INTRODUCING BIOCHAR TO RURAL BANGLADESH: A BRIEF SYNOPSIS

Preliminary Draft V 0.2

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Presented to the Christian Commission for Development in Bangladesh

January 21, 2014

Contents

Biochar. 2

The Bangladeshi Context. 3

Stoves. 4

Fuels. 5

Biochar Applications. 6

Socioeconomic Impacts. 6

Conclusion and Recommendations. 7

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BIOCHAR

This synopsis is a introduction to how biochar may be used in Bangladesh to improve sustainable food production, but it is also on how biochar technology will have to be adapted to meet local conditions. The main difficulties are a shortage of biomass and a large population that has limited disposable income. One approach is to make biochar as a by-product of cooking with gasifier stoves, then use the biochar with composts and manures in homestead gardening. The ultimate goal is to increase food security for a people facing strong consequences of climate change. Meeting this goal is an exciting, interdisciplinary challenge.

Biochar is a type of charcoal that is resistant to decomposition, and made with the ultimate goal making long-term increases in soil organic matter (www.biochar-international.org). The persistence of biochar is important for the soils of Bangladesh, because in the humid tropics, the decomposition of plant residues is rapid with nearly all of the carbon returning to the atmosphere within a decade. In soil, biochar performs of the functions of regular humus, including ion exchange, water-holding capacity, aeration, and tilth; all of which improve crop yield. Because biochar does not readily break down, it is not a good source of nitrogen and carbon-energy for soil biota. However, this is easily corrected. The adsorptive capacity of biochar can be used to advantage for conserving plant nutrients from composts and manures, thereby increasing the efficiency of nutrient cycling in agroecosystems. This further builds soil organic matter, and reduces or eliminates the need for inorganic fertilizers. Although the use of charcoal in agriculture is a very old technology, the importance of biochar for sustainable tropical agriculture was not fully appreciated until recently studies in the Amazon Basin. A typical rainforest soil in the Amazon is highly weathered and infertile, however there are fertile patches of human-made dark earths (called "Terra preta"), that contain charcoal. These dark earths are 500 to 1500 years old.

The natural and human ecology of the countryside has to be considered if biochar is made in substantial amounts. Biochar is formed by the thermal treatment of organic residues—usually in the range of 450-750 °C—by pyrolysis (by heating in the absence of oxygen) or by gasification (by partial burning in limited oxygen). The feedstock biomass is converted to charcoal, gases and heat. Sustainable production must consider (1) the source of biomass, and (2) production of biochar along with its co-products. It is safe to say that nearly all biomass gathered from the countryside will not be 'waste,' but is already serving an important ecological role in sustaining a myriad of natural organisms, and soil productivity. Therefore, to minimize the ecological impact we should make biochar as a co-product of biomass people have already collected for cooking and heating. The situation in urban areas is quite different. Here, organic refuse may be causing pollution, and making biochar by industrial pyrolysis could help with its disposal. Biochar from urban waste is beyond the scope of this synopsis. We will focus on rural households.

THE BANGLADESHI CONTEXT

Bangladesh is extremely vulnerable to the effects of climate change. Three of the most severe challenges are: (1) a very high population density that will increase as land is lost to rising sea levels; (2) greater extremes in weather including drought; and, (3) sanitization of soils through seepage and storm surges. Although these challenges will have to be addressed in many ways, biochar can make a substantive contribution by improving food security and reducing poverty. Resistance of crops to drought is increased by raising the levels of soil organic matter which will improve the growth of plant roots, and the water-holding capacity of soil. Salinity is a more complicated problem that will require the attention of soil chemists. Biochar has been used to restore soils flooded by a tsunami, but it is not clear if biochar is helpful, or detrimental, to soils that are chronically affect by seepage or periodic inundation with saline water. In the salt affected regions along the south coast, biochar could be used to increase food production on the higher ground where homesteads are located.

There are strong constraints for making biochar in Bangladesh. The population density is one of the highest in the world (ca. 1000 people per km², Bangladesh Bureau of Statistics, 2011), the per capita income is ca. \$2,000 yr^{-1} (purchasing power parity, International Monetary Fund, 2012), and country is energy-poor. Together these are reflected in Bangladesh having the lowest per capita energy consumption in the World (World Bank, 2011). A large proportion of the population relies on biomass fuel for cooking, especially in rural areas, and energy-stress is reflected in the type of fuels they used. Cooking fuel includes a high proportion of cow-dung, leaves, and rice straw. The preferred biomass fuel is wood, but forest cover is only around 17% of the geographic area, and most of it concentrated in regions (Sundarbans and Chittagong Hill Tracts) away from where the population density is highest. For decades (since the Bangladesh Forest Policy of 1984) the country has been struggling to maintain and increase its forests in the face of a rising demand for wood.

