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Information note: **Use of biochar (charcoal) to replenish soil carbon pools, restore soil fertility and sequester CO_2**

Abstract

The world's soils hold more organic carbon than that held by the atmosphere as CO2 and vegetation, yet the role of the soil in capturing and storing carbon dioxide is often one missing information layer in taking into consideration the importance of the land in mitigating climate change. Extraordinary demands are being placed on agricultural systems to produce food, fiber and energy and yet the inevitable changes in the flow of carbon into or out of soils have significant effect on a global scale. Biomass burning and the removal of crop residues reduce carbon in soil and vegetation, which has implications for soil fertility and the global carbon cycle.

The land has an unparalleled capacity to hold carbon and to act as a sink for green house gases making it imperative to focus on activities that enhances rehabilitation, protection and sustainable management of degraded lands. Conventional means to increase soil carbon stocks depend on climate, soil type and site specific management. Over the years, most efforts to manage greenhouse gases have involved planting trees, since the amount of carbon that can be sequestered in this way is substantial. However, the drawback of conventional carbon enrichment is that this carbon-sink option is of limited duration. The associated humus enrichment follows a saturation curve, approaching a new equilibrium level after some 50 to 100 years. The new carbon level drops rapidly again as soon as the required careful management is no longer sustained.

There exist opportunities to include sustainable land management processes and in particular the use of biochar into the CDM negotiation process through focused policy actions that include institutional synergy as well as better understanding of the sustainability cost-benefit of Biochar. This process could be undertaken starting in Poznan and towards the Copenhagen agreement.

Pyrolysis (of agricultural residues resulting in charcoal and energy production) with biochar carbon sequestration provides a tool to combine sustainable soil management (carbon sequestration) and renewable energy production. The process of pyrolysis or carbonization is known globally and can be implemented at both small scale (e.g. cooking stove) and large scale levels (e.g. biorefinery). About 50% of the carbon can be captured if biomass is converted to biochar. Charcoal enriched soils like Chernozems and in particular Terra Preta soils are among the world’s most fertile soils and prove that soil organic carbon enrichment beyond the maximum capacity is possible if done with a recalcitrant form of carbon such as biochar.

The soil properties determine the different capacities of the land to act as a store for carbon that has direct implications for capturing greenhouse gases. Biochar offers unique options to address issues emerging from the conflicts and complementarities between cultivating crops for different purposes, such as for energy or for CO_2 sequestration or for food and the impacts on food security, land/soil degradation, water, and biodiversity. The fact that many of the drylands soils have been degraded means that they are currently far from saturated with carbon and their potential to sequester carbon may be very high (Farage et al 2003) making the consideration of Biochar, as a strategy for enhancing soils carbon sequestration, imperative.

Required policy actions

The global carbon trade market must be made accessible to land managers, especially in the tropics where sustaining SOC and soil fertility is most challenging and CO_2 emissions due to land use change are highest.

All stakeholders need to engage in the dialogue for the post 2012 climate regime. This approach of soil organic carbon restoration constitutes a significant adaptation tool to climate change, in addition to sequestering carbon. This could be a strong link between the three Rio conventions as it simultaneously addresses climate change, desertification and biodiversity issues.

There is the need to include into the negotiation agenda of UNFCCC practical approaches such as biochar-related mitigation (CDM) and other LCA adaptation initiatives, focusing on increased land productivity, which simultaneously takes into account the issue of climate change, desertification and biodiversity issues.

According to the IPCC biochar management would be a valid C sink in the current and post 2012 LULUCF guidelines. However, the following policy action is urgently required:

1. Raising awareness on the role of the land on mitigation and adaptation to climate change and in particular the importance of Biochar in enhancing the sequestration of carbon in the soils.
2. Inclusion of biochar in the CDM mechanism along with currently already included afforestation and reforestation (A/R).
3. Revision of the additionality rules in order to take into account the fact that biochar is a permanent means of carbon capture that has more value than the potentially reversible (A/R).
4. In view of item 3 above, increase the level of CERs that an annex I Party can use towards meeting the Kyoto Protocol targets from the current 1% to a higher percentage. This would result in large financial flows for both mitigation and adaptation to developing countries where use of this technique would result in the highest returns, due to the high losses of SOC.

The Values of Soil Organic Carbon (SOC)

According to Sombroek et al. (1993) it is important to separate effects due to organic matter per se (maintenance and improvement of water infiltration, water holding capacity, structure stability, retention of nutrients, healthy soil biological activity) from those due to decomposition (source of nutrients). The SOC pool is an important indicator of soil quality, and has numerous direct and indirect impacts on it such as, improved structure and tilth, reduced erosion, increased plant-available water capacity, water purification, increased soil biodiversity, improved yields, and climate moderation (Lal 2004). This is essential to sustain the quality and productivity of soils around the globe, particularly in the tropics where there is a greater proportion of nutrient poor soils with a greater susceptibility to carbon loss.

