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Use of biochar for greenhouse gas mitigation

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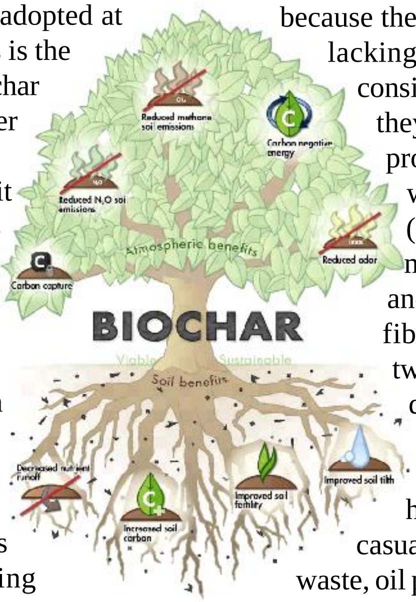
Climate change is threatening food security globally. Countries like India are more vulnerable in view of the tropical monsoon climate and poor coping capacity of the small and marginal farmers. Several agricultural practices like indiscriminate use of agro-chemicals and crop residue burning contribute to emission of greenhouse gases leading to warming of the atmosphere. Sequestration of carbon both in the vegetation and soil is the most effective means of mitigating GHG emissions. There are several strategies of soil carbon sequestration which can be adopted at farm level. One of the recent developments is the conversion of crop residue biomass into biochar and using the char as a soil amendment rather than directly using the crop residues.



Biochar is a name for charcoal when it is used for particular purposes, especially as a soil amendment. Like all charcoal, biochar is created by pyrolysis of biomass. Pyrolysis produces biochar, liquids, and gases from biomass by heating the biomass in a low/no oxygen environment. The absence of oxygen prevents combustion. The relative yield of products from pyrolysis varies with temperature. Biochar is a stable solid, rich in carbon and can endure in soil for thousands of years. They produced it by smoldering agricultural waste (*i.e.*, covering burning biomass with soil) in pits or trenches at temperature 400-500^0 C. Slow process yield-50 per cent char. The other products obtained from pyrolysis are gas, bio oil. A modern pyrolyser yields 3-9 times more biochar. The term "biochar" was coined by Peter Read to describe charcoal used as a soil improvement. Biochar is a material containing hydrocarbon aromatic polycyclic carbon with functional groups. Biochar has surface area and porosity which are significant in improving water holding capacity, adsorption, and nutrient retention. Biochar can affect soil structure, texture, porosity, particle size distribution, and density so it can improve *aerase*, water storage capacity and microbes, and nutrient availability in the root zone of plants. There are many different types and qualities of biochar. The key chemical and physical properties of a biochar are greatly affected by the type of material being used and the conditions of the pyrolysis process (*i.e.* temperature and time).

Agricultural waste is usually handled as a liability, often because the means to transform it into an asset is lacking. Crop residues in fields can cause considerable crop management problems as they accumulate. The major crop residues produced in India are straws of paddy, wheat, millet, sorghum, pulses (pigeonpea), oilseed crops (castor, mustrad), maize stover and cobs, cotton and jute sticks, sugarcane trash, leaves, fibrous materials, roots, branches and twigs of varying sizes, shapes, forms and densities. Some of the common agricultural by-products available in large quantities include bagasse, rice husk, groundnut shell, tea waste, casuarina leaf litter, silk cotton shell, cotton waste, oil palm fibre and shells, cashew nut shell, coconut shell, coir pith etc. These residues are either partially utilized or un-utilized due to various constraints.

The availability of biomass in India (2010-2011) is estimated at about 500 million tons/year. The surplus residues *i.e.*, total residues generated minus residues used for various purposes, are typically burnt on-farm. Residue burning traditionally provides a fast way to clear the agricultural field of residual biomass and facilitating further land preparation and planting. Other reasons for intentional burning include clearing of fields, fertility enhancement, and pest and pasture management. It also provides a fast way of controlling weeds, insects and diseases, by both eliminating them directly or by altering their natural habitat.

Burning is also perceived to boost soil fertility, although burning actually has a differential impact on soil fertility. It increases the short-term availability of some nutrients (e.g. P and K) and reduces soil acidity, but leads to a loss of other nutrients (e.g. N and S), organic matter and microbial activity required for maintaining better soil health.

About three-fourths of greenhouse gas (GHG) emissions from agro-residues burning were CH_4 and the remaining one-fourth was N_2O. Burning of wheat and paddy straws alone contributes to about 42 per cent of GHGs. On the other hand, maintenance of a threshold level of organic matter in the soil is crucial for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform its agricultural production and environmental functions. Hence, conversion of organic waste to produce biochar using the pyrolysis process is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality. Biochar has the potential to increase conventional agricultural productivity and enhance the ability of farmers to participate in carbon markets beyond the traditional approach by directly applying carbon into the soil.

Biochar is fine-grained and porous substance, similar in its appearance to charcoal produced by natural burning. It is produced by pyrolysis, a thermo-chemical process where biomass is heated in the absence of oxygen. Biochars refer to the high carbon materials produced from the slow pyrolysis (heating in the absence of oxygen) of biomass. Chars and charcoal-like materials occur naturally in soils and are considered part of the soil organic carbon pools. As results, bio-oil, synthesis gas with different energy values and black carbon (biochar) are obtained.

