Slash and Char

Soil Charcoal Amendments (agrichar or biochar) maintain Soil Fertility and establish a Carbon Sink

The existence of an anthropogenic and carbon (C) enriched dark soil in different parts of the world and especially in Amazonia (Amazonian Dark Earths (ADE) or Terra Preta de Índio) proves that the predominant Ferralsols and Acrisols can be transformed into fertile soils. Charcoal formation and deposition in soils seems to be a promising option to transfer an easily decomposable biomass into refractory soil organic matter (SOM) pools. The production of charcoal for soil amelioration purposes (slash and char) out of the aboveground biomass (secondary forest and crop residues) instead of converting it to carbon dioxide (CO_2) through burning (slash and burn) could establish a C sink and could be an important step towards sustainability and SOM conservation in tropical agriculture.

On a global scale, crop residue biomass represents a considerable problem as well as new challenges and opportunities. Bio-char soil management systems can deliver tradable C emissions reduction, and C sequestered is easily accountable, and verifiable. The described mixture of driving forces and technologies has the potential to use residual waste carbon-rich residues to reshape agriculture, balance carbon and address nutrient depletion.

Tropical forests account for between 20 and 25% of the world terrestrial carbon (C). Soils under tropical forest contain approximately the same amount of C as the lush vegetation above it. The current conversion of Amazonian forest to agricultural land makes disturbance of this C stock important to the global C balance and net greenhouse gas emissions. Changes in land use, particularly by clearing forests, reduce organic C by 20% to 50% in the upper soil layers. Furthermore, this reduction of soil organic matter (SOM) is causing soil degradation. Thus agriculture is not sustainable without nutrient inputs beyond 3 years of cultivation. The efficiency of conventional fertilizers (such as nitrogen (N)) is limited by a low nutrient retention capacity conjoined with strong tropical rains. On the other hand, large amounts of phosphate fertilizers are needed to overcome the soil’s high P-fixation capacity.

The existence of an anthropogenic and C-enriched dark soil in different parts of the world and especially in Amazonia (Amazonian Dark Earths (ADE) or Terra Preta de Índio) proves that the predominant Ferralsols and Acrisols can be transformed into fertile soils. The ADE’s fertility is most likely linked to an anthropogenic accumulation of phosphorus (P), calcium (Ca), and black C as charcoal. Charcoal persists in the environment over centuries and is responsible for the stability of the ADE’s SOM. Today and as assumed also in the past, those soils have been intensively cultivated by the native population.

Charcoal formation and deposition in soils seems to be a promising option to transfer an easily decomposable biomass into refractory SOM pools. However, charcoal represents just 1.7% of the pre-burn biomass if a forest is converted by the traditional slash and burn technique. The production of charcoal for soil amelioration purposes (slash and char) out of the aboveground biomass (secondary forest and crop residues) instead of converting it to carbon dioxide (CO2) through burning (slash and burn) could establish a C sink and could be an important step towards sustainability and SOM conservation in tropical agriculture.

Charcoal production is a common activity of many settlers in the Amazon and is frequently used as an alternative land clearing method. The residues from charcoal production are abundant and used to some extent for soil amelioration purposes. However, many farmers fail to produce enough crops for a sufficient family income mainly due to the soils’ infertility and the family’s incapability to afford fertilizers.

Most C is lost if burned in a slash and burn scenario and lost to a high percentage (~50%) if used for charcoal production. Therefore, a C trade could provide an incentive to cease further deforestation; instead re-forestation and recuperation of degraded land for fuel and food crops would gain magnitude.

Charcoal is influencing soil quality in manifold ways, most importantly by reducing available Al and reducing acidity. Furthermore, charcoal has the potential to reduce N leaching and adds potassium (K) to the soil. The effects of charcoal on soil biological, chemical and physical properties are complex, making it difficult to isolate single significant charcoal effects, but added up charcoal amendments caused a significant increase in crop production.

On a global scale, crop residue biomass represents a considerable problem as well as new challenges and opportunities. Before the green revolution and the introduction of mineral fertilizers, crop residues were a valued resource and mostly either returned to the soil as organic fertilizer or used for various other purposes (fuel, fodder, building material, others). Since then, the importance of these uses declined continuously, mainly because of the availability of cheap inorganic fertilizer and the increasing opportunity costs of organic fertilizer use. Simultaneously, increasing yields lead to ever greater quantities of residues available and intensification of land use resulted in less and less decomposition time between cropping seasons for managing them. Therefore, many farmers find it more expedient to burn crop residues than to incorporate them into the soil. The field burning is causing severe air pollution.

Currently most biomass conversion systems produce either charcoal (mainly in Japan as waste management) or energy through complete biomass gasification (Güssing GMBH, Austria, Choren, Germany. Incomplete gasification results in charcoal production.

A system converting biomass into energy (hydrogen-rich gas) and producing charcoal as a by-product (Day et al. 2005) might offer an opportunity to address these problems. Charcoal (bio-char, agri-char) can be produced by incomplete combustion from any biomass and it is a byproduct of the pyrolysis-technology used for biofuel and ammonia production. This establishes the possible link of this technology to crop residues in general and the now widespread new interest in bioenergy. Energy from crop residues could lower fossil energy consumption and CO2-emissions, and become a completely new income source for farmers and rural regions. Linking energy production with charcoal production results in 30.6 kg C sequestration for each GJ of energy produced. The bio-char byproduct of this process could serve to recycle nutrients, improve soils and sequester carbon. A review by Lehmann et al. (2006) and the article “Black is the new green” (Marris 2006) emphasise the potential of bio-char on a global scale. A global analysis revealed that up to 12% of the total anthropogenic C emissions by land use change (0.21 Pg C) can be off-set annually in soil, if slash and burn is replaced by slash and char. Agricultural and forestry wastes such as forest residues, mill residues, field crop residues, or urban wastes add a conservatively estimated 0.16 Pg C yr-1. Using published projections of the use of renewable fuels in the year 2100, bio-char sequestration could amount to 5.5-9.5 Pg C yr-1 if this demand for energy was met through pyrolysis, which would exceed current emissions form fossil fuels (5.4 Pg C yr-1). Bio-char soil management systems can deliver tradable C emissions reduction, and C sequestered is easily accountable, and verifiable. The described mixture of driving forces and technologies has the potential to use residual waste carbon-rich residues to reshape agriculture, balance carbon and address nutrient depletion.

Further Literature:

Day D, Evans R J, Lee J W and Reicosky D 2005 Economical CO2, SOx and NOx capture from fossil-fuel utilization with combined renewable hydrogen production and large-scale carbon sequestration. Energy 30, 2558-2579

Lehmann J, da Silva Jr J P, Rondon M, Cravo M d S, Greenwood J, Nehls T, Steiner C and Glaser B 2002 Slash and char - a feasible alternative for soil fertility management in the central Amazon? In 17th World Congress of Soil Science, Bangkok, Thailand, 14. - 21. 08. 2002, 2002. Ed T I U o S Sciences. pp 1-12.

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

Mann C C 2002 The Real Dirt on Rainforest Fertility. Science 297, 920-923

Marris E 2006 Black is the new green. Nature 442, 624-626

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

Steiner C, Teixeira W G and Zech W 2004b Slash and Char: An Alternative to Slash and Burn Practiced in the Amazon Basin. In Amazonian Dark Earths: Explorations in Space and Time. Eds B Glaser and W I Woods. pp 183-193. Springer Verlag, Heidelberg.