Greenhouse Gas (GHG) Emissions from Agriculture

The global SOC pool in the upper 1 m for the world's soils contains 1220 gigatons (Gt, 10^9 = billion tons) carbon, 1.5 times the total for the standing biomass (Sombroek et al. 1993). The total soil carbon (organic and inorganic) is 3.3 times the size of the atmospheric carbon pool (Lal 2004). As most agricultural soils have lost 50 to 70% of their original SOC pool (Lal 2003) they represent a considerable carbon sink if efforts are made to restore SOC, but also a huge source of GHG if soil management and deforestation rates are not changed. There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades (25-90% between 2000 and 2030) (IPCC 2007).

Replenishing SOC Pools and the Global Potential of Biochar Carbon Sequestration

Increasing SOC with conventional means e.g. conservation tillage, use of manures, and compost, conversion of monoculture to complex diverse cropping systems, meadow-based rotations and winter cover crops, and establishing perennial vegetation on contours and steep slopes can sequester carbon. The sequestration potential depends on climate, soil type, and site specific management. SOC of cropland increases only if either SOC additions are enhanced or decomposition rates reduced (Sauerbeck 2001). Accumulating crop residues in the field can cause considerable crop management problems (increasing the susceptibility to wildfire, insect attach and disease, increasing N_2O and CH_4 emission). Therefore many farmers find it more expedient to burn crop residues than to incorporate them into the soil. Worldwide, the total carbon release from fire is of the order of 4-7 Gt of carbon per year. This flux is almost as large as the rate of fossil fuel consumption (about 6 Gt per year in 1990) (Goudriaan 1995).

Reduced decomposition is an advantage of charcoal (biochar). Biochar formation has important implications for the global carbon cycle. In natural and agroecosystems residual charcoal is produced by incomplete burning. As the SOC pool declines due to cultivation, the more resistant charcoal fraction increases as a portion of the total carbon pool (Zech and Guggenberger 1996, Skjemstad 2001, Skjemstad et al. 2002) and may constitute up to 35% of the total SOC pool in ecosystems (Skjemstad et al. 2002). Carbon dating of charcoal has shown some to be over 1500 years old, fairly stable, and a permanent form of carbon sequestration (Lal 2003).

An anthropogenically-enriched dark soil found throughout the lowland portion of the Amazon Basin and termed *Terra Preta de Índio* is one example how soil management can increase the productivity of soils for centuries (Woods 1995). These soils contain high concentrations of charcoal (Glaser et al. 2001); and significantly more plant available nutrients than in the surrounding soils (Lima et al. 2002). The existence of *Terra Preta* proves that infertile soils can be transformed into permanently fertile soils in spite of rates of weathering 100 times greater than those found in the mid-latitudes.

Systems (pyrolysis) converting biomass into energy (hydrogen-rich gas and bio-oil) and producing biochar as a by-product offer an opportunity to combine renewable energy production, carbon sequestration and soil restoration. Biochar can be produced by incomplete combustion from any biomass, and it is a by-product of the pyrolysis technology used for biofuel and bioenergy production. If the demand for renewable fuels by the year 2100 was met through pyrolysis, biochar sequestration could exceed current emissions from fossil fuels (Lehmann et al. 2006).

Biochar and Soil Fertility

The recalcitrant nature of charcoal makes biochar rather exceptional. Recent studies showed that soil biochar amendments are indeed capable of increasing soil fertility by improving chemical, biological, and physical properties. Biochar significantly increase plant growth and nutrition (Lehmann et al. 2003, Steiner et al. 2007). Lehmann et al. (2003) and Steiner et al. (2008) found improved efficiency of nitrogen fertilizers on biochar containing fields. The effects on soil biology seem to be essential as biochar has the potential to alter the microbial biomass (Steiner et al. 2004) and composition (Birk 2005) and the microbes are able to change the biochar's properties (Glaser et al. 2001). The majority of experiments conducted show that biochar soil amendments result in enhanced colonization rates my mycorrhizal fungi (Warnock et al. 2007). Rondon et al. (2007) found increased biological nitrogen fixation by common beans through biochar additions. Lehmann and Rondon (2006) reviewed 24 studies with soil biochar additions and found improved productivity in all of them ranging from 20 to 220% at application rates of 0.4 to 8 tons carbon ha^{-1}.

