North Vietnam Villagers Develop Strategies to Help Combat Global Warming and Improve Household Health; Results of First 18 months Of Village Biochar Program

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Introduction

The overall objective of the project is to contribute to sustainable rural development in the upland areas of Vietnam by simultaneously addressing energy, poverty, and soil degradation constraints on development, and contributing to national policies on poverty reduction, deforestation, and rural development. In January 2012 we reported on the early stages of this work (published at: (www.biochar-international.org/profile/Stoves_in_Vietnam) undertaken by CARE Denmark/Vietnam, the Population, Environment and Development Centre (PED), the Soil Fertilizer Research Institute and Thai Nguyen University, the women's union and farmers union in Thai Nguyen and Thanh Hoa Province, Cornell University, and the University of New South Wales (NSW), Australia. Funding is provided by the Energy and Environment Partnership (EEP) for Mekong, Government of Finland, and CARE Denmark.

In the 2012 published report (see (www.biochar-international.org/profile/Stoves_in_Vietnam), we showed that some women had developed innovative techniques of making biochar by soaking wood and bamboo in a nutrient rich pond and subsequently used the clay laden biomass in an open fire. The clay slowed the combustion process, resulting in a large amount of biochar. Women also produced biochar from rice husks and rice straw both in the open fire and from burning the rice straw stubble in the field. They mixed the biochar with NPK fertilizer and used it in their home gardens. We reported on the development and testing of a small drum biochar oven and a biochar stove. At the time of writing 50 stoves had been built and sold to households. Based on user feedback the stoves were modified and tested, resulting in the production and distribution of a further 400 stoves (DK-T2M) by the women's group members (figure 1). PED developed a number of innovative sheet metal working machines to help mass produce the stoves. Continuous monitoring of the stoves' social and economic acceptability was undertaken and based on this feedback PED continued to improve the design.

b

Figure 1; a: Women's Group Leader delivering DK stove; b: Controlled cooking test in June 2012

Figure 2; Women's groups making biochar and compost with training from SRFI personnel

An additional four drum ovens were built and operated by women's groups to produce approximately 2 tons of biochar. This was made from a mixture of bamboo and wood soaked in nutrient rich ponds for approximately six months, along with rice husks and straw coated in lime and clay (Figure 2). Some of this biochar was used to make compost and the remainder was stored for later addition to the field trials. The women's groups were taught by SFRI how to make compost from buffalo manure utilizing the biochar, and added micro-organisms and an indigenous leaf (Chromolaena odorata (L) or Eupatorium odoratum L.) that accelerates the composting. The clay and lime were added to the biochar feedstock to: 1) reduce the low yields achieved when pyrolyzing wheat straw in drums; and 2) to boost the mineral content on the surface of the biochar. Previous research carried out by Fischer and Glaser (2011) indicated that adding minerals to biochar improved the yields and quality of the compost.

Evaluation of the Stove Impact on Households

As the project had only 1.5 years of funding, an evaluation of the stoves was initiated in August 2012. The first phase of the evaluation was undertaken over a five day period by Stephen Joseph and the second phase over two weeks by a CARE consultant who focused on the impact of introducing improved composting methods. The emphasis on the first phase evaluation was to

a) Determine fuel savings and emissions levels of the DK-T2M stoves,
b) Gauge user acceptability of the stoves in two communes in Thai Nguyen,
c) Gain feedback from Women Union's project officer on possible strategies for widespread dissemination
d) Evaluate the new stove model developed by PED with respect to patterns of biochar use and acceptability by households that adopted the new stove.

Recommendations taken from first phase evaluation spurred changes to the stove design to further reduce emissions, reduce fuelwood consumption, increase lifetime, improve ease of use, and make it more attractive for households to pay a commercial price. Also recommendations were made on whether the project should be up-scaled and if so, strategies for this. The following summarizes the results.

1. **Emissions of the DK-T2M and DK-T3M stoves**

Approvecho Research Institute (ARI) carried out testing in Hanoi in September (2012) at a training workshop. A standard water boiling test was carried out to determine the thermal efficiency. Instrumentation was set up (Figure 3) to measure both particulate emissions and CO as well as fuel consumption and time to boil. A test procedure similar to that described by Jetter et al 2010 was established.

