco sanitation and ecological farming, and biochar and ash can be used to deodourise waste and it can also be used as a filter media in the use of waste water for agriculture. The ash / biochar is a product from the ICS (mud stove).

Biochar from cook stoves has been sold (although only seen on a small scale) for ironing in India.

Encouraging the use of biochar from stoves as a soil amendment

- The desire for use requires that stove user has land, which is not optimised for cultivation. Production in stoves for soil improvement is unlikely to occur if biochar is free already or readily available. The benefits of biochar have to be understood, and also successfully realized (e.g. biochar will have to be added at the right season, and in combination with other soil conditioners). There has to be full information then free choice by the user to determine the preferred use.
- It is difficult to send an accurate message to users about the benefit of biochar. If investigate is done by the users, the change they see may be due to other reasons, and not due to the presence of biochar. For example the trials may not include an accurate control. Trials with controlled ‘with’ and ‘without biochar’ plots can use a straightforward design which would be suitable for small scale investigations.
- The extra effort to put the biochar into the ground is also a disadvantage, and biochar / ash from fires has competing uses for example in toilets.

Technologies for biochar production

Gasification cook stoves

Sampanda, Anderson's TLUD, EverythingNice, Anila gasifier stoves research are being investigated as part of the University of Edinburgh’s project based in Cambodia and India http://biocharinnovation.wordpress.com/.

The Flannagan stove has been developed in China.

TLUD Biochar producing stoves from GEO include the Magh series http://goodstove.com/. GEO have designed more than 25 TLUD stove designs including natural draft and forced air, all of the designs are declared as Open Knowledge. The price of stoves varies from just 4 cents to $100 or more. However an appropriate model for a family of five could be made using locally available material at the cost of $7 natural draft and $10 forced air.

Emissions

TLUD paper looks at emissions from different stoves Anderson_Stove comparison tlud.pdf.

Adoption

TLUD adoption is slow as the technology is different from traditional stoves, its operation/use requires training to the stakeholders

Pellet stoves

The pellet TLUD stoves leave users dependent on the supply of pellets which is a disadvantage, although their performance is good, their adoption is low, because the recurring cost on pellets is not bearable by many low-income communities. The facilitation, awareness, cost of stove, preparation of fuel / fuel cost and training on their operation are the major challenges. But with a high efficiency (about 40%), demand for them could increase rapidly.

Institutional stoves

The TLUDs for institutions and community cooking are in immediate demand (in India), if proper designs are made and facilitated. In general the users would not be prepared to remove the char from the stove by quenching, hence it would burn down to ash. This helps to account for the efficiency of the stove.

Biochar production in stoves (which reduces efficiency) vs efficiency and emissions reductions (which have proven to be very good in gasification stoves anyway)?

- The stove must fit the needs of the user, so some biochar producing stoves should be available. But the biochar producing ability must not be at the expense of ease of use or desired efficiency levels.
- Feedback from users is required, so that the stove fits the needs of the user.
- Gasification stoves do provide benefits in some situations, because they can use materials not used in traditional or conventional stoves (biomass waste).
- Biochar can be beneficial, so can be stored by users, in a metal container if desired, although the cost of the metal container (which effectively extinguishes the biochar) is another expense.
- TLUD stoves are often not designed for char production, although they are often capable of char production, so it is an option if the user does wants to empty the stove to save the char.
- Emptying a stove is difficult – the stove is hot, and it is dangerous and difficult to extinguish (especially when you are in the middle of cooking!). The char can be quenched with water while in the stove, but this can induce rusting depending on the type of metal used, which shortens the life span of the stove.
- The TLUD-FD (Forced Draft = with fan) does not usually produce any char, but the benefit of this design is in the increased emissions reductions and efficiency.
- A good TLUD cooking stove will give from 20 to 50 g of char from 1 kg of fuel if it is left to burn out. If you stop the process when flame is over it will be from 50 to 100 g. Other TLUD stoves will provide almost double this quantity of char, but then is less efficient in energy conversion for cooking.

Open pyrolysis units

Adam Retort is designed for mediul-scale biochar production. Read these resources for further information 331_Adam AdamRetort09.pdf and ICPS-Photosheet_brFO_adam.pdf and http://biocoal.org/3.html.

Biochar Kilns (and stoves) - https://docs.google.com/fileview?id=0B3ZW1BCHOSzWZGFjNzc3NGItMDg4Mi00NmQ1LWFiMTctOTQyYTBlYWY4Y2Vh&hl=en&pli=1&authkey=CJOJr_QH (this is another presentation from the workshop in India http://biocharinnovation.wordpress.com/workshop-india/)

Biochar can be produced using very simple methods (similar to traditional charcoal making) on the farm, for example a heap of biomass covered over with earth and set alight. Even burning rice husk in the open produces 30% biochar (which is perhaps less than with other biomass feedstocks because of the high Si content). However, fugitive emissions of N_20 and CH_4 (both powerful greenhouse gases) would argue against using technologies that do not include a gas clean-up unit whereby N_20 and CH_4 are converted to CO_2.

Two simple systems based on TLUD and Downdraft principles, using locally available in India produced from empty tins / drums http://e-maghcm-ii.blogspot.com and http://maghbiocharretort.blogspot.com/.

Controlled pyrolysis units

Gasolysis unit India - http://biocharinnovation.files.wordpress.com/2010/09/biochar-workshop-099.jpg..This unit is in the ARTI field station in Phaltan, and has been used for their biochar research.

Gasification is an important technology, especially for rice husks since there is an unusually high char and stablised carbon yield compared to other woody biomass (may be due to the silica shells which seem to protect the carbon in the biomass from conversion). Feedstock is free and where it is for waste management, it pays for its self. Negative consequences to this system are limited and can probably be avoided (e.g. tar production in the gasification, health issues from rice husk burning where this is feedstock). Gasification in Cambodia has been particularly effective since energy is relatively expensive so it makes economic sense, and rice husk is readily available. This has been explored in Cambodia as a case study: http://biocharm.wordpress.com/biochar-production/biochar-sme/.

Torrefraction converts biomass to use in co-firing power plants or dedicated biomass combustion and is another option which requires further investigation.

References and resources

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still a lot of investigation to be done, but there can be no doubt that amorphous silica can cause health problems.

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Groups and networking

Biochar Society of India http://www.biocharsoc.org/

Biochar India Google Group http://groups.google.com/group/biocharindia/

South East Asia Biochar Interest group: http://sea-biochar.blogspot.com/

Other International Biochar Initiative groups in the region can be found here:
http://www.biochar-international.org/network/communities