Advantages of Biochar Carbon Sequestration

- No competition between SOC restoration, bio-fuels and food production

Numerous researchers warn of deleterious effects on soil fertility if crop residues are removed for bio-energy production (Sauerbeck 2001, Lal 2004). Pyrolysis with biochar carbon sequestration provides a tool to combine sustainable SOC management (carbon sequestration), and renewable energy production. While producing renewable energy from biomass, SOC sequestration, agricultural productivity, and environmental quality can be sustained and improved if the biomass is transferred to an inactive carbon pool and redistributed to agricultural fields. The uses of crop residues as potential energy source or to sequester carbon and improve soil quality can be complementary, not competing uses.

- Pyrolysis or gasification with biochar carbon sequestration

Bioenergy with biochar carbon storage facilitates the generation of carbon-negative energy. Biochar producing gasifiers can have a broad range in size and in technological complexity. Biochar can be produced as a byproduct from cooking (biochar producing kitchen stoves). Decentralized small scale projects are feasible and large capital investments are not necessary. As biochar is a byproduct of gasification, no carbon capture technology is necessary. There is no risk of harmful CO_2 leakage from biochar.

- Fast SOC buildup beyond the maximum sequestration capacity

From biomass to humus a considerable fraction of carbon is lost by respiratory processes, and also from humus to resistant soil carbon. Only 2-20% of the carbon added as above ground residues and root biomass enters the SOC pool by humification. The rest is converted to CO_2 due to oxidation, and furthermore the SOC pool is not inert to oxidation (Lal 2004). Soils can only sequester additional carbon until the maximum soil carbon capacity, or soil carbon saturation, is achieved, which requires a steady input of biomass and careful management practices. In contrast, about 50% of the carbon can be captured if biomass is converted to biochar (Lehmann et al. 2006).

The existence of Terra Preta proves that SOC enrichment beyond the maximum capacity is possible if done with a recalcitrant form of carbon such as biochar. These soils still contain large amounts of biochar derived SOC in a climate favorable for decomposition, hundreds and thousands of years after they were abandoned.

- Reduced deforestation

Only re-growing plant biomass can establish a carbon sink. The carbon trade could provide an incentive to cease further deforestation; instead reforestation and recuperation of degraded land for fuel and food crops would gain magnitude. As tropical forests account for between 20 and 25% of the world terrestrial carbon reservoir (Bernoux et al. 2001), this would reduce emissions from tropical forest conversion which is estimated to contribute globally as much as 25 % of net CO_2 emissions and up to 10 % of N_2O emissions to the atmosphere (Palm et al. 2004).

- Easy accountability and reduced risk

Current CDM projects dealing with charcoal aim either at reduction of methane emissions during charcoal production or substitution of fossil fuels by burning charcoal. In both cases the charcoal does not reduce GHG in the atmosphere.

Biochar as a soil amendment would provide a large permanent carbon sink. Potential drawbacks such as difficulty in estimating greenhouse gas removals and emissions resulting from land use, land use change and forestry (LULUCF), or destruction of sinks through forest fire or disease do not apply to biochar soil amendments. Furthermore, the biochar carbon sink is easily quantifiable. Biochar production transforms carbon from the active (crop residues or trees) to the inactive carbon pool. Biochar is a formally authorized soil amendment in Japan and is discussed to be part of Australia's emissions trading scheme. New Zealand invested in research development and commercialization of biofuel and **biochar**. The 2008

Farm Bill (H.R. 2419, the Food and Energy Security Act of 2008) was passed by the U. S. Congress and establishes the first federal-level policy in support of biochar production and utilization programs in the world, and is one of a handful of new, high-priority research and extension areas.

The avoided emissions of greenhouse gases are between 2 and 5 times greater when biochar is applied to agricultural land than used solely for fossil energy offsets. The potential revenues from carbon trading alone can justify optimizing pyrolysis to produce biochar for application to land (Gaunt and Lehmann 2008).

References

Bernoux, M., P. M. A. Graça, C. C. Cerri, P. M. Fearnside, B. J. Feigl, and M. C. Piccolo. 2001. Carbon storage in biomass and soils. Pages 165-184 *in* M. E. McClain, R. L. Victoria, and J. E. Richey, editors. The biogeochemistry of the Amazon basin. Oxford University Press, New York.

Birk, J. J. 2005. Einfluss von Holzkohle und Düngung auf die mikrobielle Zersetzergemeinschaft und den Streuumsatz in amazonischen Ferralsols. Diplomarbeit. University of Bayreuth, Bayreuth.

Farage P., Pretty J., and Ball, A., 2003 Biophysical Aspects of Carbon Sequestration in Drylands University of Essex Feb 03

Gaunt, J. L., and J. Lehmann. 2008. Energy balance and emissions associated with biochar sequestration and pyrolysis bioenergy production. Environmental Science & Technology

Environ. Sci. Technol. **42**:4152-4158.