Table 1. Summary results from the Approvecho Research Institute comparing the DK-T2M and Traditional Stove

IWA Performance Metrics	Units	DK-T2M	Steel Tripod Traditional Stove
High Power Thermal Efficiency	%	0.26	0.11
Indoor Emissions CO	g/min	1.46	2.29
Indoor Emissions PM	Mg/min	36.62	135.70
Low Power Specific Consumption	MJ/min/L	0.037	0.11

Figure 3; Testing of DK-T2M in Hanoi

Further testing in five households in two communes in Thai Nguyen were carried out by scientists from the University of Hanoi using a modified version of the procedure developed by Kar *et al* (2012) (Figure 4). A probe from a calibrated portable gas analyzer was held approximately 5 cm from the cook's mouth and the CO and NOx emissions were measured during the controlled cooking test that included the preparation of a vegetable soup and rice. Each household cooked once on the traditional stove and once on the new stove. Two of the households had fireplaces with chimneys, two households had no fireplace, and one household cooked outside in an area where there was a covered courtyard.

Figure 4 a) Women cooking on traditional rebar open fire b) woman cooking outside in covered area c) modified hood test to compare the new DK-T3M with the DK-T2M and traditional stove.

Results of tests are given in Table 2. Considerable variation was observed between the tests, reflected in the different kitchen configurations. On average the emissions of the DK-T2M stove were half those of the open fire, and the maximum reading was on average nearly one third lower. These emissions levels are lower than both the Vietnam in door air quality QD-3733-02-Byt standard and the World Health Organization (WHO) standard for Indoor Air Quality, which is a maximum of 35mg/cu.m for one hour.

Table 2. Average emission and specific food consumption results from testing in five households

	Open Fire	STDEV	DK- T2M Stoves	STDEV
Duration of test (minute)	39	6.6	47	5.6
Maximum reading (ppm)	63.2	46.3	21.4	21.7
Average of CO over the test (ppm)	13.8	14.4	6.7	6.9
Wood Used	876	282	540	55
Biochar Produced	26	13.4	152	140
Weight food/wood + husk used	4.2	1.4	4.8	1.0

