Biochar: Soil Amendment to Combat Global Warming, Improve Agricultural Sustainability and Reduce Environmental Impacts

Summary

Biochar and ***bioenergy*** production from ***biomass*** can combat ***global climate change***, displace fossil fuel use, ***sequester carbon*** in soil, and dramatically ***reduce nitrous oxide emissions.***

Introduction to Biochar

Biochar and bioenergy co-production from urban, agricultural and forestry ***biomass*** can help combat ***global climate change*** by displacing fossil fuel use, by sequestering carbon in stable soil sinks, and by dramatically reducing emissions of nitrous oxides, a more potent greenhouse gas than carbon dioxide.[1,2] As a soil amendment, biochar helps to improve the Earth's soil resources by increasing crop yields and productivity, by reducing soil acidity, and by reducing the need for some chemical and fertilizer inputs.[3,4] Water quality is improved by the use of biochar as a soil amendment, because biochar aids in soil retention of nutrients and agrochemicals for plant and crop utilization,[5,6] reducing leaching and run-off to ground and surface waters.

Biochar production and utilization systems differ from most biomass energy systems because the technology is ***carbon-negative***: it removes net carbon dioxide from the atmosphere and stores it in stable soil carbon "sinks".[7] Other biomass energy systems are *at best* carbon-neutral, resulting in no net changes to atmospheric carbon dioxide.

Biochar Production

Bioenergy and ***biochar*** are co-produced from thermal treatment of biomass feedstocks. Thermal conversion of biomass, under complete or partial exclusion of oxygen, results in production of biochar and bioenergy or other bioproducts. Biochar production processes can utilize most urban, agricultural or forestry biomass residues, including wood chips, corn stover, rice husks, peanut hulls, tree bark, paper mill sludge, animal manure, and recycled organics, for instance.

Under controlled production conditions, the carbon in the biomass feedstock is captured in the biochar and the bioenergy co-products. Theoretically, the ***biochar*** co-product will retain up to 50% of the feedstock carbon in a porous charcoal structure; and the remaining 50% of the feedstock carbon will be captured as ***bioenergy.*** While it is technically infeasible to capture 100% of the biomass carbon, since energy is invariably used and lost in the production process, the optimal biochar production process can capture roughly half the biomass carbon in biochar and half as bioenergy.

Biochar can be produced by ***pyrolysis*** or ***gasification*** systems. ***Pyrolysis*** systems produce biochar largely in the absence of oxygen and most often with an external heat source. There are two types of pyrolysis systems in use today: ***fast pyrolysis*** and ***slow pyrolysis*** systems. ***Gasification*** systems

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[1] Yanai et al., 2007, Effects of charcoal addition on N2O emissions from soil resulting from rewetting air-dried soil in short-term laboratory experiments, ***Soil Science and Plant Nutrition***, 53:181-188.

[2] Rondon, M., Ramirez, J.A., and Lehmann, J.: 2005, Charcoal additions reduce net emissions of greenhouse gases to the atmosphere, in ***Proceedings of the 3rd USDA Symposium on Greenhouse Gases and Carbon Sequestration***, Baltimore, USA, March 21-24, 2005, p. 208.

[3] Glaser, B., Lehmann, J. and Zech, W., 2002, Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal --- a review, ***Biology and Fertility of Soils***, 35: 219-230.

[4] Lehmann, J. and Rondon, M., 2006, Biochar soil management on highly weathered soils in the humid tropics. In Uphoff N (ed.), ***Biological Approaches to Sustainable Soil Systems***, CRC Press, Boca Raton, FL, pp. 517-530.

[5] Lehmann, J., et al., 2003, Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments, ***Plant and Soil***, 249: 343-357.

[6] Steiner, C., et al., Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil, ***Plant and Soil***, 291: 275-290.

[7] Lehmann, J., Gaunt, J., and Rondon, M., 2006, Bio-char sequestration in terrestrial ecosystems – a review. Mitigation and Adaptation Strategies for Global Change, 11:403-427.

produce smaller quantities of biochar in a directly-heated reaction vessel with air introduced. Biochar production is optimized in the absence of oxygen.

Gasification and pyrolysis production systems can be developed as mobile or stationary units. Small scale gasification and pyrolysis systems that can be used on farm or by small industries are commercially available with biomass inputs of 50 kg/hr to 1,000 kg/hr. The bioenergy produced from these systems, which can be in the form of a synthetic gas, or ***syngas***, or ***bio-oils***, can be used to produce heat, power or combined heat and power. At the local or regional level, pyrolysis and gasification units can be operated by co-operatives or larger industries, and can process up to 4,000 kg of biomass per hour.

Biochar

Biochar is a fine-grained, porous charcoal substance that, when used as a soil amendment in combination with sustainable production of the biomass feedstock, effectively removes net carbon dioxide from the atmosphere.[8] In the soil, biochar provides a habitat for soil organisms, but is not itself consumed by them to a great extent, and most of the applied biochar can remain in the soil for several hundreds to thousands of years[9],[10] (see also ***Terra Preta soils***). The biochar does not in the long-term disturb the carbon-nitrogen balance, but holds and makes water and nutrients available to plants. When used as a soil amendment along with organic and inorganic fertilizers, biochar significantly improves soil tilth, productivity, and nutrient retention and availability to plants.[11]

Bioenergy

The ***bioenergy*** produced during biochar production may be in the form of thermal energy, a synthesis gas, aka ***syngas,*** or a ***bio-oil***. The syngas or bio-oil can be used to heat the pyrolysis unit for continued production, and surplus syngas or bio-oil can be used to provide additional energy for on-site uses, such as heat and electricity. ***Syngas*** is rich in hydrogen, methane and carbon monoxide and in addition to its use for heat or power, it can be converted to ***liquid fuels*** or industrial ***chemicals.*** The bio-oils can also be used for on-site power and heat generation, or converted to ***liquid fuels*** or industrial ***chemicals***.

Economics of Biochar Systems

The co-production of biochar from a portion of the biomass feedstock reduces the total amount of bioenergy that is produced by the technology, but even at today's energy and fertilizer prices the net gain in soil productivity is worth more than the value of the energy that would otherwise have been derived from the biomass feedstock. As the cost of carbon emissions rises and the value of CO_2 extraction from the atmosphere is also considered, the balance becomes overwhelmingly attractive in favor of biochar co-production.

Rural and Developing Country Applications of Biochar Systems

Biochar systems can reverse soil degradation and create sustainable food and fuel production in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. Low-cost, small-scale biochar production units can produce biochar to build garden, agricultural, and forest productivity, and bioenergy for eating, cooking, drying and grinding grain, producing electricity and thermal energy, for instance.

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[8] Ibid.

[9] Pessenda, L.C.R., Gouveia, S.E.M., and Aravena, R., 2001, Radiocarbon dating of total soil organic matter and humin fraction and its comparison with ^{14}C ages of fossil charcoal, ***Radiocarbon***, 43: 595-601.

[10] Schmidt, M.W.I., Skjemstad, J.O., and Jager, C., 2002, Carbon isotope geochemistry and nanomorphology of soil black carbon: Black chernozemic soils in central Europe originate from ancient biomass burning. ***Global Biogeochemical Cycles***, 16: 1123.

[11] Glaser, B., Lehmann, J. and Zech, W., 2002, Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal --- a review, ***Biology and Fertility of Soils***, 35: 219-230.