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Capacity Building for Efficient Utilization of Biomass for Bioenergy & Food Security in the GMS [TA7833-REG]

Feasibility Study for a Pilot Project Demonstrating Biochar Production and Use

Cambodia

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Landell Mills
DEVELOPMENT CONSULTANTS

nexus
Carbon For Development

KEY DATA

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1. OVERVIEW OF PROPOSED PILOT AND FEASIBILITY WORK UNDERTAKEN

1.1. PROPOSED PILOT LOCATION

Tramkak district in Takeo has a total of 34,138 households with the total population of 152,170 (Census 2008) and it is located about 12 km west of the provincial city of Takeo. Beside rice, it has more potential for growing maize and vegetables than other districts in Takeo. Most of the people are involved in rice and vegetable production and livestock raising. Tramkak can be easily accessed by the national road No. 3.

Dang Tung district in Kampot has 12,178 households with the population of 54,261 people while Chhouk district has 22,650 households with 99,587 people. Dang Tung can be accessed from two sides – on national road no. 33 at Kampong Trach market through a dirt road about 2-2.5 hours drive to get to Dang Tung, but can also reach Dang Tung about 1.5-2 hours through national road no. 3. Dirt roads from both sides are in poor condition. But much easier to reach proposed villages in Chhouk district.

The selection of these communes and villages are based on crops of interest for demonstration, present of biodigester installed and functioned and the interest of farmers and local authority for collaboration. In Tramkak, a total of 11 villages in three communes have been proposed by DAEng and the Takeo PDA and in both Chhouk and Dang Tung districts, a total of 21 villages in 10 communes have been proposed by CEDAC for the pilot demonstration (Table 1).

Table 1: Locations proposed for the pilot demonstrations using biochar from rice husk

District	Commune name	Village name	Biodigester installed and functioned	Selected for interview
Tramkak	1.Tramkak	1.Kolkorm	Yes	
		2.Trapaing Chak	Yes	
		3.Trapaing Rosey	Yes	x
		4.Neal	Yes	
	2.Leach Bo	5.Vihear Khpous	Yes	
		6.Toul Tbaing	Yes	
		7.Tropaing Chhouk	Yes	x
	3.Trapaing Thom Khan Tbaung	8.Tropaing Chhouk	Yes	x
		9.Prey Kdey	Yes	
		10.Tropaing Prey	Yes	
		11.Trokeat	Yes	
Dang Tung	1.Domnak Sokrorm	1.Kchay Khang Lech	Yes	
		2.Angkor Pairk	Yes	
		3.Tropaing Rosey	Yes	
		4.Kraing Ampauv	Yes	x
	2.Meanrith	5.Preykraing Khang choeung	Yes	
		6.Preykraing Khang Tboung	Yes	
	3.Srechea Khang Choeung	7.So Phy	Yes	x
		8.Propy	Yes	
	4.Dang Tung	9.Kcheay Khang Choeung	Yes	
		10.Kcheay Khang Tboung	Yes	

		11.Tropaing Veng Khang Lech	Yes	x
	5.Kcheay Khang Tboung	12.Chhleach Leu	Yes	
		13.Chhleach Kroam	Yes	
Chhouk	6.Satt Porng	14.Tropaing Angdong	Yes	x
	7.Daun Yoy	15.Tropaing Mean Chey	Yes	
		16.Prey Khmom	Yes	
	8.Pa Neav	17.Ta Lang	Yes	
		18.Ta Mom	Yes	
		19.Tropaing Tasek	Yes	x
	9.Kraing Snay	20.Domnak Troab Khang Tboung	Yes	x
	10.Tromeng	21.Chheuteal Chrum	Yes	

Note: X is indicative for villages that were randomly selected for the feasibility study

1.2. DESCRIPTION OF STAKEHOLDERS

1.2.1. Department of Agricultural Engineering

The Department of Agriculture Engineering has shown their interest in biochar and has the willingness to conduct on farm demonstrations in Tram Kak district in Takeo province with the collaboration of the Provincial Department of Agriculture in Takeo. The crops of farmers' interest in the selected villages in Tram Kak are rice, vegetable and maize to be tested using biochar from rice husk as soil amendment. The Department of Agriculture Engineering has technology from Japan called Kuntan kiln, and has copies of the low cost Laos technology and the oil drum model from Viet Nam. The Department has been producing biochar from rice husk using the Kuntan Kiln, and has concurrently added some of the Kuntan kiln technology into the Viet Nam drum kiln. The intentions of the department is to (i) continue development work on local biochar kiln designs, (ii) provide training of trainers for the Kuntan Biochar Kiln and (iii) contract the construction of biochar kilns to be distributed to participating end users.

1.2.2. CEDAC

Centre d'Etude et de Développement Agricole Cambodgien / Cambodian Center for Study and Development in Agriculture (CEDAC) has been working to build the capacity and knowledge of rural farmers in ecologically-sound agriculture since its establishment in 1997. With initial support from the French NGO GRET, today CEDAC stands as the preeminent Cambodian organization in the fields of agricultural and rural development, and is especially recognized for its farmer-led extension services, agricultural innovation trainings, support for farmer organizations and publications. The organization currently provides direct assistance to about 150,000 families from 6,179 villages, 953 communes and 131 districts in 22 provinces of Cambodia. CEDAC has been identified as a potential institution to implement the pilot demonstration. CEDAC has branch office in Chhouk and Dang Tung districts in Kampot.

1.2.3. Rice Mills

It is estimated that the number of rice mills vary from 23,000 to 47,000 in Cambodia. Rice mills in Cambodia tend to be small by international standards, and there are only a handful of mills that can produce more than 0.5-1 ton of paddy per hour for village rice mill and 10 tons per hour for commercial rice mill. Over the past two years several larger rice mills have considerably up-graded their milling equipments regarding with the quality of milled rice and output per hour.

Most rice varieties are composed of roughly 20% rice husk, 11% bran layers, and 69% milled rice. In an ideal milling process this will result in the following fractions: 20% husk, 8-12% bran depending on the milling degree and 68-72% milled rice or white rice depending on the variety. The husk is used for fertiliser and burning. However, under the Renewable Electricity Action Plan (REAP) 2002–2012, the Cambodian government has been encouraging private sector investments in renewable and more affordable power resources, including support for rice husk power generation plants with electrical power for selling and ash from the generator called "biochar" is used for fertiliser.

1.2.4. Farmers / Beneficiaries

Kampot has the total rice cultivated land of 140,357 ha of which 9,157 ha for dry season rice. The total yield of rice in 2012-2013 was 688,400 tons of paddy rice with the average yield of 3.12 tons per ha. Takeo has a total cultivated land for rice of 295,275 ha of which 96,507 ha for dry season rice. The total yield of rice was 1,147,195 tons of paddy rice with an average yield of 3.89 tons per ha. Both Kampot and Takeo have small areas dedicated for vegetable and maize production. Kampot has 1,134 ha for maize and 2,194 ha for vegetable of all types while Takeo has 480 ha for maize and 2,214 ha for all types of vegetable. Farmers in Kampot mainly cultivate maize and vegetable in the rain season, while farmers in Takeo also produce vegetable in the dry season (1,097 ha).

Among 151 interviewees, 61.6% are male and 38.4% female. About 58% of farmers indicated that they attended primary school, 33.1% attended secondary school, 2% attended high school and only 1.3% studied in the university. However, 6% of respondents indicated that they had no education. 98% of interviewees engage in farming, which includes rice and vegetable production and livestock keeping. On average, farmers own land size of rice is 0.98 ha, while the land size of vegetable and maize are 0.15 ha and 0.5ha.

Farmers in both provinces have two main sources of income – 54% from own farm and 45% from non-farm activities. The source of own farm income is from cattle (40.7%), rice (21.1%), pig (13.7%), other crops (8.8%), poultry (8.3%) and vegetable (7%). The non-farm activities' income is from the garment factory work, construction and oversea works.

All respondents cultivate rice, 70% grow vegetables and 44% plant other crops. There is a range of rice varieties cultivated such as Srov Krohorm (67.5%), IR 66 (25.2%), Krachark Chab (25.2%), sticky rice (23.8%), Romdoul (17.2%), Car 1 (13.2%), Tumleak Sleuk (9.9%), Kaun Sar (7.3%), Malis (6.6%), Sen Pidor (4.6%), Vietnamese varieties (3.3%), Phkar Knhei (2%), Sombark Totim (2%), Champar Meas (1.3%) and other (5.3%).

In terms of vegetable production, cucumber is grown by 32.5% of farmers, water spinach (22.5%), pumpkin (22.5%), wax gourd (18.5%), spey kmao (15.9%), chi (15.9%), yard long bean (14.6%), eggplant (10.6%), pitsai (9.9%), ridge gourd (9.3%), salad (7.3%), porpeay (7.3%) and other types of vegetable (10.6%). About 66% of respondents grow vegetable over 10 years.

In regard to other crops, 28.5% grow corn, 19.2% cultivate bean, 14.6% water melon, 4.6% cassava/sweet potato, 3.3% sugar cane, 2% mango and only 0.7% coconut. About 48% of farmers reported that they have grown corn for over 10 years.

1.3. WORK UNDERTAKEN DURING THE FEASIBILITY

The feasibility study is conducted in the period of 8 weeks with the tentative dates to begin in July and the completion by end of September 2013. The study is divided in to 3 stages – the preparation of feasibility study, conduct field work and reporting.

Stage 1: During the preparation of the study, a desk study was conducted reviewing documents relevant to biomass production, utilization and challenges, meetings and consultations were organized with the key stakeholders such as DAEng, CEDAC, PDA in Takeo and local authorities in Takeo and Kampot. Their inputs from meetings and consultations are incorporated into the design of the study and the questionnaires. The key stakeholders were assisted in the selection of communes and villages for the feasibility study. The proposed study design including the Inception Report was submitted to TA7833 for comments and suggestions and approval before carrying out the field work. The questionnaires were pre-tested in Kandal province and team meetings were organized to discuss the timetable for field work and also allow team members to understand the methodology of the study and the questionnaires.

Stage 2: The main study instruments are questionnaires, participatory techniques such as field observation and focus group discussion. The study team met and discussed with the concerned officers at the District Agriculture Office to get ideas and views of the demonstration of biochar in their selected communes and districts.

