Biochar carbon sequestration in tropical land use systems

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Introduction

Issues of permanence, leakage, land tenure and additionality are the greatest obstacles for land use and forestry (LULUCF and REDD) projects. Furthermore, the “permanence” and vulnerability of these sinks is likely to change in a warming climate. Therefore C sequestered by LULUCF projects is generally considered only temporarily sequestered.

Biochar C sequestration is fundamentally different to other forms of bio-sequestration. Carbonization of biomass increases the half-live time by order of magnitudes and can be considered a manipulation of the C cycle. While fire accelerates the C cycle the formation of biochar decelerates the C cycle. Therefore issues of permanence, land tenure, leakage, and additionality are less significant for biochar projects.

Tropical land use systems provide unique conditions for biochar C sequestration. The humid tropics produce more biomass than anywhere else and the abundance of “waste” biomass is huge. Decomposition of labile SOC is fast and in strongly weathered tropical soils, SOC plays a major role in soil productivity. Therefore both, the conditions to produce biochar as well as the benefits of soil biochar applications are greatest in the humid tropics. We estimate the carbon sequestration potential and implications for the global carbon trade in different land use systems.

Results and Discussions

Slash-and-Burn

The burning of fallow biomass is a cheap and easy practice for land clearing. Increasing pressure on land by a growing human population, market factors, and changes in agricultural practices, has led to land use intensification, and a decrease in the length of possible fallow periods. This shortening of the fallow period and/or lengthening of the cropping period is leading to a loss of crop productivity and sustainable livelihoods for small farmers. Failing to adjust land management techniques to these changing agricultural practices has led to soil degradation and to an increased need for agrochemicals such as fertilizers and pesticides. To overcome these limitations of low SOC soils with low nutrient availability and low nutrient-retention capacity will require alternatives to slash-and-burn and alternative fertilization methods [1,2]. Slash-and-char is inspired by recreation of Terra Preta. The goal of slash-and-char is the purposeful creation of biochar through efficient mechanisms of carbonization and incorporation of this material into the soil for sustained and enhanced fertility and crop productivity.

Given the application of biochar to the soil surface and an expectation for minimal mineralization of the biochar the SOC levels can be increased rapidly. Multiple repetitions of the cropping – fallow – carbonization cycle would allow for a build-up of SOC, potentially to levels found in Terra Preta (Figure 1).

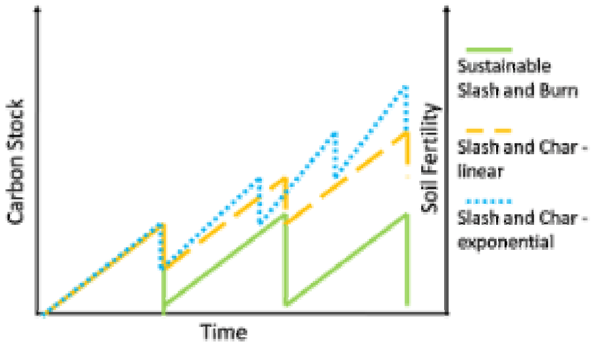

Figure 1. Sustainable slash-and-burn agriculture (green line) maintains carbon stocks and soil fertility over several cropping-fallow cycles. Slash-and-char would capture up to 50% of the C stored in the fallow vegetation and transfer the C into recalcitrant SOC pools. Assuming a faster regeneration of biomass (blue line) the gains in SOC could increase exponential.

The carbon sequestration potential depends on carbon accumulation in fallow based cropping systems. A potential C sequestration of 7.7 Mg of CO_2 ha^{-1} yr^{-1} was estimated in Indonesia if slash-and-burn is replaced by slash-and-char. However, monitoring, reporting, verification and implementation costs might pose significant obstacles in a rural small holder community. Ex-ante credits, such as those issued by the Plan Vivo System can provide the necessary capital.

Oil Palm Plantations

Depending on the replaced vegetation and soil conditions (low carbon soil or tropical peatlands) oil palm plantations can either be a sink or a source of greenhouse gases. The mills typically process 60 Mg of full fruit bunch (FFB) per hour. The available amount of biomass is 13.2, 8.1 and 3.3 Mg h^{-1} with a moisture content of 65%, 42% and 7% for EFB, fiber and shells respectively.

Table 1. Main biomass streams in oil palm plantations and potential for biochar carbon sequestration at the mill and in the field.

Biomass	Biomass Mg ha^{-1} yr^{-1}	Biochar – C[1] Mg ha^{-1} yr^{-1}	CO_2 Mg ha^{-1} yr^{-1}
At the mill			
EFB 8% of FFB	1.55	0.33	1.21
Fiber 8 % of FFB	1.63	0.34	1.25
Shell 5.5% FFB	1.10	0.23	0.84
Total at the mill	**4.28**	**0.9**	**3.30**
In the field			
Fronds[3]	11.4	2.39	8.77
Trunks[4]	3.02	0.63	2.31
Fronds and rachis[4]	0.58	0.12	0.44
Total in the field	**15.00**	**3.14**	**11.52**
Total (mill + field)	**19.28**	**4.04**	**14.82**

* Biomass data from [3] and [4]. Biochar-Carbon assuming a conversion efficiency of 30% and a mean carbon content of 70. 2The dry weight of fronds from annual pruning, 3every 25 years at renovation (75.5 and 14.4 Mg ha^{-1} 25 yrs^{-1})

Timber Plantations

The visited plantation in Indonesia covers 12,000 ha of which 9,000 ha are planted with *Acacia mangium* and *Paraserienthes falcataria*. The trees are harvested after 8 years and 1,000 ha are harvested annually. The plantation is thinned after 2 and 4 years. Logs and branches with a diameter of less than 7 cm remain in the field and serve to reduce the impact of heavy machinery during harvesting operations. Assuming a conservative carbonization efficiency of only 20% the annual biochar production from waste biomass (after harvesting) could be 5,640 Mg (0.7 Mg ha^{-1} yr^{1}), taking half of the available biomass (*5*), which represents 17,000 Mg CO_2 (2.1 Mg ha^{-1} yr^{-1}). This does not include biomass from thinning operation after 2 and 4 years.

Natural Forest Management

A significant amount of waste biomass is produced during logging operations. Reducing the impact on the remaining trees is crucial in order to allow a fast re-generation of the forest and C stocks. However, successful implementation of biochar C sequestration might create an incentive to increase waste biomass generation and fire is not an integral part of forest management in the humid tropics. It is uncertain if harvesting and removal of waste biomass and killed trees for biochar production would cause further damage. As long as the forest is not disturbed too much, re-growth is relatively fast and decomposing wood might play an important ecological role in forest regeneration.

According to [5] 63.5% of the wood waste generated at pulp mills is used to generate power the rest is deposited in landfills. This waste (mainly bark) could be used for biochar production and thus saving the costs for landfill disposal. Integrating biochar into existing compost (potting soils, soil amendments etc.) production might promise a business independent of C credits or not and would increase the value (mainly due to its stability) for land restoration purposes.

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