Biochar can be used as soil amendment to improve soil quality, crop yield and as a carbon (C) sequestration method. It may improve the physical structure of the soil and can also modify soil hydraulic properties. Given that the pore size of biochar is relatively fixed, it increases available moisture in sandy soils while has a neutral effect in medium textured soils and decreases moisture availability in clay soils. In general, soil organic matter increases soil water holding capacity. In biochar-enriched *terra preta* with their associated high levels of organic matter, Glaser *et al.* (2002) found a water retention capacity that was 18 per cent higher than in the adjacent soils. Biochar has been found to decrease nutrient leaching thus enhancing nutrient availability (Chan *et al.*, 2007 and Yamato *et al.*, 2006).

Evidence suggests that biochar porosity contributes to nutrient adsorption or covalent interaction on a large surface area. Furthermore, its cation exhange capacity (CEC) is consistently higher than that of the whole soil. In fact, the concentration of negative charges on biochar surfaces increases with age as well as the adsorption of charged organic matter. Artificially produced biochar is a product of the renewable-energy-focused pyrolysis technology which produces biofuel to displace fossil fuel use. Apart from the carbon offset due to the production of biofuel, the relatively stable nature of biochar material also could have carbon sequestration value. Also, biochars can potentially be used as soil amendments for improving the quality of agricultural soils. Using biochar to sequester carbon in agricultural land as a way to combat climate change can only be accomplished economically if the sequestered C has beneficial soil amendment and/or fertilizer values.

Biochar for climate change mitigation:

Carbon sequestration: Soil C sequestration is the removal of atmospheric CO_2 through photosynthesis to form organic matter, which is ultimately stored in the soil as long-lived, stable forms of C. The global carbon cycle is made up of flows and pools of carbon in the Earth's system. The important pools of carbon are terrestrial, atmospheric, ocean, and geological. The carbon within these pools has varying lifetimes, and flows take place between them all. The conversion of biomass carbon to biochar leads to sequestration of about 50 per cent of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition (less than 10-20% after 5-10 years). Production and application of biochar to farm soils can tackle many global and domestic policy issues. Nevertheless, the application of biochar at the farm level is discouragingly slow, largely due to financial constraints.

Mitigation of greenhouse gas emissions: Burning of residues emits a significant amount GHGs. One ton straw on burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2. This change in composition of the atmosphere may have a direct or indirect effect on the radiation balance. These gases are important for their global impact and may lead to a regional increase in the levels of aerosols, acid deposition, increase in tropospheric ozone and depletion of the stratospheric ozone layer. Apart from carbon sequestration, there are other environmental benefits that can be derived from the application of biochar in soils which include reduction in the emission of non-CO_2 GHGs by soils.

Potentials of biochar use in India: Efficient and sustainable disposal of organic waste remains a key issue in rural farm areas and in urban societies. Most wastes are either burnt or end up in landfill, which degrade the environment and also produce large amounts of GHGs. The production of biochar from farm wastes and their application in farm soils offer multiple environmental and financial benefits. Biochar use has a very promising potential for the development of sustainable agricultural systems in India, and also for global climate change mitigation.

There is significant availability of non-feed biomass resources in the country as potential feedstock for biochar production. Biochar having high pH value can be a good remedy for acid soil amelioration. North-East India has the potentiality of producing 37 million tons of agricultural waste biomass. If only 1 per cent of this biomass is converted to biochar, about 74 thousand tons of carbon can be sequestered annually. Out of this, if 1 per cent of the process of producing biochar is carried out through modern equipments, about 1300 and 900 tons of bio-oil and biogas can be produced, respectively which is equivalent to 31 terra joule of energy.

Moreover, in rural India, women cook their food with biomass (mostly wood and charcoal) in highly polluting stoves, which represent a number of problems including deforestation, lots of time spent on wood collection and on cooking, back pains and other life-threatening risks. Furthermore, charcoal is inefficiently produced in the earth-mound kiln releasing a considerable amount of methane emissions. Therefore, the establishment of the commercialization chain of highly-efficient biochar-making cook stoves, diffusion of improved small-scale kilns, pyrolysis of agricultural residues that are burnt otherwise, offer an opportunity to enhance the living conditions of rural families, counteract deforestation, protect biodiversity, increase crop production, improve agricultural waste management and remove carbon from the atmosphere as a carbon-negative strategy to fight global warming.

Constraints of biochar use in India: Production of biochar is, of course, not the only use that can be made of biomass. Numerous other applications for various types of biomass have been used in the past, are in current demand, and may become popular in the future. The crop residues and other biomass are used for animal feeding, soil mulching, biomanure making, thatching for rural homes and fuel for domestic and industrial use. emissions of CH_4, N_2O, soot or volatile organic compounds combined with low biochar yields (for example, from traditional charcoal kilns or smouldering slash piles) may negate some or all of the carbon-sequestration benefits, cause excessive carbon-payback times or be detrimental to health.

Conclusion: Climate change and food production are causally linked as 13.5 per cent of radiative forcing is attributable to greenhouse gases emitted through agricultural activity. The carbon release associated with switching land previously under natural or unmanaged vegetation to crop production releases typically large amounts of carbon from standing biomass, and also from the soil. Since biochar could be used on a large scale and cannot be removed from soil once applied, there is a need to carefully assess the potentially negative impacts on occupational health, environmental pollution, water quality, and food safety.

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