Glaser, B., G. Guggenberger, L. Haumaier, and W. Zech. 2001. Persistence of Soil Organic Matter in Archaeological Soils (Terra Preta) of the Brazilian Amazon Region. Pages 190-194 *in* R. M. Rees, B. C. Ball, C. D. Campbell, and C. A. Watson, editors. Sustainable management of soil organic matter. CABI Publishing, Wallingford.

Goudriaan, J. 1995. Global Carbon and Carbon Sequestration. Pages 3-18 *in* M. A. Beran, editor. Carbon sequestration in the biosphere. Processes and prospects. Springer Verlag, Heidelberg, Berlin.

IPCC. 2007. Fourth Assessment Report, Climate Change 2007: Synthesis Report. IPCC.

Lal, R. 2003. Global Potential of Soil Carbon Sequestration to Mitigate the Greenhouse Effect. Critical Reviews in Plant Sciences **22**:151-184.

Lal, R. 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science **304**:1623-1627.

Lehmann, J., J. P. da Silva Jr., C. Steiner, T. Nehls, W. Zech, and B. Glaser. 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.

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

Lehmann, J., and M. Rondon. 2006. Bio-Char Soil Management on Highly Weathered Soils in the Humid Tropics. Pages 517-530 *in* N. U. e. al., editor. Biological Approaches to Sustainable Soil Systems. CRC Press, Boca Raton, FL, USA.

Lima, H. N., C. E. R. Schaefer, J. W. V. Mello, R. J. Gilkes, and J. C. Ker. 2002. Pedogenesis and pre-Colombian land use of "Terra Preta Anthrosols" ("Indian black earth") of Western Amazonia. Geoderma **110**:1-17.

Palm, C., T. Tomich, M. v. Noordwijk, S. Vosti, J. Gockowski, J. Alegre, and L. Verchot. 2004. Mitigating GHG emissions in the humid tropics: case studies from the alternatives to slash-and-burn program (ASB). Environment, Development and Sustainability **6**:145-162.

Rondon, M. A., J. Lehmann, J. Ramirez, and M. Hurtado. 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. Biology and Fertility of Soils **DOI 10.1007/s00374-006-0152-z**.

Sauerbeck, D. R. 2001. CO_2 emissions and C sequestration by agriculture - perspecives and limitations. Nutrient Cycling in Agroecosystems **60**:253-266.

Skjemstad, J. 2001. Charcoal and other resistant materials. Pages 116-119 *in* Net Ecosystem Exchange Workshop Proceedings. Cooperative Research Centre for Greenhouse Accounting, Canberra ACT 2601, Australia.

Skjemstad, J. O., D. C. Reicosky, A. R. Wilts, and J. A. McGowan. 2002. Charcoal carbon in US agricultural soils. Soil Science Society of America Journal **66**:1249-1255.

Sombroek, W. G., F. O. Nachtergaele, and A. Hebel. 1993. Amounts, Dynamics and Sequestering of Carbon in Tropical and Subtropical Soils. Ambio **22**:417-426.

Steiner, C., B. Glaser, W. G. Teixeira, J. Lehmann, W. E. H. Blum, and W. Zech. 2008. Nitrogen Retention and Plant Uptake on a Highly Weathered Central Amazonian Ferralsol ammended with Compost and Charcoal. Journal of Plant Nutrition and Soil Science.

Steiner, C., W. G. Teixeira, J. Lehmann, T. Nehls, J. L. V. d. Macêdo, W. E. H. Blum, and W. Zech. 2007. 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.

Steiner, C., W. G. Teixeira, J. Lehmann, and W. Zech. 2004. Microbial Response to Charcoal Amendments of Highly Weathered Soils and Amazonian Dark Earths in Central Amazonia - Preliminary Results. Pages 195-212 *in* B. Glaser and W. I. Woods, editors. Amazonian Dark Earths: Explorations in Space and Time. Springer Verlag, Heidelberg.

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Warnock, D. D., J. Lehmann, T. W. Kuyper, and M. C. Rillig. 2007. Mycorrhizal responses to biochar in soil - concepts and mechanisms. Plant and Soil **300**:9-20.

Woods, W. I. 1995. Comments on the Black Earths of Amazonia. Pages 158-165 *in* F. A. Schoolmaster, editor. Papers and Proceedings of the Applied Geography Conferences. Applied Geography Conferences, Denton, Texas.

Zech, W., and G. Guggenberger. 1996. Organc matter dynamics in forest soils of temperate and tropical ecosystems.*in* A. Piccolo, editor. Humic substances in terrestrial ecosystems. Elsevier.