Thus, in rural Bangladesh there is no spare biomass. In some regions, such as in the North West, removal of crop residues from the field and reduced manuring by cattle is partly to blame for low soil organic matter. Biochar could be used to re-build soil organic matter, but at the field scale, it would require massive amounts and years to accomplish. Twenty metric tons of biochar per hectare would be needed to raise the soil organic matter content by 1% (v/v) in the top 0-15 cm of soil and this would take twenty years to accomplish if 5 Mg/ha/yr of rice straw is converted to 1 Mg/ha/yr of biochar. For substantive applications to agricultural fields, the production of biochar will have to be well-established, and some may come from urban areas and industry.

Strong ecological and socioeconomic constraints require us to look for ways of making biochar from biomass already gathered. There would be no increase in biomass harvesting and in fact, net carbon sequestration, if we made biochar with efficient, gasifier cookstoves in rural households. Using the biochar in homestead gardens will have an immediate impact on household nutrition and may create disposable income.

STOVES

The most common gasifier cookstove is called a top-tilt updraft gasifier (TLUD). The technology is quite simple. A vertical, cylindrical combustion-chamber is loaded with fuel and is ignited at the top. The fire — called flaming pyrolysis — is fed by a limited supply of air that passes upward through the fuel from holes in the bottom of the fuel chamber. Since oxygen for combustion is limited, the fuel burns only partially, producing a flammable 'smoke' and charcoal. The flaming pyrolysis moves down through the unburnt fuel, leaving charcoal above. The 'smoke,' containing flammable CO, H_2, and volatile organic gases, passed up through the charcoal and is ignited as a gas fire above the fuel chamber. It is this gas fire that does most of the cooking. TLUD cookstoves can achieve cooking efficiencies between 30-40% (compared to 10% for a traditional chula and 30% for an improved chula), and produce biochar as a by-product. Because the smoke is burnt, air pollution is low, but TLUDs should still be operated in well-ventilated areas, or with a chimney. Apart from TLUDs, there are also gasifiers in the South East Asia designed specifically for loose rice hulls.

An advantage of TLUDs is that they produce a steady heat for the duration of a burn, and do so unattended, but they are not suited to all fuels and cooking tasks, so we should not expect them to replace existing chula stoves outright. A disadvantage of TLUD stoves is that they are fastidious about fuel quality: they work well with pellet fuel, rice-hull briquettes broken into pieces, or small chunks of wood; they don't work well with crop residues and leaves that have a low particle density, and poor air flow through inter-particle spaces. Fuel preparation may be required, adding an extra chore and requiring tools; and, the fuel must be dry. In a TLUD (without fan-forced air), the flaming pyrolysis should be around 600 °C or more and produce gases that ignite easily. Cool smouldering fires around 350 °C produce larger molecular weight gases and soot particles that don't ignite at stove operating temperatures. There are about twenty-four million households in rural Bangladesh that cook with biomass (Khaleq-uz-zaman, 2008). In the 2011 Census, 35% of these households used wood as the main cooking fuel, and 59% used straw, leaves and cowdung (Bangladesh Bureau of Statistics, 2011). Essentially, all households use the full range of biomass fuels in traditional and improved chulas. TLUDs could be used for specific fuels and cooking tasks, but not all the time.

There are a number of commercial TLUD stoves available, and non-proprietary plans. The more durable models have fire chambers made of stainless steel, and some of the commercial models include a small electric fan to raise their heat output. Some of these models could be adopted by more affluent homes, but they are too expensive for most rural households, and it could be hard to get them serviced. Therefore, the best approach would be to develop local TLUD designs, using local materials, or designing cylindrical metal inserts to modify existing chula cookstoves. Besides households, TLUDs should be designed for institutional kitchens, and small businesses such as par-boiling rice.

The development of TLUD stoves and biochar should involve their users to insure a successful programme. World-wide, including Bangladesh, the replacement of traditional stoves with improved cookstoves has met with slow acceptance, despite greater fuel efficiency and reduced smoke pollution. Sometimes, poor acceptance resulted from a failure of stove developers to work closely with women to meet their needs and cooking culture. Often, it has been important to get wider community involvement with local business selling, repairing and manufacturing stoves. In Bangladesh, stove NGOs, such as the Bondhu Chula group, have a lot of experience with dissemination of improved cookstoves. Their experience will be invaluable to establishing widespread use of biochar.

Besides TLUDs, it may be possible to modify the grates of improved chula stoves to pass more unburnt charcoal. We should expect, however, that the quality of biochar produced this way will be less consistent than TLUD biochar, containing charcoal produced at < 450 °C, uncharred biomass, and completely burned ash.