In each target district in Takeo and Kampot, 2-3 focus group discussions were organized with key informants in the villages in order to understand their views on crops of interest such as rice, vegetable and maize, their views in soil fertility and management and their production of inputs, constraints and opportunities. A total of 151 households and 27 small rice mills in 3 districts in Kampot and Takeo provinces were interviewed using the questionnaires. The key questions in the questionnaires were:

- **Household:** general information regarding households; resource of income in the household member; agricultural activities and inputs; milling/processing; soil fertility and fertilizer used; biochar; yield, cost and return of households' produce; awareness of market information and general interest in agricultural production;
- **Rice mill:** general information regarding rice mills; income of the rice mills and rice mill status.

Stage 3: The qualitative and quantitative data on households and rice mill were coded and entered in to the excel spreadsheet. The data was analyzed using the descriptive statistical package for social sciences (SPSS version 14.0). The results are presented as percentages, mean values by provinces, production systems and overall mean. The report writing was divided by each team member according to the expertise and the final compilation of the report was the task of the team leader.

2. BIOMASS AVAILABILITY AND FLOWS

2.1. BIOMASS FROM RICE HUSK AND STRAW

There are several types of biomass which are available in the selected districts of this feasibility study and the tree branches that are grown as green fence around residential areas, paddy field bounds, forest nearby, etc. however the potential for the production of biochar can be from straw remained in paddy field but with lesser extend rice husk.

The outputs after milling paddy rice are 62.6±0.66% of white rice, 16.7±1.19% of rice bran, 1.69±0.30 of broken rice (broken very small for animal feed) and 19.0±1.15% of rice husk according to the results of the interviews of rice millers in Takeo and Kampot provinces. The percentage of different parts after milling is lower in terms of white rice as compared with IRRI Rice Knowledge Bank of 68-72%. This variation in percentage after milling depends on variety of rice, care and preservation during and after harvesting, types of rice mill, etc. however in Cambodia most rice mills could get between 62-65% of milled rice or white rice.

Assuming that 20% of the total yield of paddy rice of 9,290,940 tons (7,136,139 tons in wet and 2,154,801 tons in dry rice season) in 2012-2013 (MAFF 2013), Cambodia would have approximately 1.8 million tons of rice husk from both rainy and dry seasons' rice of which Takeo and Kampot should produce 83,220 tons and 217,967 tons of rice husk respectively (Table 2).

Table 2: Rice husk in Cambodia and by provinces calculated using statistics 2012-2013 from MAFF 2013

No	Province	Paddy production, Tons	Yield, Tons			
			Rice	Rice bran	Broken rice	Husk
1	Banteay Mean Chey	608,412	380,866	101,605	10,282	115,598
2	Battambang	881,773	551,990	147,256	14,902	167,537
3	Kampong Cham	781,717	489,355	130,547	13,211	148,526
4	Kampong Chhnang	503,187	314,995	84,032	8,504	95,606
5	Kampong Spue	343,789	215,212	57,413	5,810	65,320
6	Kampong Thom	688,400	430,938	114,963	11,634	130,796
7	Kampot	437,998	274,187	73,146	7,402	83,220
8	Kandal	400,021	250,413	66,804	6,760	76,004
9	Koh Kong	26,947	16,869	4,500	455	5,120
10	Kratie	155,236	97,178	25,924	2,623	29,495
11	Mondulkiri	45,782	28,660	7,646	774	8,699
12	Phnom Penh	37,537	23,498	6,269	634	7,132
13	Preah Vihear	163,215	102,173	27,257	2,758	31,011
14	Prey Veng	1,194,432	747,714	199,470	20,186	226,942
15	Pursat	416,011	260,423	69,474	7,031	79,042
16	Rattanakiri	66,047	41,345	11,030	1,116	12,549
17	Siem Reap	559,231	350,079	93,392	9,451	106,254
18	Preah Sihanouk	50,235	31,447	8,389	849	9,545
19	Steung Treng	73,680	46,124	12,305	1,245	13,999
20	Svay Rieng	522,331	326,979	87,229	8,827	99,243
21	Takeo	1,147,194	718,143	191,581	19,388	217,967

22	Oudor Meanchey	150,876	94,448	25,196	2,550	28,666
23	Kep	11,282	7,063	1,884	191	2,144
24	Pai Lin	25,607	16,030	4,276	433	4,865
Grand total		**9,290,940**	**5,816,128**	**1,551,587**	**157,017**	**1,765,279**

Dried rice stalks minus the flowers or grains are called rice straw. It normally has two parts – the top part (top rice straw) is harvested with grain and it is commonly stored for cattle and buffalos feeding and ground part left in the field which some time is burn or partly harvested for mushroom cultivation. CelAgrid and FAO 2012 reported that top part of rice straw is about 54.4% and the ground part left in the field is 45.6%. Nationally, this is equivalent to 17,652,786 tons of fresh rice straw being removed and 14,772,595 tons left in field. The dry matter content of rice straw is 80.8%. The total fresh straw in Cambodia is 32.4 million tons of which Takeo has 4.0 million tons and Kampot has 1.2 million tons. If the target is only the ground part which is not used for animal feed, we have 14.8 million tons to be used for biochar production (Table 3).

Table 3: Rice straw production, tons

Province	Paddy land	Fresh top rice Straw	DM, top rice straw	Fresh rice straw left in the field	DM, rice straw left in the field	Total fresh rice straw	Total DM of rice straw
Banteay Mean Chey	225,000	1,155,983	934,034	967,375	781,639	2,123,358	1715673
Battambang	250,500	1,675,369	1,353,698	1,402,019	1,132,831	3,077,388	2,486,529
Kampong Cham	165,500	1,485,262	1,200,092	1,242,930	1,004,287	2,728,192	2,204,379
Kampong Chhnang	108,000	956,055	772,493	800,067	646,454	1,756,123	1,418,947
Kampong Spue	110,000	653,199	527,785	546,625	441,673	1,199,824	969,457
Kampong Thom	210,000	1,307,960	1,056,832	1,094,556	884,401	2,402,516	1,941,233
Kampot	126,000	832,196	672,415	696,417	562,705	1,528,613	1,235,119
Kandal	40,000	760,040	614,112	636,033	513,915	1,396,073	1,128,027
Koh Kong	9,440	51,199	41,369	42,846	34,619	94,045	75,988
Kratie	32,100	294,948	238,318	246,825	199,435	541,774	437,753
Mondulkiri	20,000	86,986	70,285	72,793	58,817	159,779	129,102
Phnom Penh	11,420	71,320	57,627	59,684	48,225	131,004	105,851
Preah Vihear	57,700	310,109	250,568	259,512	209,686	569,620	460,253
Prey Veng	250,000	2,269,421	1,833,692	1,899,147	1,534,511	4,168,568	3,368,203
Pursat	98,000	790,421	638,660	661,457	534,458	1,451,878	1,173,118
Rattanakiri	27,500	125,489	101,395	105,015	84,852	230,504	186,247
Siem Reap	179,090	1,062,539	858,531	889,177	718,455	1,951,716	1,576,987
Preah Sihanouk	16,000	95,447	77,121	79,874	64,538	175,320	141,659
Steung Treng	26,500	139,992	113,114	117,151	94,658	257,143	207,772
Svay Rieng	165,500	992,429	801,883	830,506	671,049	1,822,935	1,472,932
Takeo	170,000	2,179,669	1,761,172	1,824,038	1,473,823	4,003,707	3,234,995

Oudor Meanchey	64,400	286,664	231,625	239,893	193,833	526,557	425,458
Kep	3,080	21,436	17,320	17,938	14,494	39,374	31,814
Pai Lin	4,000	48,653	39,312	40,715	32,898	89,368	72,210
Total	**2,369,730**	**17,652,786**	**14,263,451**	**14,772,595**	**11,936,256**	**32,425,381**	**26,199,708**

2.2. AVAILABILITY OF RICE HUSK AND STRAW

2.2.1. Rice Husk

In order to estimate the availability of rice husk in the country, we should know the consumption of milled rice in the country and milled rice for export and understand the flow of paddy rice out of Cambodia to Thailand and Vietnam. Per capita consumption per year of 160 kg of milled rice of an estimate population of 14,952,665 in 2012 and the 3.58 million tourists visiting Cambodia in 2012 (assuming that on average each stay 2 days in Cambodia) and 205,717 tons of milled rice or 321,433 tons of paddy rice exported in 2012, Cambodia would have milled 3,743,391 tons of paddy rice in 2012 and this would produce 748,678 tons of the rice husk.

According to the World Bank's 2011[1] report, in 8 months (July 2010-February 2011) 447,780 tons were traded through the border of seven provinces such as Svay Rieng, Takeo, Banteay Meanchey, Prey Veng, Kampong Cham, Kandal and Kampot to Vietnam and Thailand. No documents or study report which can indicate the export of paddy to these two neighboring countries however, FAO said Cambodia was expected to export a total of 1.3 million tons of rice, but that most of this would be in the form of unprocessed paddy, which is then processed across the country's borders in Thailand and Vietnam[2]. This would mean that if Cambodia continues to export unprocessed rice, we are losing the by-products such as rice bran, small broken and especially rice husk.

In order to understand the flow and availability of rice husk at the target provinces, a total of 27 rice mills in 11 villages in 9 communes of 3 districts were interviewed using the questionnaire. Rice mill is not the only work they do for their income, 66.7% rice mill owners also cultivate rice as their main occupation. For local consumption in both Takeo and Kampot, farmers mill their rice in small milling machines with the capacity of 300-500 kg per hour (Table 4). Farmers normally mill small quantity of paddy (20-30 kg) just enough for 7-10 days consumption. The arrangement with the mill owners is that the farmers pay for the mill or they can leave the bran, however most farmers, particularly those who raise pigs like to pay in cash than taking rice bran for their animals.

