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In-Field Biochar Production from Crop Residues: An Approach to Reduce Open Field Burning in Northern Thailand

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Introduction

In much of Northern Thailand maize is grown on steep slopes by ethnic minority farmers who use the grain to feed their livestock (Ekasingh et al., 2004). Soil fertility management in these areas is poor and the open field burning of maize stover is common practice. Farmers burn their fields as a low-cost, low-effort way to clear them for planting, but also in the belief that burning sanitizes the soil and that the ashes return nutrients to the soil. The ashes, however, are extremely light and blow away or are washed away by the first rains. Burning, therefore, results in a decrease in organic matter, soil fertility and the soil's ability to store nutrients and so in increased nutrient leaching.

Open field burning also has important, negative public health and climate change consequences. It releases large quantities of PM_{10} and $PM_{2.5}$, as well as CH_4, CO_2, CO, NO_x and SO_x. During the dry season when farmers burn their fields, all of Southeast Asia suffers from massive clouds of black carbon and particulate matter dense enough to obscure the sun. During this time people suffer from respiratory diseases and the incidence of heart attacks increases sharply. Alternatives to burning, which is illegal in Thailand, exist and have been tested successfully at demonstration sites. One promising technique to reduce emissions of smoke and greenhouse gases (GHGs) is the production of biochar from crop residues, and the subsequent use of the biochar mixed with compost or manure as a soil amendment to improve soil fertility and sequester carbon. (Lehmann, 2007).

This paper presents the first results from field trials of biochar production in the remote and difficult to access highland areas of Northern Thailand. The present study compares the production of biochar from maize stover to the common practice of burning. First year results permit initial assessment of the potential of biochar production to reduce emissions, as well as the subsidiary question of farmers' belief that field burning sterilizes the soil. Analysis of the impact on soil fertility is ongoing.

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Material and Methods

For the present study, biochar was produced in a small, locally built, TLUD (top lit, up draft) kiln. The kiln consists of a 200 L oil drum with a perforated bottom. The drum's top is cut off and fitted with a 1 meter chimney. The kiln is filled and the top is set back in place on top of spacers that provide a 3 cm gap between the top of the drum and the lid. The feed stock is lit and rising hot gases create a chimney effect. This pulls oxygen up from the perforated bottom to where it can react with the slowly downward moving pyrolytic front.

To evaluate the performance of the kiln with respect to gas and particulate emissions three test burns were conducted in a closed room. A gas analyser (Testo 350 XL, UK) was placed 2 meters above the kiln chimney to measure emissions during pyrolysis and to test the efficacy of the kiln in eliminating particulates, exhaust gases were passed through a quartz fiber filter at Ø = 47 mm (QM-A Whatman, Maidstone, UK)) and analysed for PM_{10}. Each PM_{10} sample was collected at a flow rate of 5.0 l/min by using the mini volume air sampler (Air metric, USA). Subsequently, the filters were pre- and post-weighed on a microbalance (MX5, Mettler Toledo, Switzerland). Each test used 4.0 kg of field dried feed-stock consisting of maize stover from a mountain field.

The experiments on the maize fields of ethnic minority, small-holder farmers started at the end of the dry season when farmers would normally burn in preparation for planting the new crop. Three locations in Northern Thailand were selected: two fields of Hmong farmers in Hang Dong and Mae Chaem Districts, Chiang Mai Province, and one field of a Lahoo farmer in Pang Mapa District, Mae Hong Son Province. At each location, all treatments were repeated on three 10 x 10 m plots in a regular, organized experimental design (9 plots per location). The treatments were as follows: Control (C): Farmers' regular practice - open burning of the maize stover with ashes left on the ground; Biochar (BC): Pyrolysis of corn stover – biomass collected and converted to biochar using the TLUD kiln; and Mulch (M): Soil surface mulching – biomass collected, chopped and re-spread on soil surface without burning.

In all cases, dry maize stover was collected plot by plot and weighed. In the control treatment (C) the maize stover was then redistributed prior to burning. Thermocouples were placed at 10 cm above, at and 5 cm below the soil surface to measure temperatures during the burn. Data were recorded by a buried data logger T390 (PCE Instruments, Germany). In the BC treatment the time required to collect the maize stover and fill the experimental kiln were recorded and calculated as man*hours. Pyrolysis time and the number of burns required per plot were recorded.