An interesting question is the potential effect of commercial energy sources such as natural gas, photovoltaic panels, and electrical grid connections on the use of biomass fuels. Would electrified households start cooking with electricity and junk the chula and TLUD? Experience so far indicates that this would not happen, because electricity is used for lighting, fans, radio and TV, and not for cooking. Although kerosene and gas are used for cooking, many rural households keep the biomass stove for special meals, or as a backup if the commercial fuel runs out, becomes too expensive, or is unavailable. Cooking with biomass in Bangladesh is going to be around for a long time to come.

FUELS

Fuels should be tested along with the development of TLUD stoves. Preliminary trials have shown that broken rice-hull briquettes burn well in a TLUD and for relatively long time. A vertical bundle of jute stems gasifies very well, but burns out quickly. Sugar cane bagasse gasified, but was not a good TLUD fuel because it burned at a cool temperature and was smoky. Pellets fuels (4-6 mm diam, 10-15 cm long) are ideal fuels for TLUDs but are not available in Bangladesh. Research should be conducted into the feasability of pelleting, although there are some disadvantages with pellets: durable pellet mills are costly, and some spare parts may have to be imported rather than made locally, the pellets may not be stable in a humid climate, and pellets do not store and transport as easily as rice-hull briquettes. Some biomass, such as high-silica rice residues, are abrasive. In the end, formal testing of fuels in TLUDs is needed to examine the temperatures of combustion, cooking efficiencies, emissions, and characterize the biochar produced according the protocols recommended by the International Biochar Initiative. Special tests will be required for unique circumstances (e.g., biochar from high-silica rice residues should be checked for dioxin content).

Biochar Applications

Biochar has a number of applications and once villagers get involved, they are likely to invent more uses. Biochar is versatile because of three main properties: (1) it is biologically stable; (2) it has a high absorptive capacity for cations and anions; and, (3) it can provide a support matrix for microbial biofilms. Fresh biochar is more likely to be a sink rather that a source of plant macro nutrients. Thus it is advisable to pre-treat the biochar with nutrients, or use it in some aspect of biological waste management. Biochar can also function as a carbon filter, and may have a role to play in water filtration.

Biochar added to anaerobic manure digestors acts as a matrix for microbial biofilms allowing a consortia of microbes to co-exist: fermentors, acetogens, and methanogens. Biochar can also adsorb ammonium reducing its toxic effects on microbes. The net effect is that anaerobic digestors treated with biochar produce higher volumes of total gas and methane than untreated digestors. In the aerobic digestion of composts and manures, biochar can adsorb ammonium reducing the loss of gaseous nitrogen as ammonia and nitrous oxides. Potassium, phosphate and other soluble plant nutrients are also adsorbed and held against leaching. Once rapid decomposition processes are complete, we have biologically stable compost that can be used as a potting soil or gardening soil.

Research is needed on integrating biochar into local organic waste management systems, and in applying it to homegarden horticulture. When human waste is involved, we need to be especially concerned about pathogens. The Amazon dark earths and the "garden cities" they supported are taken as a paradigmatic example of sustainable tropical agriculture. The current hypothesis is that these dark earths were not mere deposits of charcoal, but were midden soils; organic refuse heaps including charcoal.

Socioeconomic Impacts

In time, as biochar technology is introduced and understood in a community, it may be advisable to study its acceptance and socioeconomic impact. We should understand what motivates people to use biochar (or not use it), how it affects their future intentions, how it impact their quality of life, and how they might respond to various hypothetical situations such as prices of fuels (esp. wood and charcoal) and biochar, or the availability of energy alternatives (e.g., electrification). Studies like these are usually stratified or correlated according to the sex, age and education of the respondent, household income, land tenure, distance from forest, and distance from town or city. What is particularly important is to be able to detect negative effects before they become serious, such as increased drudgery for women, rather than empowerment; an increase in the price of wood making it too expensive for the poor; increases in deforestation; and uneven development whereby land-holders are winners and landless are losers. Revealing the effects of biochar on the population would be important to determine the direction of research and development in the longer term.

CONCLUSION AND RECOMMENDATIONS

Biochar technology is multidiciplinary so its development will involve various research groups for: the development of TLUD stoves; testing of fuels and characterizing the biochar produced; uses of biochar as a fertilizer carrier, aerobic composting, anaerobic digestion, human waste management, poultry litter, water filtration, etc.; testing and demonstrating in horticulture; remediation of saline soils; involvement of households, institutions and businesses; monitoring of the socioeconomic impact; and more. On way to build momentum could be to hold a symposium called "Biochar in Bangladesh," with the papers published in a special edition of a scientific journal (e.g., J. Bang. Agr. Univ.) and/or on www.biochar-bangladesh.org. The interrelated nature of biochar in cooking, nutrient cycling, and food production will be mutually reinforcing and help to overcome challenges that are unique to Bangladesh.