Table 4: Years operation and capacity of milling

Province	Operation, years	Capacity of rice mill, kg/hour
Takeo	7.67±3.02 (n=9)	455.6±31.8 (n=9)
Kampot	5.06±0.73 (n=18)	437.2±52.9 (n=18)
Mean	5.93±1.11 (n=27)	443.3±36.4 (n=27)

On average, mills operate from 13.2±1.76 days of 1.89±0.49 hours in the wet season and 18.5±1.70 days of 2.78±0.33 hours in the dry season (Table 5). The reasons of operating few hours daily or few days per month is because there are so many small mills owned by farmers in each village and farmers only mill a small quantity each time. In the wet season, mills operate few days than dry season. In the dry season, they mill more days and hours, because rice is available after harvest and they mill paddy to sell milled rice to bigger mills for further processing. The overall

[1] *World Bank, 2011. Global Food Price Volatility and Implications for Cambodia, Special focus.*

[2] *Cambodia Daily August 2013. FAO Predicts Rice Crop to Match Last Years'*

mean of paddy rice milled is 19.6±9.47 tons in the wet season and 26.05±5.26 tons in dry season. The annual average is 45.6±12.6 tons. In the target district of Takeo, it has no rice husk available in the wet season due to the small quantity of paddy rice to be milled.

Rice husk has always been used by farmers for different purposes. Most (96.3%) of rice millers use unprocessed rice husk as fertilizer of which they apply directly to the rice field or sometimes they store underground together with animal manure (cattle, pig or chicken) as compost before they apply to rice filed. If millers sell rice husk, 66.7% is used by rice wine producers as fuel, 14.8% used by rice noodle producers, 14.8% burn to produce smoke to chase mosquito from cattle at night and 11.1% grinds it together with rice bran to sell to pig producers. The price of rice husk is 863±62.2 riel per bag (about 26.1±2.55kg/sack). As they normally mill 20-30 kg of paddy it would produce only 4-6 kg of rice husk each time.

Table 5: Number of hours and days operation

	# hours operate per day		# days operate per month		Quantity of milled rice	
Province	**Wet**	**Dry**	**Wet**	**Dry**	**Wet, tons**	**Dry, tons**
Takeo	1.06±0.29	2.33±0.58	12.6±2.75	22.3±2.69	5.65±2.22	25.7±9.40
Kampot	2.31±0.71	3.00±0.40	13.6±2.29	16.6±2.07	26.6±14.0	26.2±6.53
Mean	1.89±0.49	2.78±0.33	13.2±1.76	18.5±1.70	19.6±9.47	26.05±5.26

Picture 1: Village rice mill in study sites

Picture 2: Village rice mill funded by DED.

Picture 3: Single pass, single stage rice mill for home use (Picture from rice knowledge bank, 2009)

Picture 4: Single pass, two stage rice mill (picture from rice knowledge bank, 2009)

3. RECOMMENDED PILOT INVESTMENT - OUTPUTS, ACTIVITIES, DEMO PLOT PLANS AND PERFORMANCE INDICATORS

3.1. KEY ISSUES

a) Policy issues

Having seen the growth rectangles 2009-2013 to (1) enhance agricultural sector; (2) to further rehabilitate and construct physical infrastructure; (3) to develop private sector and employment; and (4) to build human capacity and seeing some of the MAFF Agriculture Sector Strategy Development Plan 2009-2013 to ensure food security, productivity, and diversification and market access for agricultural products and its policy to increase annual productivity and diversification by 10% of all important crops by 2015. With the ambitious millennium development goal of halving the number of Cambodians living in poverty by the year 2015 and agriculture could make this happen, particularly for rural people. Further, the policy to promote paddy rice production and export set 2015 as the target year to export at least one million tons of milled rice.

MAFF has made significant progress during ASSDP 2009-2013. The best ten rice varieties were introduced to farming communities. Paddy production reached 9.3 million tons in 2012 (MAFF 2013) with the surplus of paddy rice of 4.73 million tons or 3.03 million tons of milled rice. Comparing with Cambodian neighbors Vietnam reached an average of 5.3 tons per hectare in 2012[3] while the average yield of rice in Thailand is similar to Cambodia[4]. In addition there is a trend to cultivate the early rainy season rice (9.6% of the total rice cultivated areas in 2012 compared with 7.3% in 2011) as to ensure that they could get some rice for home consumption and sale if the yield of main wet season affects by climate change. This early monsoon rice was also seen in most villages except some villages in Dang Tung district, Kampot province of which farmers have faced drought since 2011.

b) Findings from field work

The total income of each family is US$2,312.20 or US$464.30 per person (US$1.27 per day) and with this figure they just live on the poverty line of US$1.25 per day. The important sources of income and livelihood of the villagers in the three districts of Tramkak in Takeo, Chhouk and Dang Tung in Kampot are 54% from own farming activities, 45% from non-farm activities and 1% from off-farm work. The sources of own farm income is from cattle (40.7%), rice (21.1%), pig (13.7%), other crops including maize (8.8%), poultry (8.3%) and vegetables (7%).

Cattle in the past were mainly kept for draught animals, but at present more agricultural machinery is used and cattle is more for fattening. The main markets will be in Phnom Penh and Ho Chi Minh City, Vietnam. Pigs have not been the profit business in the last few years due to price fluctuation and diseases including blue ears, but in 2013 the price of fattening pigs look more promising which encourages farmers to begin fattening pigs. Pigs are mainly for the market in Krong Kampot and Takeo and Phnom Penh. Poultry including both ducks and chickens are sources of family food security but they are also raised for sale. The most important constrain of poultry raising is the control of diseases which annually the outbreaks of Newcastle, cholera and fowl pox have killed 60-70% of the annual total flock.

Below we just want to highlight the particular interest of our feasibility study on the use of biochar on rice, vegetable and maize. To look at these agriculture activities, the study is looked in different angles including factors impeding the performance of this sector which include availability of water

[3] Vietnam's 2012 output seen steady at about 42 million tons. http://www.reuters.com/article/2011/12/16/vietnam-rice-output-idUSL3E7NG0QS20111216

[4] *FAO 2013. Rice Market Monitor. http://www.fao.org/docrep/017/aq144e/aq144e.pdf*

and irrigation, types and quality of inputs including seeds, fertilizer, cropping periods of both wet and dry seasons and farmers' knowledge.

All respondents cultivate rice, 70% grow vegetables and 44% plant other crops and they grow 2-3 cycles per annum (Table 6). Factors affecting crops' yield in the studies sites are lack of water (89.3%), outbreak of insects and pests (65.1%), timely fertilizer application (44.3%), poor soil quality (43.0%), weed (11.4%) and other factors such as poor quality of seed and late in cultivation etc. Farmers have applied both types of fertilizer, animal manure and chemical fertilizer. Cattle manure is widely use in all fields of rice paddy, vegetable and corn, approximately 76%, 80% and 62% of farmers, respectively. In regard to chemical fertilizer, 93%, 49% and 27% of farmers use on rice field, vegetable and maize respectively.

Table 6: # crops per year of farmers cultivate rice, vegetable and corn in Takeo and Kampot.

	Rice, %	Vegetable, %	Maize, %
1 crop	100.0	69.5	37.1
2 crops	45.7	42.4	6.0
3 crops	-	22.5	-

Farmers refer to compost natural fertilizer, pig manure, cattle manure, chicken manure and bio-slurry (most of villages in Takeo have biodigesters functioning). Chemical fertilizer includes imported organic fertilizer, Buffalo head, NPK, DAP, Fruit, USA, Urea, Philippine and NPK 20-20-18. The total average application of compost is 1,420kg/ha, 2,608 kg/ha and 1,324kg/ha respectively in rice, vegetable and corn fields. The average application of chemical fertilizer is 122kg/ha, 96kg/ha and 98kg/ha respectively in rice, vegetable and corn fields.

Farmers (98.4%) get the natural fertilizer from their own farms and only 1.6% gets it from other farms. Chemical fertilizer is purchased from markets (68.5%), agricultural shops (27.2%), directly from company (2%), middleman (1.6%) and other sources from company staff and government employees (0.8%). The most commonly chemical fertilizer used by farmers are DAP and urea. The price of DAP is US$34.5 and urea is US$29.3 per 50 kg bag. Although natural fertilizer is not available for sale, an opportunity cost was used for this calculation. The average price of natural fertilizer is 9,573 riel per bag of 51 kg or 211 riel per kg.

Farmers learn how to use these inputs through verbal explanation by the vendors rather than practical demonstration or from government extension services. According to ADB (2008), farmers use fertilizer at inappropriate times and/or in the wrong amounts. Paradoxically, fertiliser is overused during the dry season when the farm gate price of paddy is lower, raising the question of the economics of fertiliser use. The Cambodia Agricultural Research and Development Institute (CARDI) have disseminated recommendations about fertiliser application by agro-ecological region and soil type, but these are not followed due to the lack of information and knowledge (ADB 2008)[5].

Rice Production

When water is available through intensification, farmers are willing to produce two crops per year – early monsoon and wet season rice. Out of 151 interviewed farmers, 55% cultivates one crop per year and 45% cultivates 2 crops (mostly early monsoon rice with 3 months varieties). A range of rice varieties have been cultivated by farmers in these selected villages. Srov Krohorm (67.5%), IR66 (25.2%), Krochork Charb (25.2%), Damneb (23.8%), Rumduol (17.2%), Kha 1 (13.2%), Tomleak Sleuk (9.9%), Kong Sor (7.3%), Malis (6.6%), Sen Pidor (4.6%), Youn (3.3%), Pkar Kgnei (2%), Sambork Toteum (2%), Champar Meas (1.3%) and other (5.3%) were mentioned to be varieties of rice cultivated in the region. Among these varieties, 5 varieties have been introduced

[5] Asian Development Bank (2008), “Issues and Options in Agriculture and Natural Resources Sector in Cambodia” (Manila: ADB)

some years ago by the government. Srov Krohorm was mentioned by farmers to be the best traditional variety in Takeo and Kampot. This variety is pest and drought resistant of which they can get yield to feed family under difficult circumstances.

The wet season rice is commonly rain dependant and yield per hectare is usually lower than the national average (2.4 tons per ha versus 3.1 tons of the dry season in 2012) and lower than the provincial averages (Takeo was 3.9 tons and Kampot 3.1 tons per hectare). In terms of fertilizer application, farmers use about 43% below the recommended rate by White al., 1997 on Prateah Lang soil but farmers use about 1.4 tons of compost per ha of rice field. White et al., 1997 recommended 25 kg of urea, 50 kg of DAP and 50 kg of KCL as basal application and 50 kg of urea for topdressing.