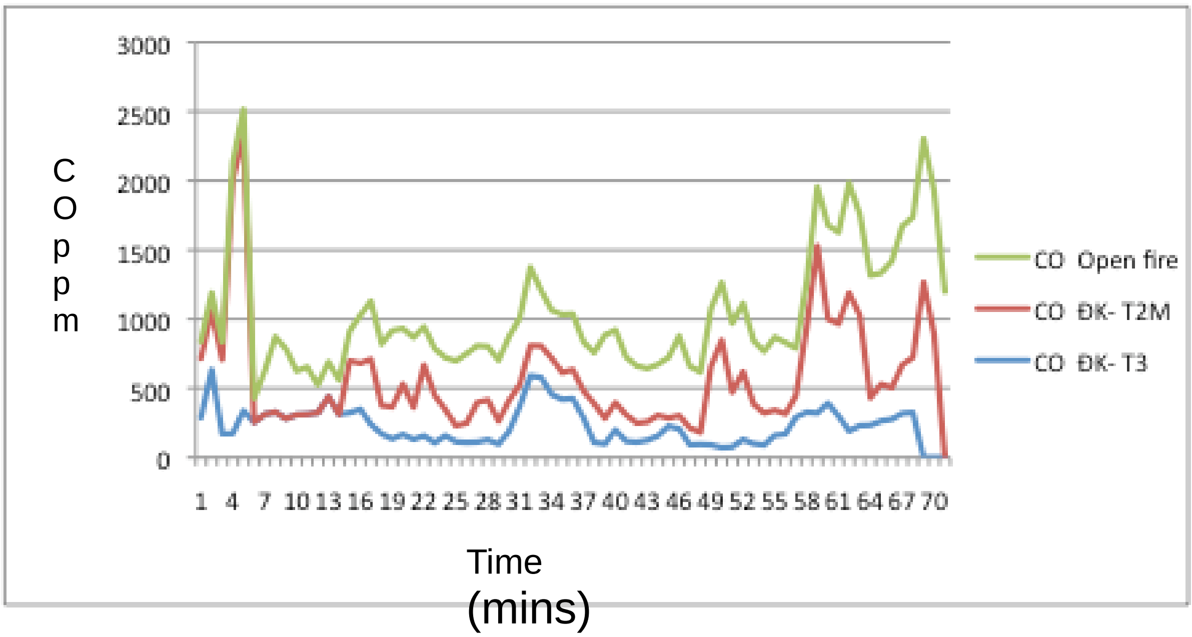

Figure 5. Difference in CO emissions between DK-T3M, DK-T2M and open fire

The CO emissions profile of the latest DK stove (DK-T3M,), the DK-T2M and the open fire are given in figure 5. Total CO emissions of the DK-T3M were approximately 50% lower than the open fire and the DK-T2M emissions were 18% less than the open fire. Further tests are required to determine if these trends are significant and if so, what factors affect CO levels that women inhale. In particular, further tests should address questions such as: are emissions higher in households where kitchens are not well ventilated or where the inner chamber of the stove has significantly deteriorated?

2. Kitchen Performance Tests

Kitchen performance tests were initially carried out when the DK-T2M stove was first produced in June (2012) (Figure 1b).

In these tests:

a) Five DK-T2M stoves were compared with one open fire. Women who had already received a stove and had been operating this stove for over a week were chosen to carry out the tests.
b) The method was a modified version of controlled cooking test.

c) One dish of sweet potatoes was cooked by all of the women and then one pot of water was boiled to simulate the cooking of vegetables.
d) Each woman using the DK stove had the same weight of a mixture of wood and rice husk.
e) Only wood was used on the open fire.
f) The test recorded the time to ignite the fire, bring water to boil, and cook the food..
g) The test recorded the weight of the wood used, food cooked and biochar produced.

The results of the first kitchen performance tests are given in Table 3. The variation in performance between the five different users is high and reflects different skill levels. Three of the women participating in the tests had used an earlier model of the stove and the other two had only a week of practice prior to the test. Due to the need to take measurements of biochar and air quality, the regular cooking methods were disturbed and these tests are only indicative. Time did not permit longer cooking tests so the performance of the stove relates to short cooking times when only a simple green vegetable and rice are cooked. It should be noted that the DK stove is not used for cooking rice in households with rice cookers, gas cookers and in some houses with open fire. The stoves varied in age from five months (4 stoves) to eight months (1 stove). The inner chamber of the oldest stove had deteriorated and needed replacement. Damage to the inner chamber was apparent on the five month old stoves. Slight damage had occurred to the archway of the stove door. Although the DK stove on average had lower fuel consumption, the large variation in results meant that this difference was not significant. From observation it appears that higher levels of damage to the inner lining of the stove resulted in a lower difference between values observed for the open fire and the DK stove. More extensive testing is needed to determine average savings in time and fuelwood and the effect of damage of the inner chamber on performance in both districts to allow a more accurate assessment of the economic costs and benefits of this intervention.

Table 3. Summary of the first kitchen performance tests, June 2011

	Open fire	DK (Ave. 5 tests)	STDEV
The amount of used wood (gm)	2680	1352	191
The amount of used rice husks (gm)	0	640	0
The biochar (gm)	64	430	86
Total weight wood + biomass adjusted for char use (gm)	2594	1412	212
Total weight of food cooked (gm)	7100	5744	1200
Total weight food cooked/total weight fuel	2.7	4.1	1.0
Total time for cooking + boiling water (mins)	64	59.6	2.4

3. Acceptance of the Stove in the Household where Tests were Undertaken

The following is a summary of the results of both structured and open-ended questions. All five households visited used the stove 2 - 3 times every day mainly for cooking meat and vegetables and boiling water. All households reported that they saved time and wood with 4 out of 5 women saying that they could leave the stove unattended while simmering which allowed them to attend to other tasks. Four out of the 5 households reported reduction in burns and smoke inhalation. These households allowed their children to use the stove due to its ease of use and safety.

Four of the households were prepared to purchase a stove at $25 but their main concern was the short lifetime of the inner chamber. They were also concerned that there was no local person from whom to buy replacement parts for the stoves. One women said the disadvantages were: there is no place to keep warm rice when it is dried, the stove legs should be stronger, and pot holders should be shorter/lower down to prevent the flame blowing out of the door. The local women's union officer was concerned that the poorer households could not afford the cost of the stove. When asked whether the women's union would organize the sale of spare parts the project officer said that would have to be discussed by management.

To overcome these concerns a much larger dissemination project is required to develop sales and repair outlets, refine the design or develop a number of different designs to meet a range of needs, run demonstration and training programs, and mass produce the stoves to bring the cost down.

