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Biochar, Carbon Reduction and Sustainable Soils — Role in Asia and the Pacific?

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ABSTRACT: Biochar is the solid remains of heating biomass in an oxygen-depleted environment (Lehmann and Joseph, 2009). Unlike the carbon found in most organic matter, biochar carbon is chemically altered during the heating process and forms into aromatic carbon ring structures that are very resistant to attack by microorganisms (Lehmann *et al.*, 2009). As a consequence, biochar carbon can remain in soil for long periods of time — hundreds to thousands of years — and could be an important method for storing carbon that has been scavenged from the atmosphere during photosynthesis. Biochar can be produced from simple charcoal-making technologies, but unless fugitive emissions and soot are properly controlled, such production methods are likely to produce greenhouse gases such as methane and nitrous oxide and be otherwise unsustainable. Biochar can also be produced from modern technological systems such as pyrolysis and gasification used for generating fuels and/or electricity from biomass, and energy generation is likely to be the main driver for biochar production in the near future.

KEYWORDS: *biochar, carbon storage, rice husk char, BIOCHARM*

Introduction

When combined with bioenergy generation, biochar production can potentially avoid the emission of CO_2 resulting from the use of fossil fuels. Woolf *et al.* (2010) estimate that in a policy context that strongly favours biochar deployment, the annual carbon abatement arising from the biochar option globally by 2050 would be between 1 and 1.8 $GtCy^{-1}$, thus making a potentially important contribution to carbon mitigation and removal. The most important constraint on the quantity of biochar, which can be produced sustainably, is the availability of suitable biomass that does not otherwise have an application (meaning largely crop and woody residues and organic waste streams) and, by extension, the quantity of land that is available for sustainable biomass cultivation (e.g., without incurring an excessive “carbon debt” through direct and indirect land-use change (Fargione *et al.*, 2008). Biochar can enhance

Figure 1. Rice Husk Char (RHC) from a gasification unit at an ice factory in Cambodia

Figure 2. ARTI's single barrel kiln for sugarcane and maize cobs in operation

soil "health" and has been demonstrated to promote plant growth and crop productivity in some situations, though much remains to be learnt about the mechanisms which account for these effects (Jeffery *et al.*, 2011). Some of the principal mechanisms that can help explain the benefits of biochar are its alkalinity, water holding capacity, cation exchange capacity, nutrient content and physical impacts on soil properties (Sohi *et al.*, 2010).

The objectives of the APN-supported BIOCHARM project were to assess the opportunities for biomass-bioenergy-biochar systems in three countries: India, Cambodia and the Philippines. In particular, we evaluated two types of biochar with respect to impact on net carbon equivalent abatement; physio-chemical and structural properties and stability of the char carbon; environmental and health & safety impacts; impacts on crop yield and soil in replicated (and non-replicated) pot and field trials with a range of crop types (rice, maize and vegetables) and other soil amendments. A typical char heap in Cambodia is shown in Figure 1.

Methodology

The two types of biochar used in the project were rice husk char (RHC), which is the by-product from small- to medium-sized (150–300 kW capacity) gasifiers located in rice mills utilizing rice husks as the fuel (Shackley *et al.*, 2011); and biochar produced from sugarcane leaf litter and maize cobs using much simpler up-draft gasifier kilns (Figure 2).

In some regions there is a surplus of rice husk relative to demand (and a surplus of rice husk where the husks are used in boilers). Hundreds of kilograms of RHC are produced daily from the gasifiers and very large piles build up (approximately 1000 tonne at one site). Such piles are largely inert, but could generate a pollution risk through leaching or wind/water erosion into the air, water or ingestion by animals, etc. (Shackley *et al.*, 2011). The agricultural waste feedstock such as sugarcane leaf litter and maize cobs (after grain removal) are plentifully available and are not, in most instances, being used for any specific purpose. Examination of RHC char samples were done via 3D imaging (Figure 3a) and Scanning Electron Microscopy (SEM) reveals a highly porous but heterogeneous material (Figure 3b).