Farmers keep their commodity paddy rice as seed and none of them practices seed purification. They normally thresh paddy all together and from the mount, they take the amount required as seed. They get new seeds through projects or they just get the seed from other villagers. Srov Krahorm is very common traditional rice variety but it has never been purified. Agriculture Quality Improvement Project (AQIP), a registered seed distribution company in Cambodia, claims that sales of its seeds represent only 3 to 5 percent of the market share, with 10 to 20 percent of the market share taken up by seeds from Vietnamese producers and the rest supplied by a few small domestic distributors and made up of seeds that farmers keep from their previous harvest (interview with AQIP representative, 24 March 2010)[6].

Vegetable Production

More than 60% of farmers grow vegetable 2-3 times per year and their vegetables in the wet season is limited to small plots and traditional vegetables such as wax gourd, pumpkin and egg plants. Varieties of vegetable including tubers like Chinese carrot, leafy vegetable like mustard, cauliflower, Chinese kale, tomato, cucumber, etc. are mainly grown in the dry season. The absence of vegetable production is due to the lack of technology to protect vegetables from rain, protection equipment and materials require high investment and in rainy season farmers are mostly busy with rice cultivation.

In terms of vegetables, cucumber is grown by 32.5% of farmers in Takeo and Kampot, water spinach and pumpkin by 22.5% of farmers, wax gourd by 18.5%, mustard by 15.9%, Chi by 15.9%, long bean by 14.6%, eggplant by 10.6%, pitsai by 9.9%, ridge gourd by 9.3%, salad by 7.3%, porpeay by 7.3% and other kinds of vegetable by 10.6%. With regards to the other crops, 28.5% of farmers grow maize, 19.2%, 14.6%, 4.6%, 3.3%, 2% and only 0.7% cultivate bean, water melon, cassava & sweet potato, sugar cane, mango and coconut respectively. About 64% of farmers cultivate vegetable 2-3 times per year while 86% of farmers cultivate maize once a year.

Maize Production

There are two types of maize – the sticky white maize and yellow one. In Takeo, maize is grown mainly for human consumption. The variety is short and the maturity is 50-60 days. They can grow twice annually at the early wet season and during the rainy season. Although several villagers in Dang Tung grow yellow maize they can also do two crops. The yellow maize is mainly for animal feed industry. The yellow maize is hybrid seed and they have to buy new seed annually. Yellow is sold to Vietnamese traders. No specific problem was mentioned on maize except those listed above.

Availability of Biomass

Two biomass can be potential for biochar production – rice husk and rice straw. Calculating from paddy yield 2012-2013, Takeo and Kampot could have 217,967 tons and 83,200 tons of rice husk which could produce 65,390 tons and 24,960 tons of biochar (conversion rate at 30%) but going down to village level, it is not easy to look for the rice husk as most farmers sell paddy out mostly

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[6] *SAW 2009-2013*

at the harvest and only quantity enough for family annual consumption. Rice husk is available at the small village mill as described on II. Biomass Availability and Flow. At the same time rice husk has been used by rice vine distillery in the village.

Rice straw that remained in the paddy can be potential for biochar production. Each family could harvest about 5 tons of rice straw; however using rice straw might require additional technology to handle it, such as cutting machine.

3.2. KEY PILOT INTERVENTIONS

The aim of this project is to identify possible ways to introduce biochar in farming practices as this can be produced locally at the target sites or bring it from other provinces nearby. As experiences shown by CelAgrid in Cambodia and elsewhere, the use of biochar would help mitigate climate change, increase crops and soil productivity and reduce production cost, etc. The primary objectives of intervention of biochar are:

- to demonstrate to farmers, that applying biochar as supplement in either chemical or organic fertilizer or compost, would increase crop yields and at the same time the potential could reduce fertilizer inputs;
- to demonstrate to farmers, that using biochar will gradually help to improve their soil fertility due to increased cation-exchange capacity, increase number of beneficial soil microbes and earthworms; and
- to demonstrate to farmers, that using biochar to help increase water availability to be used by plants.

3.2.1. Specific Interventions

The program will include the introduction and demonstration of the production of biochar and use of biochar as a soil amendment in cropping systems directly incorporated into soil or through its addition to other biomass products and biofertilizers in Cambodia, with supporting due diligence. The scope of the program will be limited to testing low cost kiln to produce biochar for the inclusion in cropping systems linked to existing organic rice and vegetable production, SRI Rice production, and maize.

a) **Making biochar available**: there will be two stages to make biochar available to farmers' practice.
   - **First:** to bring biochar which is available in most provinces to farmers. Many medium and big rice mills with capacity of 5-10 tons of milled rice per hour at present have installed gasifiers to produce fuel to replace fossil fuel due to the high price of electricity and fossil fuel. Also, rice mills have installed modern paddy driers which burn rice husk at 350-650^{o}C. Biochar of 25-30 kg bag, costs US$.20-0.25 (Norm Srim and Domnak Teuk Rice mills). In Tram Kak, there is one recently installed rice mill, which is fully run by rice husk and therefore biochar is available there. Canadia bank rice mill installed in 2012 will install paddy drier with the capacity of 150 metric per loading. CEDAC in Kampot is going to put the gasifer for farmers' association rice mill in Dang Tung.
   - **Second:** Small quantity to rice husk is available in those selected villages and therefore it is more convenience to have the kiln distributed to the adapted kilns produced by DAEng to rice mills in the tree target districts in Takeo and Kampot. Rice mill will produce biochar using the distributed kilns and will sell biochar to farmers or their mill users at the competitive price.
   - **Third:** the distribution of kilns to the existing farmer groups or organizations in those selected villages. They will use kiln to produce biochar from rice straw. Each family owns almost 1 ha of paddy field and therefore they will have about 4.55 tons of rice straw remained in own paddy field which could produce 0.9-1.4 tons of biochar from rice straw.

b) **Rice production:** rice production can be carried out in two seasons or two crops in wet season depending on the availability of water and rain.

- **Wet season:** First crop – as farmers' practice, they grow the early monsoon rice from May-June and harvest in August-September. This will use the improved CARDI short term (3 months) varieties such as Sen Pidao or RI66. Second crop – same as farmers' current practices, they prepare nursery of the medium and long term varieties ready for transplanting after harvesting the early monsoon rice. The varieties can be listed above but it is suggested to try with Srov Krahorm as traditional variety and Rumduol as medium term variety of improved breed.
- **Dry season rice:** due to the lack of irrigation, few farmers especially those in Tramak district cultivate dry season rice. The production season will start in January and harvest in April. Farmers use more chemical fertilizer as they have water secure for their yield.

c) Vegetable production:

- As an option, water spinach, yard long bean, mustard and cucumber can be tested with biochar. Yard long bean and cucumber can be tested in early wet season and in the dry season. While in the dry season cucumber and yard long bean can be tested in the paddy field after harvesting rice, but in early wet season they can be tested in the high land to avoid too much water from rain.

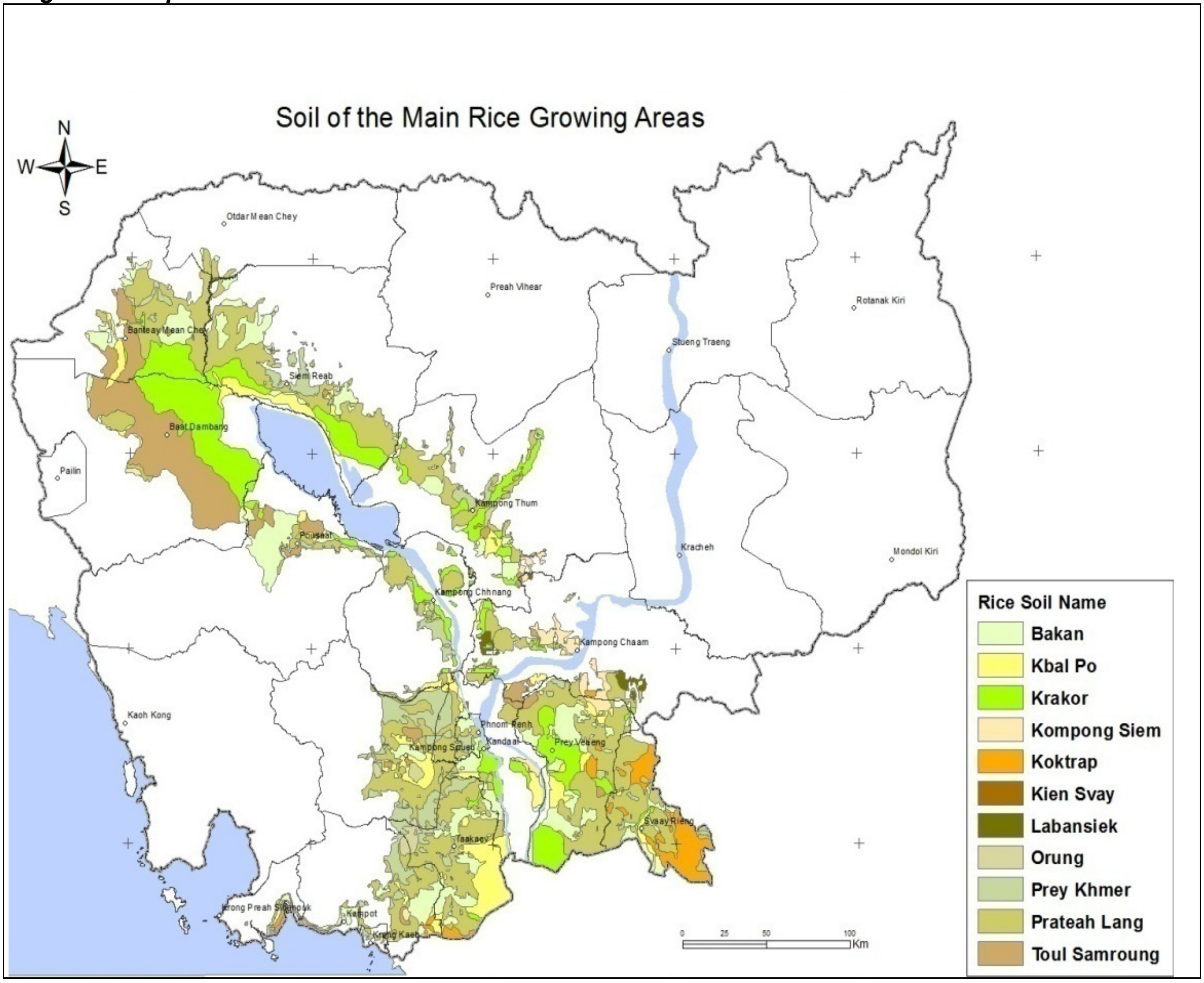
d) **Maize production:** maize is not an important crop in both Takeo and Kampot, but farmers do grow it for human consumption (sell boiled fresh as snack to people in the villages). In Dang Tung in Kampot as it is close to Vietnam, farmers grow red maize to be used as livestock feed industry, although CEDAC has not included in their plan for the trial it is important to do trial as this would be a complementary income for those who have land dedicated to this crop.