4. Utilization of Biochar from the Stove

All households were adding the rice husk biochar produced by the stoves in the animal pens. Four out of 5 households had started composting animal manure with the stove biochar using the new technique introduced by SFRI and the other household intended to start soon. All households reported complete removal of odors and reduction in moisture content of the manure. All households had increased the use of biochar in their gardens and reported improvements in quality and yield. Four of the households had already trialed the biochar compost made with biochar in the home gardens and field and reported significant improvements in yields. One woman reported that she had reduced her use of chemical fertilizer by 50%. Another woman was going to increase the use of biochar + compost in her rice paddy from 360 sq.m. to 1000 sq.m.

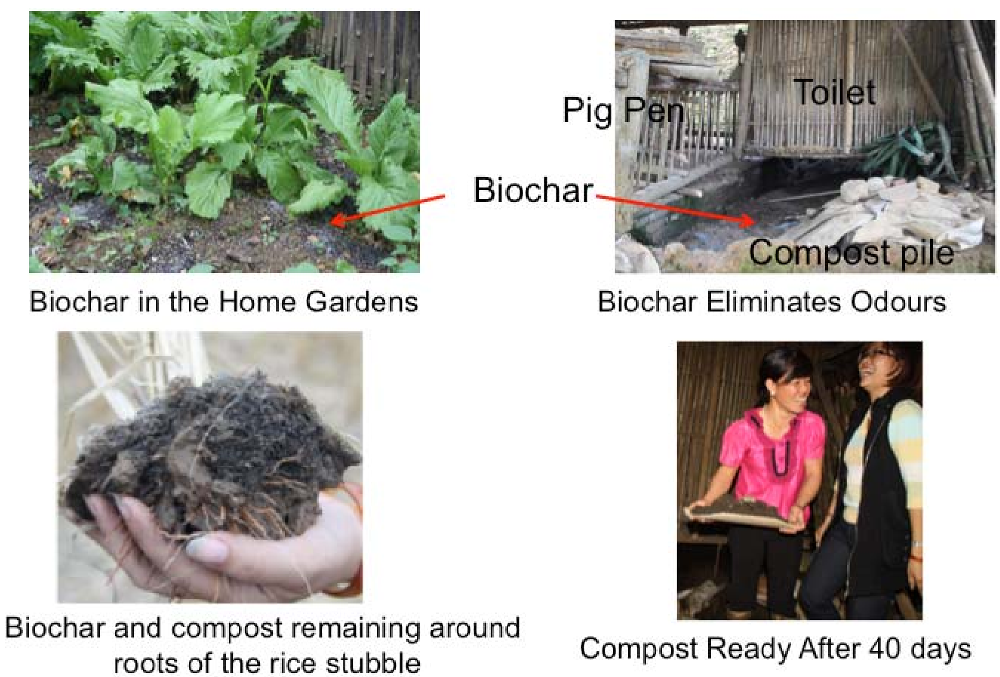

Figure 6; Top right shows pig pen, toilet and area where the manure and human waste are composted with biochar. Bottom right is the odorless composted product being taken to the field.

Two of the households were adding biochar and lime to human waste and were mixing the biochar and manure and then composting it (Figure 6). The Life Science Institute of Thai Nguyen University measured the level of Salmonella, fecal coliforms, staphylococcus and total aerobic micro-organisms. No Salmonella and faecal coliform were detected, the total coliform was 1100MPN/g, staphylococcus $1.4*10^5$ cfu/gm and total aerobic micro-organisms was $2.5*10^7$ cfu/gm.

The fecal coliform level for grade A compost in USA EPA 503 regulations is 1000MPN/g. An acceptable level of staphylococcus in prepared food set by NSW Food Authority (Australia) is $1.0*10^5$ cfu/gm. These initial tests indicate that this compost is safe for application to the fields and home gardens would be much safer than using the raw manure which is still applied on both gardens and fields without adequate composting.

A more detailed evaluation by CARE reported that the addition of biochar made compost easier to transport due to the lower content of water and the lower weight per cubic meter. Farmers who were interviewed estimated that the biochar/compost mixture was 60-70% lighter than compost without biochar. Previously, women transported and applied compost to the fields. In a number of the communes it was reported that a number of men had started to assist the women to transport and apply compost as most of the odors had been eliminated.