Results and Discussion

The carbon and energy balance of the rice husk gasifiers (Figure 4) was calculated and the physio-chemical properties of the

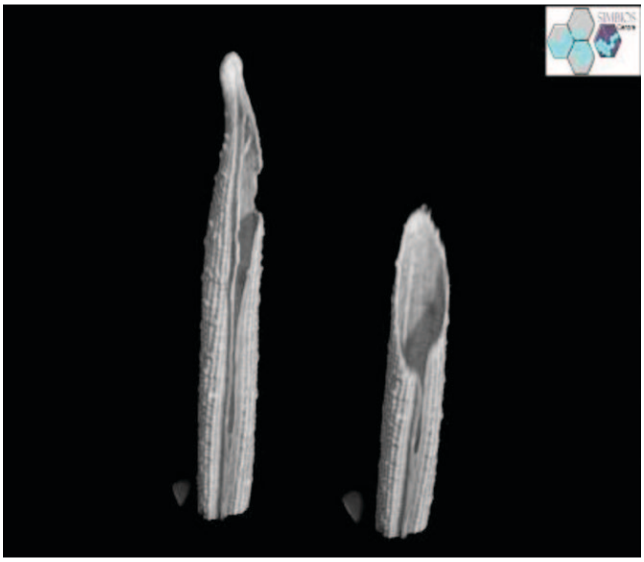

Figure 3a. Three-dimensional image of rice husk char (courtesy of Wilfred Otten, University of Abertay, Dundee)

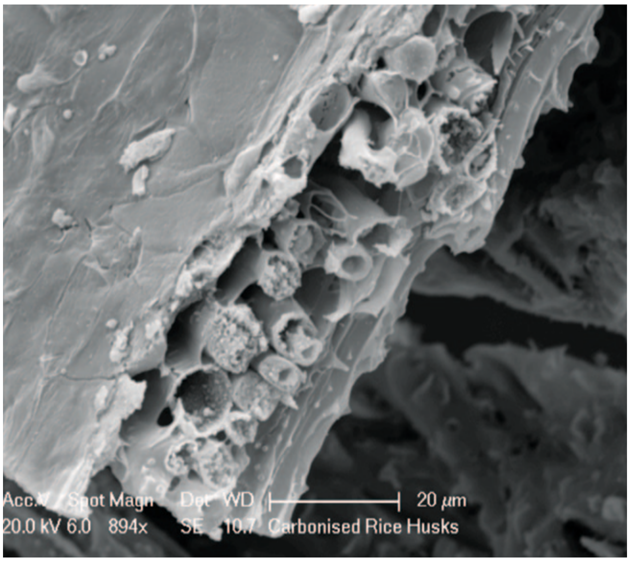

Figure 3b. Scanning electron microscope cross-section of rice husk char (RHC) showing the presence of macro-pores

two biochar samples were examined. The unstable carbon — the component which is expected to be lost through decomposition in the time-scale of hours to several years — was estimated using accelerate ageing laboratory techniques (Masek *et al.*, 2011), so permitting an estimate of carbon that would be stored in the long-term. Simplified life cycle assessment methods were used to measure how much carbon dioxide equivalent (CO_2, N_2O and CH_4) were reduced and removed from the atmosphere across the biomass life-cycle (i.e. from growth to soil incorporation). We found that 0.86 tonne of CO_2 is removed from (or avoided from entering) the atmosphere per tonne of rice husk gasified (Shackley *et al.*, 2011a).