Results and Discussion

The results of the gas analysis showed that the emissions from pyrolysis were under the detection limit of the gas analyser for CO_2 (< 2 vol %), NO (< 40 ppm), SO_2 (100 ppm) and NO_2 (40 ppm). H_2 was detected indicating that some residual moisture was released from the air dried feed stock during the pyrolysis process and not entirely consumed in the secondary combustion of the flue gases. The only measurable exhaust gas, which would also have been released to the atmosphere during a field burn, was CO, which peaked at 500 ppm for a short time. Higher concentrations were detected toward the end of the pyrolysis process (Fig. 1). Analysis of the particulate matter trapped by the quartz fiber filter produced very low values of between 4 and 48 μg of PM_{10}. Chemical analysis of the particulates showed low content of carbon compounds suggesting that carbon black had been largely combusted. Neither analysis of gas nor particulate emissions could be conducted in the open field. Simple visual observation, however, confirmed that field burning produces lots of smoke and, by implication, particulate matter.

Test data suggest that farmers' belief that burning sterilizes the soil is false. Field burns move very fast, such that contact time for any soil area is very short – less than 100 seconds at any specific place. While temperatures at 10 cm above ground peaked at 650° C and remained above 100° C for 250 seconds, soil surface temperatures increased only from 25°C to 60-80°C and soil temperatures at 5 cm below the surface did not increase at all (Fig. 2).

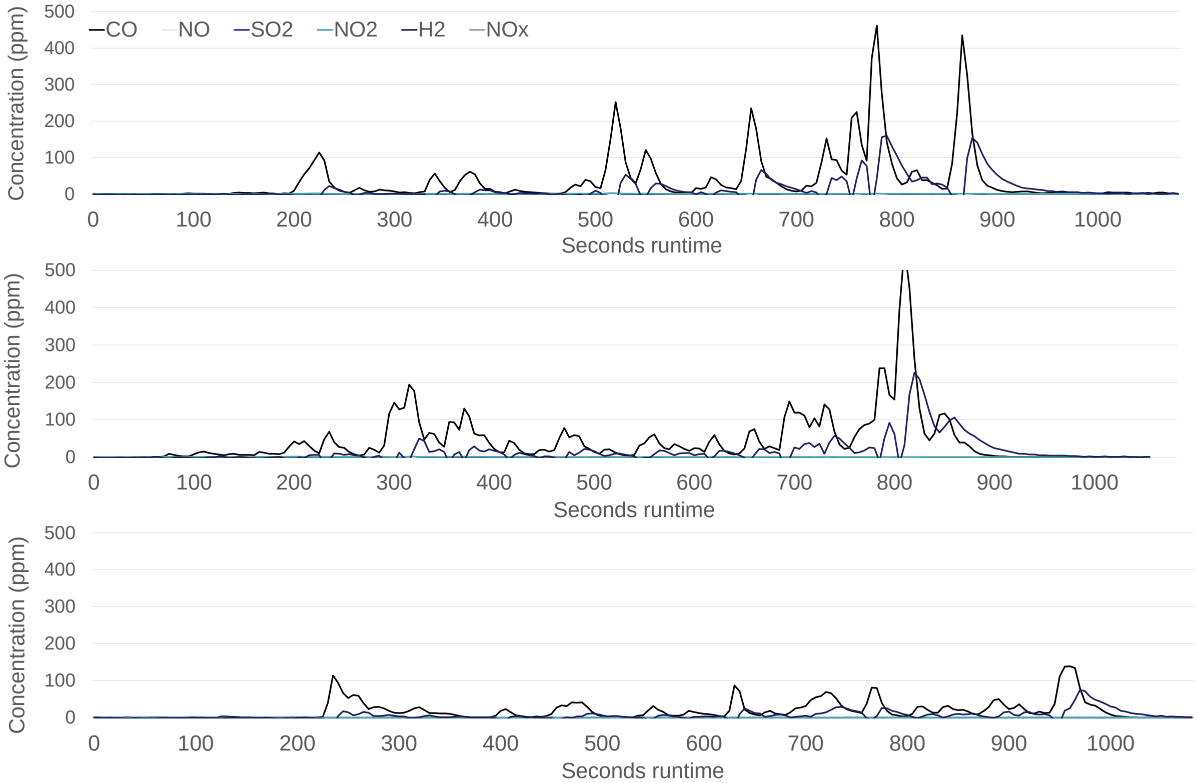

Figure 1: Analysis of gas efflux from the pyrolysis process of producing biochar in the test kiln in three subsequent trials