- As most farmers do one crop of maize in early wet season, it is therefore recommended that a trial is conducted in the wet season.

3.2.2. Soil Types and Fertilizer Application

The requirement of nutrient for crops depends on varieties and soil types. In Cambodia, soil is classified in 11 types using local names which easily help practitioners to identify types of soil for their crops (Figure 1). The soil of the target districts of Tramkak in Takeo, Chhouk and Dang Tung in Kampot are mostly Prateah Lang but some are Prey Khmer.

Figure 1: Map



The fertilization rates for the soil types are in Table 7. The rate of basal application per hectare for Prateach Lang soil is 10 kg of urea, 50 kg of DAP and 25 Kcl and the topdressing of 20 kg for first and 10 kg for second application of urea for intermediate and late maturing varieties of rice. For early maturing varieties of rice grown in the wet and dry season, the rate of fertilizer application will be 25 kg of urea, 50 kg of DAP and 50 kg of Kcl and only one top fertilizer application of 50 kg of urea per hectare is needed during the tillering and panicle initiation.

Table 7: Major soil types and fertilizer application

Major rice soil types[7]	Early maturing (wet and dry season)				Intermediate and late maturing (wet season)				
	Basal application (kg/ha)			Topdressing (kg/ha)	Basal application (kg/ha)			Topdressing Urea (kg/ha)	
	Urea	DAP	KCl	Urea	Urea	DAP	KCl	1st	2nd
Prey Khmer	20	25	50	25	10	20	40	20	10
Prateah Lang	25	50	50	50	10	50	25	25	25
Bakan-Orung	50	60	50	80	25	25	25	50	25
Toul Samrong	50	50	0	100	25	50	0	25	25

[7] White, P.F., Oberthür, T. and Pheav, S. 1997. The soils used for rice production in Cambodia, a manual for their recognition and management. Los Baños, Philippines, IRRI, 71 p.

Koktrap	50	75	50	75	10	50	50	40	35
Kampong Siem	50	0	0	50	30	0	0	45	30
Kien Svay	60	0	0	60	For early maturing grown in both wet and dry				

3.2.3. Trial Designs

As they are going to be the on farm trial, simple designs should be used for this purpose. Below are the designs for the 3 important crops for the demonstrations/trials:

a) **Rice demonstration / trial**: There are a total of 200 demonstrations on rice of which 100 demonstrations will be using SRI technique for Chhouk and Dang Tung while in Tramkak, DAEng and PDA will use the regular rice production techniques.

- Each plot will be 500m^2 as proposed by CEDAC and DAEng. The plot should be divided into 2 sub-plots of which one will be used as a control without biochar and the other sub-plot is treated with biochar. As CelAgrid experience, yield increases linearly with increasing levels of biochar, however in this demonstrations / trials, it is recommended to limit the level of biochar to 10 tons per hectare. In this case, each sub-plot of 250m^2 will need 250kg of biochar (1 kg per m^2). The rate of fertilizer application will follow recommendation by White et al., 1997 on the types of agriculture soil and fertilizer application. As the results from our field work, on average farmers in the three districts use 130kg of DAP and urea (50:50) and 1,682kg of compost per hectare and farmers do not use KCL at all.

Below are specifics rate of fertilizers to be used according to seasons, rice varieties, modes of fertilizer application and biochar for demonstration of 500 m^2.

- **Dry and wet seasons:** for rice early maturing varieties such as Sen Pidao and IR66, the rate of basal fertilizer is 1.25kg of urea (if effluent from biodigester is used to mix with biochar then urea is reduced to 0.75kg), 2.5kg of DAP, 2.5kg of KCL and 250kg of biochar. For topdressing, 2.5kg of urea will be used at the tillering and panicle initiation stage.
- **Wet season:** for intermediate and late maturing rice varieties such as Pha Rumduol, Phka Chan Sen Sar, Phka Rumdeng, Srov Krahorm, etc., the rate of fertilizer is 0.5kg of urea (if effluent from biodigester is used to mix with biochar then urea is not needed for basal), 2.5kg of DAP and 1.25kg of KCL and 250kg of biochar. For topdressing, 1.25 kg for 30 days after transplanting and 1.25kg for tillering and panicle initiation stage.

b) **Vegetable demonstration/trial:** There are a total of 100 demonstration plots of 200m^2 each. CEDAC will organize the vegetable demonstration using organic principles and DAEng in collaboration with PDA will be safety agriculture practice.

- The plot is divided into two sub-plots and as the plot is already small, it is recommended to plant a maximum of two kinds of vegetables. The plot can be divided into 4 sub-plots, of which two plots will be used as control plots and two will be used as treatment plots with biochar. As vegetable is a short term crop, the trial can be repeated to get better data and information to confirm in regard to the effect of biochar on the yield but also could evaluate the effect on yield after the second crops.
- Assuming that the yield of mustard green is 12 tons per hectare for basal application (10 tons) and side dress (5 tons), farmers can apply 15 tons of compost (compost generally has 0.6% nitrogen, 0.48% phosphorus and 0.85% potassium[8]), 250 kg of DAP from basal application (200 kg) and side dress (50 kg) and 250 kg of urea for side dressing (150 kg) and topdressing (100 kg) applications.

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[8] *HKI Cambodia 2003. Handbook of Home Gardening in Cambodia*

Below are the specific rate of fertilizers to be used, modes of fertilizer application and biochar for demonstration of 200 m^2.

- The basal fertilizer is 240 kg of compost, 4 kg of DAP and 200 kg of biochar;
- The side dress is 120 kg of compost, 1 kg of DAP, and 2 kg of urea;
- The topdressing is 2 kg of urea.

c) **Maize demonstration / trial:** Only DAEng will conduct the demonstration on maize with a total 30 plots of 500 m^2 each. The variety of maize used for the demonstrations will be sticky white maize for fresh boiled human consumption.
  - The plot will be divided into two sub-plots of which one sub-plot will be the control (farmer practice) and the other sub-plot is used for treatment with biochar. The demonstrations/trials will be conducted in the rainy season as majority of farmers have regularly practiced it. The average of farmers' practice is 145 kg of DAP and urea and 1937 kg of compost/animal manure or 7.25 kg of DAP and urea and 97 kg of compost/animal manure.
  - It is not as rice where recommendations on fertilizer uses are available, for maize a calculation using literature (Field Crop Manual: Maize 2008) is required. The removal of nutrients per ton in grain is 16 kg of nitrogen, 3 kg of P and 4 kg of K. Our data from field work shows that the average yield of maize is 5 tons per ha and therefore it removes 80kg of nitrogen, 15kg of P and 20kg of K per ha.

We just use the average yield of 5 tons of maize per hectare or 250kg of 500m^2. Below are specifics rate of fertilizers to be used, modes of fertilizer application and biochar for demonstration of 500 m^2

- The basal fertilizer application is 2 kg of nitrogen, 0.75 kg of P and 1 kg of K or 4.35 kg of urea and 1.63 kg of DAP, 7.6 kg of KCL and 250 kg of biochar for sub-plot of the demonstration;
- The topdressing of urea – first application is 2.18 kg and second 2.18 kg for the second application.

Note:

- Application of urea should be split between two in-crop applications. The in-crop applications are best applied at early vegetative stage when five to eight leaves are fully expanded and then again at late vegetative stage when 12 to 16 leaves are fully expanded to ensure nitrogen availability does not limit yield potential[9];
- Urea (N) fertiliser should only be applied when there is sufficient soil moisture to allow efficient uptake by the plant, ideally within 24 hours before a rain event.

3.2.4. Application of biochar

Normally effluent has high water content (up to 99% is water). The liquid effluent has 679 mg of nitrogen per liter of effluent. To get the water out it might be costly and a lot of energy is consumed. In this case as biochar has high capacity for water holding (up to 3 times of its weight) then it important to get the dry biochar and effluent to mix at field.

- Rice demonstration plot: of the 500 m^2, farmers apply 1,500 liters of effluent from biodigester. Within this amount of effluent, approximately 1 kg of nitrogen is added into biochar;
- Vegetable demonstration plot: of the 200 m^2, farmers apply 600 liters of effluent from biodigester. With the 600 liters it contains 0.41 kg of nitrogen;

[9] *ACIAR/CARDI 2008. Field Crop Manual: Maize. A Guide to Upland Production in Cambodia*

- Maize demonstration plot: of the 500 m^2, farmers apply 1,500 liters of effluent from biodigester. Within this amount of effluent, approximately 1 kg of nitrogen is added into biochar.

Note: Biochar should be incorporate into 15 cm upper layer of soil for paddy rice and maize and 10 cm upper layer of soil for vegetable.

3.2.5. Measurement and data record

- **Rice:** The measurements are plant height, panicle number, weight of panicle, length of panicle, number of spikelets per panicle, weight of grain and total yield.
- **Vegetable:** The plant height and numbers of leaves were measured at 14, 21 and 28 days after planting. At the harvest of 35-40 days, representative plants were harvested including the roots in order to measure total biomass yield of the vegetables. However total production will be harvested and weight to compare between control and treatment plot.
- **Maize:** The measurements are plant height, stem diameter, height of the first ear, number of forming ears, and plant population.

Note: In case, the implementers do not have enough field workers to measure all of these, the simple measurements are: total biomass yield and yield of grain.

3.3. OUTPUTS OF THE PILOT INVESTMENT

The outputs of the whole ADB-TA7833 "REG Capacity Building for Efficient Utilization of Biomass for Bioenergy and Food Security in the GMS" are

(i) Enhanced regional cooperation on bioenergy developments that fosters and safeguards food safety;
(ii) Pilot-tested climate friendly biomass investment projects, for more extensive implementation;
(iii) Strengthened capacity for the efficient use of biomass;
(iv) Developed and disseminated knowledge products.