India is the world's second largest rice producer at 132 million tonne (Mt) paddy rice in 2009–10; while the Philippines produced 14 Mt and Cambodia 7 Mt. Assuming 22% of this paddy rice production is rice husk, the potential carbon abatement from use of RHC — assuming that an arbitrary 1/3 of the rice husks could be made available — is approximately 9 Mt CO_2 (India), 1 Mt CO_2 (Philippines) and 0.5 Mt CO_2 (Cambodia). If we compare RHC to some other existing uses of rice husks, such as incorporation into irrigated rice fields, then the greenhouse gas benefit of converting to biochar becomes more significant. This is because, in anaerobic conditions, some of the carbon in rice husks added to soil converts to CH_4, a potent greenhouse gas. Compared to such a baseline, the net carbon equivalent abatement is approximately 4 tonne CO_2 per tonne of rice husk (Shackley *et al.*, 2011a). On an area-basis, the conversion to RHC may reduce greenhouse gas emissions up to five times compared with adding husks to irrigated fields.

The agronomic results provide a mixed picture of the effectiveness of biochar in existing agricultural contexts. Trials growing plants in pots in Cambodia demonstrate that biochar can have a strongly positive effect upon yields (Figure 5). There was a statistically significant (95% confidence level) response to increasing biochar additions for lettuce (harvestable mass, root mass, number of leaves and stem length) and for harvest and stem length in the case of cabbage. The irrigated rice field trials showed a statistically significant increase of 33% in paddy yield with a 41.5 tonne per Ha addition of RHC in the case of one farm, but not in another farm that used the same variety and was located close by (100 m). We cannot currently account for the difference in response, though a compost amendment was also used in

Figure 4. A biomass gasifier in Cambodia generating power from rice husk feedstock

Figure 5. Trials growing plants in pots in Cambodia

the farm where no statistically significant increase was observed. One other study using RHC at a similar rate in rice fields in Southeast Asia showed a statistically significant increase of between 16–35% in poor infertile soils, but no significant increase in better quality soils (Haefele *et al*., 2011).

A variety of non-replicated exploratory trials with vegetables and irrigated rice also gave positive results with respect to yield. The Indian pot trials did not show such a clear result as those in Cambodia. Three applications stand out as increasing fresh biomass relative to the untreated control: biochar at 20 tonne per Ha; and biochar at 20 tonne per Ha with chemical fertilizer and chemical fertilizer only. Higher biochar applications (40, 60 and 80 tonne per Ha) appear to reduce overall fresh biomass weight compared to the 20 tonne per Ha level and/or synthetic fertilizer applications. The Indian maize field trials using biochar from sugarcane trash and corn cobs did not show any statistically significant yield response. However, there was some evidence (not statistically significant) of a declining yield with biochar additions beyond 20 tonne per Ha. The increase in maize yield for the 20 tonne per Ha biochar application was significant at the 92% confidence level compared to the control. The pH of the agricultural soils where the tests were done may help to explain why the biochar may not have had the same benefits in India as it did in Cambodia. The soil pH in India was 7.4, hence the alkaline biochar would not have had the beneficial effect upon pH as in Cambodia, where the soil pH was 4.8.

Conclusions

The total value of the RHC (carbon abatement plus agronomic benefit) is between \$9 per tonne (char carbon only) and \$15 per tonne (including also offset emissions from bioenergy) (or \$31 per tonne for an avoided anaerobic decomposition baseline) (assuming a carbon price of \$5 per tonne CO_2 and an agronomic value of \$3 per tonne RHC). Potentially, therefore, RHC can be a valuable addition to farm incomes through improving yields and especially if a carbon value for the RHC could be realized. Because the carbon is fixed during the gasification process, incorporation into the field *per se* does not increase the carbon abatement (excluding indirect effects of the biochar in the soil). Hence, it would be necessary to include the gasification operation within the project boundary in addition to the field incorporation in order to acquire any carbon financing for the biochar. We believe that the results presented here justify further, more detailed, analysis of the benefits, opportunities, costs and impacts of biochar from agri-residues in the Asia-Pacific region.

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Biochar for Carbon Reduction, Sustainable Agriculture and Soil Management (BIOCHARM)

COUNTRIES INVOLVED

Cambodia, India, Philippines

PROJECT DURATION

1 year

APN FUNDING

US$ 40,000

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