Results of the Field Trials Carried out by SFRI

Figure 7a; Rice field trials and Figure 7b vegetable field trials

Field trials utilizing biochar and biochar compost mixtures (Figure 7) were carried out in rice paddies in spring and summer. Treatments investigated are given in table 4. All treatments had three replicates and a randomized block design was used to ensure that differences between treatments could be analyzed to determine if they were statistically significant. Farmers in Thai Nguyen used 85 kg of N/75kg of P_2O_5/56kg of K_2O and 9.7 tonnes of fresh manure per hectare for rice cultivation and in Thanh Hoa 102N/62 P_2O_5/46 K_2O + 10.6 tonnes fresh manure. SRFI recommends a different application rate of NPK 90N/60P_2O_5/60K_2O and this application rate was used with biochar or a biochar/compost mixture.

Addition of biochar at 2.5 tonnes/ha and NPK, and .5tonne/ha compost and NPK increased yields significantly in both provinces (18%-32%). Highest increases were achieved by the addition of biochar/compost/NPK and ranged from 18% to 33%. There was a net reduction in yields with the addition of just biochar and no significant change when only .5 tonne/ha of biochar was added with NPK.

TT	Treatments	Thai Nguyen		Thanh Hoa	
		Spring Rice	Summer Rice	Spring Rice	Summer Rice
TT		tonne/ha	tonne/ha	tonne/ha	tonne/ha
1	Farmer Practice	5.93b	5.82b	6.86b	4.75b
2	2.5t/ha biochar (BC)	4.69a	3.98a	5.09a	3.85a
3	90N/60P/K (NPK)	6.23bc	4.85ab	7.02b	4.43b
4	.5t/ha BC +NPK	6.6bc	5.27b	7.5bc	4.62b
5	2.5t/ha BC +NPK	7.1cd	6.45c	8.14bc	5.39c
6	10t/ha Compost/5%BC +NPK	7.78d	6.53c	8.47c	5.67c
	LSD, 5%	0.98	0.9	1.29	0.49
	CV,%	8.4	9.2	9.9	4.9
	% Increase treatment 5	19.70%	22.10%	18.70%	17.90%

Table 4; Treatments and results from field trials in during and summer

TT	Treatments	Thai Nguyen		Thanh Hoa	
TT		tonne/ha	%	tonne/ha	%
1	Farmer Practice	14.33a	100	16.83a	100
2	Compost +NPK	17.67b	123.3	22.43b	133.3
3	Compost +5%BC + NPK	17.5b	122.1	22.8	135.5
4	Compost +25%BC + NPK	15.00ab	104.7	17.88a	106.2
	CV,%	8.3		11	
	LSD, 5%	2.66		3.5	

Table 5; Results from trials in home gardens

Trials were also undertaken in both provinces in home gardens where green vegetables (table 5) were grown during summer. Compost with either 5% or 25 % biochar was added at 20 tonnes/ha. Farmer practice in Thai Nguyen involved the addition of 112 kg of N/42kg of P_2O_5/39kg of K/ha and approximately 20 tonnes fresh manure in Thanh Hoa 116N/52 P_2O_5/15 K_2O + approximately 20 tonnes fresh manure. For the vegetable trials a significant improvement was achieved with straight compost at 10 tonnes/ha and compost +5% biochar and NPK and compost. Increases in yields in Thai Nguyen were 22% and 35% in Thanh Hoa. Adding a high concentration of biochar of 25% to the manure did not improve the yields of the vegetables.

Conclusions from the Pilot Study

This project has met its goals in terms of the development and dissemination of a biochar stove that is acceptable to the majority of users. It has been successful in demonstrating the benefits of the stove in terms of fuel and time saving, reduction in emissions of particulates and carbon monoxide that women and children breathe in the kitchen, improved safety within the kitchen, production of a biochar that can eliminate odors from the composting of animal manure and human waste, and increase in crop and vegetable yields.

It would appear that women can produce enough biochar in the stove to add biochar at 5% to the animal manure to achieve significant improvements in yields in both the fields and the home gardens.

Development of a more robust inner liner and mass production to reduce the cost could see wide adoption of this technology. It will also be necessary to undertake a well resourced and planned extension program to train users in the operation of the stove and the new methods of composting.

More evaluation of the biochar as a material that will convert human waste to safe compost needs to be carried out to confirm the initial encouraging results. Longer term field trials along with more in-depth socio-economic evaluation to more accurately determine costs and benefits should also be undertaken.

For more information on this project, please contact Stephen Joseph or Morton Thomas

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