While the proposed specific outputs for the biochar pilot investment project are:

(i) Improved knowledge and capacity of the government, NGO staff and farmers on biochar;
(ii) Productivity of the target crops increased;
(iii) Biochar will be utilized by the farming community;
(iv) Biochar technology adopted by rice mills; and
(v) Knowledge and experience obtained from this pilot project are shared within the agriculture community in Cambodia and the region.

3.3.1. Improved Knowledge and Capacity

a) **Field staff:** the field staff can be researchers which are part of the implementers or visitors, the extension workers and field staff who directly implement this pilot demonstration will have a great opportunity to learn by interacting with farmers from preparation to the completion of the project.
b) **Lecturers and students**: Reports from this pilot project will be made available to lecturers and students through a mini-workshop or seminar at their Universities or agriculture colleges. They can be invited for field visits and interact with farmers.
c) **Farmers:** They are the end users of this pilot investment project. They will have the learning by doing with the field staff during the implementation of this project.
d) **Policy makers:** A policy brief should be produced to policy makers at the commune, provincial and central levels. Field visits can also be organized allowing them to see and believe.

3.3.2. Productivity of Target Crops Increased

Several studies in Cambodia and elsewhere show a linear increase of yield, water holding capacity, soil fertility improvement, etc. when increasing the levels of biochar application. Bounsuy (2010)[10] reported that rice yields of 3.76 tons per ha with application of 40 tons per ha of biochar compared with 1.82 tons per ha with 20 tons per ha of biochar. Afeng et al (2010)[11] reported biochar amendment at 10 and 40 tons per ha increased the rice yield by 12% and 14% in unfertilized soils and by 8.8% and 12.1% in the soil with N fertilization, but Singhal et al (2011)[12] reported that application of 2 tones rice-husk-biochar per ha increased the grain yield from less than 4 tons per ha for the control treatment to more than 5 tons per ha for the biochar treatment.

The studies at CelAgrid, applying increasing quantities of biochar, led to positive linear or curvilinear increases in biomass yield of leaves, stems and roots using biochar on vegetables. Yield increases for biochar application of 5 kg per m^2 (50 tons per ha) were of the order of 300%, 100%, 350% and 39% for celery cabbage, Chinese cabbage, mustard green and water spinach, respectively (Figure 2 and Figure 3).

Figure 2: Relationship between level of biochar and green biomass DM yield of mustard green[1]

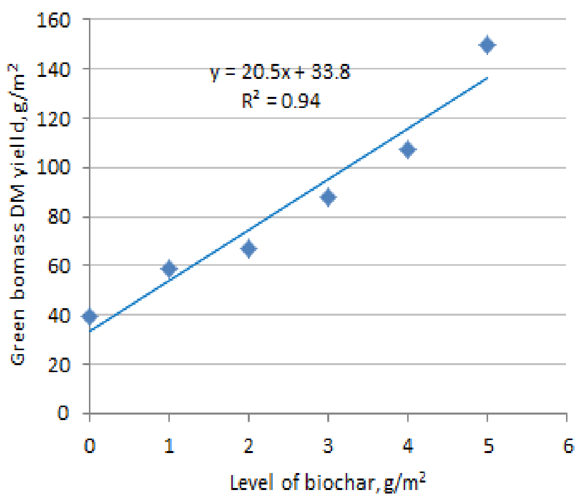
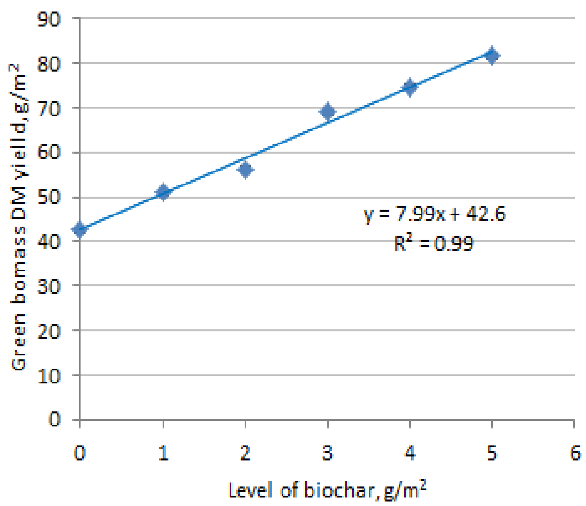


Figure 3: Relationship between level of biochar and green biomass DM yield of Chinese cabbage



We expect that these pilot demonstrations will not only increase productivity of the target crops but will also increase soil fertility and productivity including soil pH, water holding capacity, and increase the present of earthworm, etc.

3.3.3. Biochar Utilized in farming

[10] Bounsuy T 2010. Preliminary Trial On Biochar Utilization In Rice Crop On Teuk Vil Luvisol https://docs.google.com/leaf?id...sort=name&layout=list...50

[11] *Afeng Z, Liqiang C, Gengxing P, Lianqing L, Qaiser H, Xuhui Z, Jinwei Z and Crowley D 2010 Effect of biochar amendment on yield and methane and nitrous oxide emission from a rice paddy from Tai lake plain, China.http://njau.academia.edu/qaiserhussain/Papers/622642/Effect_of_biochar_amendment_on_yield_and_methane_and_nitrous_oxide_emissions_from_a_rice_paddy_from_Tai_Lake_plain*

[12] Singhal S K, Sharma V K and Pandey R N 2011. A Charred Organic Matter and Its Importance in Soil *http://www.krishisandesh.com/soil-science/biochar-a-charred-organic-matter-and-its-importance-in-soil/*

Biochar has shown the synergy when applying together with other fertilizers to increase yield from production point of view. But to make a large scale adoption of the biochar, we need to think about the availability of biomass to produce biochar and the tool or machine that can be used for the production of biochar. In addition, the technology must be simple, manageable and low cost.

As mentioned above, the potential biomass can be the remaining rice straw in their paddy field rather than burn it, using it for the production of biochar. The question is, present kiln developed by DAEng is suitable to produce biochar from rice straw. Tests will be needed and adaption is required before making them available to the farming community. However, the present kiln can be distributed to rice mills as they have rice husk available. Rice mills can produce and sell rice husk to farmers.

However, the best option for the present situation, is to use the available biochar from big rice mill that are located within the target districts or provinces. The first thing is to show the positive impact of biochar on yield and later on as always happen that farmers will by their own searching for sources of biochar.

3.3.4. Activities and Plan for Pilot Demonstration

To start organizing the pilot demonstration, the implementation should first look at the appropriate time of which crops can be implemented. The possible crops that can be implemented during the dry season 2013-2014, should start from November 2013. Vegetable is suitable for all selected villages of the 3 districts, but dry season rice might limit to some villages only in Tramkak due to the lack of water and irrigation. Maize cannot be grown in this dry season 2013-2014, but it is possible to start in the early rain season.

- First crop: planting in May and the harvest in July;
- Second crop: the planting in August-September and the harvest in October-November.

Inputs including seeds, fertilizer and biochar for these demonstrations will be provided to demo farmers, while farmers will spend on own for land preparation, nursery, transplanting, pumping water, etc.

a) Vegetable demonstration:

As common practice in Cambodia, the dry season is best for vegetable production. Between 30-40% of farmers grow vegetables. Farmers do not grow vegetables in the wet season, due to the lack of experience and high investment costs to protect crops from rain. This is why they mainly limit to grow simple fruit vegetables, such as wax gourd, winter melon, pumpkin, egg plants, etc. as these types of crops are more resistant to very wet soil.

Two vegetables are selected for the pilot demonstration – mustard green (Spey Khieu) and Chinese cabbage (Spey Kra Nhanh), but demo farmers together with DAEng and CEDAC can further discuss with demo farmers for other vegetable options as market demand immerges.

The activities and plan for the implementation of the vegetable demonstration are described in Table 8. It should be noted that the actual vegetable demonstration is only 35-40 days however we include another 20 days to allow arrangements and organization.

In Tramkak, 10 villages were selected by DAEng/PDA Takeo and therefore in each village, 5 demonstrations will be conducted. While we suggest that with 50 vegetable demonstrations in Chhouk and Dang Tung should limit to 10 villages (CEDAC has selected 21 potential villages for pilot demonstration). Making 10 villages for each CEDAC and DAEng would allow field staff to manage demonstrations more effectively and efficiently.

Table 8: Plan for the pilot demonstrations of dry season vegetable (mustard green or Chinese cabbage) 2013-2014

		Dec-13				Jan-14			
No	**Activities**	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk1**	**Wk2**	**Wk3**	**Wk4**
1	Selection of Demo farmers								
2	Meeting with them to discuss the Demo plan								
3	Making vegetable nursery or direct seeding								
4	Purchasing biochar								
5	Design of Demo, land preparation and apply biochar and basal*								
6	Vegetable transplanting**								
7	Side dressing***								
8	Top dressing****								
9	Watering and weed control								
10	Measurements, plant height, no. leaves and								
11	Harvest								
12	Field DAY								
13	Monitoring and coaching farmers								

**240 kg of compost, 4 kg of DAP and 200 kg of biochar*
***Transplanting at age of 10 days*
****side dress is 120 kg of compost, 1 kg of DAP and 2 kg of urea*
*****2 kg of urea*

b) Rice demonstration:

Most of the selected villages in the three districts have limited access to water and irrigation except a few villages in Tramkak of which dry season rice can be done. The most common dry season varieties of rice are Sen Pidao, IR66, IR504 and Malis Sral. In the past few years, IR504 was the dominant dry season and early monsoon crops, but at present due to the low demand for short term rice varieties and decline in price, farmers have changed to Sen Pidao as one of the big capacity rice mills in Tramkak has arranged contract farming with them for this variety.

Sen Pidao has the maturity of 110-120 days and RI66 has the maturity of 105-115 days. To begin, DAEng should organize meetings with farmers to select the interested one and including the appropriateness of land for dry season (access to water). The detailed activities and times are described in Table 9. As per the plan a total of 200 rice demonstrations (100 for DAEng and 100 for CEDAC) will be implemented. Due to the of shortage of water, irrigation might be limited to 25-30 demonstrations in the 2013-2014 dry season and keep the remaining of rice demonstrations to the early monsoon crop.