Most insects are not affected by the quick fires passing over the field, as hopping and flying insects can escape. Soil borne insects and diseases are not affected by the fire as there is no increased temperature at 5 cm depth. Even at the soil surface the temperature increase is not high enough to eliminate most pest insects. Fungal diseases will be reduced, but not eliminated, as spores on the ground will not be eliminated.

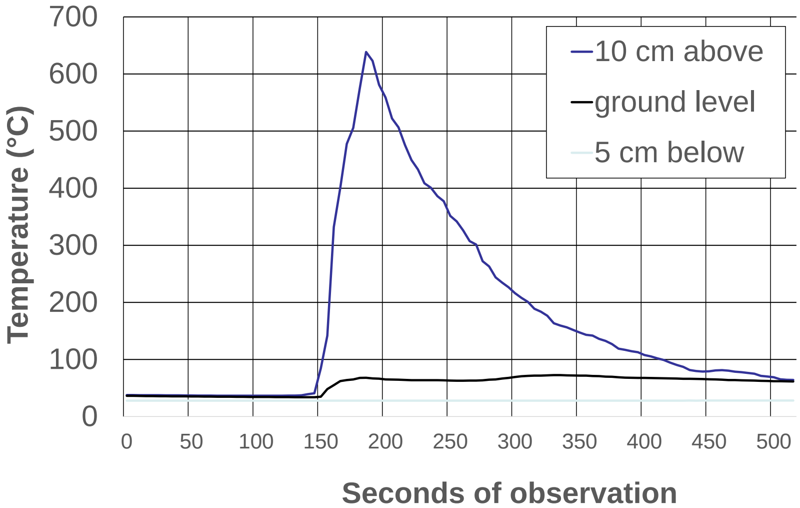

Figure 2: Temperature during open field burning of maize stover

The great advantage for the farmers is that open fires require virtually no effort and effectively clear fields for planting. After five months without rain, the stover is dry and burns easily. On the other hand, collecting the stover to produce biochar is heavy work, especially on the steep sloping fields of the target region. To collect stover and fill the kiln require approximately one man hour per 100 m^2 (Table 1) depending on the location. This could be reduced by improved logistics and handling of the stover. Pyrolysis in the small kiln takes 55 minutes. A larger kiln would speed both filling and pyrolysis. There are, however, limits on the size of kilns that can be transported in remote areas. A battery of several small kilns operating in parallel may be a viable solution.

Table 1: experimental sites and labour requirement of stover collection for biochar production

			
Site name	Thung Roeng	Bor Khrai	Pang Hin Fon
District	Hang Dong	Phang Mapha	Mae Chaem
Province	Chiang Mai	Mae Hong Son	Chiang Mai
Location	18° 46.951' N 98° 49.623' E	19° 33.405' N 98° 13.184' E	18° 32.109' N 98° 14.220' E
Inclination	Slightly sloping	Slope	Steep slope
Crop rotation	Maize – cabbage	Maize – fallow	Maize with rubber
Stover	40 kg DM / 100m^2	20 kg DM / 100m^2	18 kg DM / 100m^2
Collection time	n.a.	45 man*min / 100 m^2	
Servicing time		15 man*min / 100 m^2	
Burning time		55 min / 100 m^2	

Conclusions and Outlook

There is no doubt that the open burning of harvest residues releases large quantities of GHGs and particulates into the environment, which is harmful to man and nature. The present study shows that biochar offers a clean alternative to open field burning as pyrolysis virtually eliminates both GHG and particulate emissions. The present study also shows that one of the two primary reasons offered in defence of open burning – soil sanitation – is false. Test results, however, clearly demonstrate that while open burning is essentially effortless, biochar production is labor-intensive. Further studies will permit optimization of the feed stock collection process and kiln design. The question how to compensate farmers for their additional effort remains responsibility of the society.

Acknowledgements

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