The early monsoon rice can be implemented in the early wet season 2014, which can start from April 2014 (but it will also depend on rain – if rain begins in May, the production can start from June and the harvest will be in August-September).

Table 9: Plan for the pilot demonstrations of dry season rice (Sen Pidao or IR66) December 2013 – April 2014

		Dec-13				Jan-14				Feb-14				Mar-14				Apr-14	
No	**Activities**	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk1**	**Wk2**	**Wk3**	**Wk4**	**Wk1**	**Wk2**

1	Selection of Demo farmers*																		
2	Meeting with them to discuss the Demo plan and design																		
3	Making rice nursery																		
4	Purchasing biochar, distribution and mixing with effluent**																		
5	Land preparation, basal fert. and biochar application***																		
6	Rice transplanting****																		
7	Fertilizer top dressing*****																		
8	Water and weed control																		
9	Measurements, plant height, no. leaves and																		
10	Harvest																		
11	Field DAY																		
12	Monitoring and coaching farmers																		

*Available water/existing irrigation should be key criteria for selection
**500 kg of biochar adding 1,500 liters of effluent
*** 1.25 kg of urea, 2.5 kg of DAP, 2.5 kg of KCL and 250 kg of biochar
**** Age of rice seeding should between 15-20 days
***** 2.5 kg of urea will be used at the tillering and panicle initiation stage

c) Maize demonstration

Common maize grown by farmers is white sticky varieties of maize (local varieties), but we have seen the yellow maize grown in Dang Tung district in Kampot and this yellow maize is used particularly for animal feed industry (farmers mainly sell to Vietnamese traders).

Results from interviewing farmers, they can grow maize twice a year – in May and the harvest in July and the second crop: the planting in August-September and the harvest in October-November. So the demonstration on maize will have to wait until the early rainy season of 2014. The detailed activities and schedules are listed in Table 10.

Table 10: Plan for the pilot demonstrations of wet May – April-July 2014

No	Activities	Apr-14		May-14				Jun-14				Jul-14			
		Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4	Wk1	Wk2	Wk3	Wk4
1	Selection of Demo farmers														
2	Meeting with them to discuss the Demo plan														
3	Purchasing biochar														
4	Design of Demo, land preparation and apply biochar and basal*														
5	Planting maize seeds														
7	Top dressing**														
8	Watering and weed control														
9	Measurements, plant height, no. leaves and														
10	Harvest														

11	Field DAY														
12	Monitoring and coaching farmers														

*4.35 kg of urea and 1.63 kg of DAP, 7.6 kg of KCL and 250 kg of biochar
**first application is 2.18 kg and second 2.18 kg for the second application

3.4. PERFORMANCE INDICATORS

The key performance indicators are:

- Number of farmers who participants in these three demonstrations;
- % of direct and indirect farmers who adopts the use of biochar for their farming activities;
- % yield increase when biochar is used compared with control plots;
- Soil improvement through observation and measurement of earthworms;
- Training and capacity building given to farmers and project staff.

4. A PROPOSED CAPACITY BUILDING PROGRAM FOR IDENTIFIED NEEDS

Biochar is relatively new for Cambodia. When talking about biochar people will quickly refer to the ash after burning rice straw or rice husk in an open air and most farmers in group meetings immediately answered that this ash cannot be used for crops as their experience it damages the crop. This would mean that there is a need to not just only give them training, which is not practical at all. There should be several layers of training, including the training or seminar for students (may be last year of agriculture university) which allow them to be familiar with the technology and its application, the training and workshop for researchers and lecturers that would allow them to do further researches which will take out new discovery related to biochar and better training to young professionals.

The training of extension workers is very important but they would require different messages from what trainings are offered to students, researchers and lecturers. Their training will limit to the delivery of simples messages to farmers. And the last end users will be farmers. It is important to prepare training to respond to their capacity and usually the learning by doing is the most appropriate for them. Farmer Field School approach developed by FAO for the Integrated Pest Management has been wide adapted in Cambodia for the training of farmers.

4.1. INFORMATION OF TARGET SITES

The proposed pilot demonstration will be implemented in 31 villages of 13 communes of 3 districts in Takeo and Kampot. To understand better their livelihood, 151 persons (62% male and 38% female) as family representatives were interviewed. The average size of a family is 4.98 persons. The age of respondents are grouping as 3 categories less than 30 years (13%), 30 to 60 years (59%) and higher than 60 years (24%).

4.1.1. General Issues

- **Low yield of rice:** average yield of rice is 2.4 t/ha which is about 33% below the national average. Their poor yield links with poor agronomic practices in term of fertilizer application related to time and quantity, poor seeds which already keep trough generation (if rice seeds are still geminated they are good seeds), production which entirely depending on rain (almost no irrigation canals were seen in the target villages during the field work).
- **Low education**: low education seems to impact on what their capacity to plan, act and solve problems that they are facing. Among the interviewed farmers in 31 villages, 58% of them have primary schooling and 33% has secondary schooling, while about 10% has high schooling. Their main occupation is farming as reported by 98% of farmers. The capacity building needs to respond to the levels of the education that farmers have. The training approach that has been used successfully in the developing countries especially in Cambodia – the Farmer Field School.
- **Poor willingness to form association:** Farmers are working individually and if they come together as an association, it is because there is a project supporting them, but seems to fail after the projects end. Binding together will become force for bargaining power to input suppliers and buyers of their products.
- **Small agriculture land:** Their family members are growing and land was distributed in 1986-1987. They have to share their existing land with the married children. On average, each family owns 0.98 ha of agriculture land. Poor soil fertility management, and poor fertilizer application seems to consequence on food security unless they could manage to do two short term rice crops (early monsoon and main wet season).
- **Poor utilization of local resources:** many rice fields are burnt after harvest with intention or without intention. Some burn the straw in the field to avoid an intended fire reaching home, some burn it to clear the land for other crops and others burn to kill insects before the next planting season. However, immediately after harvest when soil is

still moist, remaining straw can be incorporated into soil by plowing using the new type of plowing machine.

4.1.2. Farmer Specific Issues

- **About soil:** farmers have a basic understanding on how to deal with the poor soil fertility. To increase soil fertility, 99.3% of farmers increase compost and manure application, 28% change methods of land preparation, 24.5% increase rate of chemical fertilizer application, 22.4% do crops' rotation and 6.3% do intercropping/diversifying crop. Training on soil topics are required such as i) know your soil and ii) what fertilizer is used for different soil types, which levels and when to apply.
- **Previous training:** 62.3% of farmers have attended different trainings, of which 51.7% attended training on rice production, 40.4% on vegetable production, 41.7% on the use of fertilizer, 38.8% on making compost, 23.8% learn about soil fertility management, 29.8% about insect control and 9.3% on plant nutrition.
- **Suggestion for capacity building:** i) planting techniques (45.1%), ii) livestock (42.2%), iii) vegetable production (18.6%), iv) insect control (11.8%), v) fertilizer rate and application (8.4%), vi) seed production and water control (2-3%).

4.1.3. Proposed Trainings

a) Training approach

The Farmer Field School is one of the appropriate methods of training as most of the farmers have low education. The FFS approach will be based on leading by doing style of which everybody is the master in the rice field. The FFS has been successful in teaching farmers in many developing countries in Asia, especially in Cambodia and Vietnam.

The learning cycle – observation, analysis and action. The FFS meetings can be organized weekly or biweekly throughout the crop cycle. The first session usually begins one to three weeks after transplanting rice, so that field observations cover all critical phases of crop growth. Improved decision-making emerges from an iterative process of analyzing a situation from multiple viewpoints, synthesizing the analyses, making decisions accordingly, implementing the decisions, observing the outcome, and then evaluating the overall impact.

New knowledge and insights at each stage require revision of earlier stages and modification of initial assumptions. This process is conducted within the framework of an agroecosystem analysis (AEA). When managing an agroecosystem, it is important to understand not only its components, but also the patterns and processes defining the relationships among them - patterns and processes are studied qualitatively, making it possible to map interrelationships.

FFS include special topic field activities designed to uncover unknown agroecosystems relationships. A classic example of such a field activity is the insect zoo which consists of placing an insect in a cage with a rice plant covered by muslin netting that allows the farmers to observe the insect in order to determine whether it is neutral (a detritivore or plankton feeder), plant-feeding or beneficial (predatory). However as our capacity building is more towards the effect of biochar on plant growth and productivity, the facilitators/trainers should concentrate most session toward the growth of the plant, analysis the changes in soil structure, moisture and pH, earthworm population etc.

Once these concepts are internalized by farmers the stage is set for better management decisions. Special topics also develop farmer research capacity by stimulating comparison of control (no biochar) and treatment (with biochar) sub-plots and by providing regular opportunities for data gathering and analysis. Once the facilitator has introduced a special topic and explained the steps to follow, participants assume active management of the activities.

Another key concept of the FFS approach is the indicator. Because successful agroecosystem management depends upon system health, the FFS emphasize the importance of health indicators and develop the capacity to formulate them. The less tangible and concrete a property, the greater the importance of indicators as management tools. An example of an agroecosystem health indicator, discovered by a FFS farmer-facilitator, is the population level of the dragonfly, an insect that is highly sensitive to pesticides. Their absence indicates that the environment is contaminated.

Developing the capacity for collective action
Each FFS meeting includes a group dynamics exercise to strengthen teamwork and problem-solving skills, promote creativity and create awareness of the importance and role of collective action. The facilitator suggests a problem or a challenge for the group to solve. These exercises usually involve physical activity but sometimes take the form of mental puzzles or brainteasers – they should be fun while offering an opportunity to work together towards solving a specific problem. To stimulate interest in FFS beyond the immediate participants, the field school invites the whole village and farmers from neighboring villages to attend the harvesting of its plots and participate in analysis of results (The Field DAY).

Specific Objectives of the FFS

- To empower farmers with knowledge and skills to make them experts in their own fields;
- To sharpen the farmers ability to make critical and informed decisions that render their farming profitable and sustainable;
- To sensitize farmers in new ways of thinking and problem solving;
- Help farmers learn how to organize themselves and their communities.

Advantages of FFS

- Shorten the time it takes to get research results from the stations to adoption in farmers' field by involving farmers experimentation early in the technology development process;
- Enhance the capacity of extension staff, working in collaboration with researchers, to serve as facilitators of farmers' experiential learning. Rather than prescribing blanket recommendation that cover a wide geographic area but may not be relevant to all farms within it, the methods train extension workers and researchers to work with farmers in testing, assessing and adapting a variety of options within their specific local conditions;
- Increase the expertise of farmers to make informed decisions on what works best for them, based on their own observations of experimental plots in their Field schools and to explain their reasoning. No matter how good the researchers and extensions, recommendations must be tailored and adapted to local conditions, for which local expertise and involvement is required, which only farmers themselves can supply;
- Establish coherent farmer groups that facilitate the work of research and extension workers, providing the demand of a demand driven system.

Principles of Farmer Field Schools
In the field school, emphasis is laid on growing crops or raising livestock with the least disruption on the agro-ecosystem. The training methodology is based on learning by doing, through discovery, comparison and a non-hierarchical relationship among the learners and trainers and is carried out almost entirely in the field.

The four major principles within the FFS process are:

1. Grow a healthy crop;
2. Observe fields regularly;
3. Conserve natural enemies of crop pests;
4. Farmers understand ecology and become experts in their own field.

b) Characteristics of the Farmer Field School Approach

Farmers as Experts: Farmers 'learn-by-doing' i.e. they carry out for themselves the various activities related to the particular farming/forestry practice they want to study and learn about. This could be related to annual crops, or livestock/fodder production. The key thing is that farmers conduct their own field studies. Their training is based on comparison studies (of different treatments) and field studies that they, not the extension/research staff conduct. In doing so, they become experts on the particular practice they are investigating.

The Field is the Learning Place: All learning is based in the field. The maize field, banana plantation, or grazing area is where farmers learn. By working in small subgroups, they collect data in the field, analyze the data, make action decisions based on the analyses of the data, and present their decisions to the other farmers in the field school for discussion, questioning and refinement.

Extension Workers as Facilitators Not Teachers: The role of the extension worker is very much that of a facilitator, rather than a conventional teacher. Once the farmers know what it is they have to do, and what it is that they can observe in the field, the extension worker takes a back seat role, only offering help and guidance when asked to do so.

Presentations during group meetings are the work of the farmers not the extension worker, with the members of each working group assuming responsibility for presenting their findings in turn to their fellow farmers. The extension worker may take part in the subsequent discussion sessions, but as a contributor, rather than leader, in arriving at an agreed consensus on what actions need to be taken at that time.

Scientists/Subject Matter Specialists Work With Rather than Lecture Farmers: The role of scientists and subject matter specialists is to provide backstopping support to the members of the FFS and in doing so, to learn to work in a consultative capacity with farmers. Instead of lecturing farmers their role is that of colleagues and advisers who can be consulted for advice on solving specific problems, and who can serve as a source of new ideas and / or information on locally unknown technologies.

The Curriculum is integrated: The curriculum is integrated. Crop husbandry, animal husbandry, horticulture and land husbandry are considered together with ecology, economics, sociology and education to form a holistic approach. Problems confronted in the field are the integrating principle.

Training Follows the Seasonal Cycle: Training is related to the seasonal cycle of the practice being investigated. For annual crops this would extend from land preparation to harvesting. For fodder production would include the dry season to evaluate the quantity and quality at a time of year when livestock feeds are commonly in short supply. For tree production, and conservation measures such as hedgerows and grass strips, training would need to continue over several years for farmers to see for themselves the full range of costs and benefits.

Regular Group Meetings: Farmers meet at agreed regular intervals. For annual crops, such meetings may be every 1 or 2 weeks during the cropping season. For other farm/forestry management practices the time between each meeting would depend on what specific activities need to be done, or be related to critical periods of the year when there are key issues to observe and discuss in the field.

Learning Materials are Learner Generated: Farmers generate their own learning materials, from drawings of what they observe, to the field trials themselves. These materials are always consistent with local conditions, are less expensive to develop, are controlled by the learners and can thus be discussed by the learners with others. Learners know the meaning of the materials, because they have created the materials. Even illiterate farmers can prepare and fuse simple diagrams to illustrate the points they want to make.

Group Dynamics/Team Building: Training includes communication skills building, problem solving, leadership and discussion methods. Farmers require these skills. Successful activities at the community level require that farmers can apply effective leadership skills and have the ability to communicate their findings to others.

Farmer Field Schools are conducted for the purpose of creating a learning environment in which farmers can master and apply specific land management skills. The emphasis is on empowering farmers to implement their own decisions in their own fields.

c) Facilitation

The success of conducting FFS will depend very much on the capacity, ability and experience of the persons who will facilitate the whole show. Facilitators should be able to bring concrete and real examples to the discussion during the FFS sessions. The facilitator's role and attitude are key factors in determining the success of an FFS. His or her duties include serving as catalyst, encouraging analysis, setting standards, posing questions and concerns, paying attention to group dynamics, serving as mediator and encouraging participants to ask questions and come to their own conclusions.

A facilitator who provides answers instead of raising new questions will fail in an FFS environment. For example, if someone asks, 'What's this insect? Is it a pest?' a good facilitator would answer with another question: 'What can we do to find out?' Extension workers, who serve as facilitators have completed a training programme that lasts an entire crop cycle and provides them with first-hand experience in rice cultivation, while developing facilitation, leadership and administrative skills. Each facilitator is expected to guide at least three FFS per year.

d) Curriculum

The FFS are based on a solid tested curriculum, which covers the entire crop or it can also be a livestock cycle. The field guides, study fields plus a collection of group dynamic exercises provide, the basis for the field school curriculum. These materials are used according to their appropriateness.

The training in the farmer field school is experiential and discovery based. The training activities are designed to have participants learn by doing. Most of the training time is spent in the field. Exchange of information and generation of knowledge is facilitated through sharing observations, brainstorming and long discussions.

A corner stone of the FFS methodology is agro-ecosystems analysis (AESA) which is the establishment by observation of the interaction between a crop/Livestock and other biotic and abiotic factors co-existing in the field. This involves regular (usually weekly) observations of the crop. Participants work in sub groups of 4 or 5, and learn how to make and record detailed observations including:

- Growth stage of the crop;
- Insect pest and beneficial numbers and weeds and disease levels;
- Weeds and disease levels;
- Weather conditions;
- Soil condition; and
- Overall plant health.

The farmers then take management decisions based on these observations. An important aspect of FFS is helping and encouraging farmers conduct their own experiments, to test out ecological crop management methods. There are no standard recommendations or packages of technology offered. Farmer groups collectively decide which methods or aspects of crop management should be studied, and undertake action based on their own findings. In this way, farmers become active learners and independent decision-makers through a process of learning by doing. These together with a group dynamic activity and a special topic, which concerns what is happening in the field, form the core of the field school curriculum. An example of a curriculum for FFS on rice production is below (Table 11).

Table 11: Training curriculum for Farmer Field School (FFS) on rice production

Sessions	Activities/Topics	Methodologies	Facilitators
Session 1 (morning or afternoon)	- Registration; - Expectation; - Basic principle of FFSs; - Regulations of FFSs; - Evaluation of the session; - Plan for session 2;	1. Record names of sexes of participants; 2. Give them a paper to write their own opinion; 3. Brainstorm and note on flip chart of participants inputs for FFS principles and regulations; 4. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 5. Discus with participants on date, time and meeting place.	Key trainers Support team
Session 2 (morning or afternoon)	- Registration; - Review of previous session; - Design of demonstration plots; - Soil preparation and basal fertilizers and biochar application; - Evaluation of the session Plan for session 3	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Brainstorm farmers experience on land preparation techniques on rice production; 4. Discuss types of fertilizers to be used for basal application, plant nutrients requirement for different growth stages; 5. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 6. Discuss with participants to prepare for the next session.	Key trainers Support team
Session 3 (morning or afternoon)	- Registration; - Review previous lesson; - Organic fertilizer and chemical fertilizer, how to apply and recommended doses; - Pre-test (question box); - Evaluation of the session; - Plan for session 4.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Brainstorm – using good and easy examples to demonstrate how and what roles of fertilizers both organic and chemical in plant growing stages. Bring for the discussion of nitrogen, phosphorus, potassium and other micro-nutrients; 4. Using folders already prepared with pictures attached to each of boxes to ease farmers giving the answers. Each farmer is given a piece of paper written with his number on the record list for each of the question. He/she has the choice to drop a piece of paper in one of the ballot boxes; 5. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation;	Key trainers Support team

		6. Discuss with participants to prepare for the next session.	
Session 4 (morning or afternoon)	- Registration; - Review previous lesson; - Announcement of the pre-test results; - Rice field agro-ecosystem analysis; - Important insects in rice production; - Evaluation of the session; - Plan for session 5.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Give a summary of the pre-test results in flip-chart and discuss with farmers what best to continue increasing their knowledge; 4. Field exercise to collect data about plant growth, insect, water control; 5. Facilitator ask farmers' experiences in identifying different insects and what kinds of effects they cause and control measures and facilitators will only bring up the most damaging insects as special topics; 6. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 7. Discuss with participants to prepare for the next session.	Key trainers Support team
Session 5 (morning or afternoon)	- Registration; - Review previous lesson; - Rice field agro-ecosystem analysis; - What is biochar? However are interaction with soil and synergy with fertilizer? How can biochar be produced and what are the biomass?; - Evaluation of the session; - Plan for session 6.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Field exercise to collect data about plant growth, insect, water control, observation on soil property changes, etc.; 4. Facilitator should take some samples of biochar to the discussion – biochar from wood, biochar made from rice husk, the ash from traditional stove, ash from burning rice husk in an open air, etc. let participants see materials then it will be easier to create an easy environment for the discuss and learning. If kiln is available then try to make the show how biochar is producing; 5. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 6. Discuss with participants to prepare for the next session.	Key trainers Support team
Session 6 (morning or afternoon)	- Registration; - Review previous lesson; - Rice field agro-ecosystem analysis; - Soil and water conservation and soil fertility management options; - Evaluation of the session; - Plan for session 7.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Field exercise to collect data about plant growth, insect, water control, observation on soil property changes, etc.; 4. Critical issues about too much water or no water should become the topic to start the discussion in regard water conservation. Facilitator should bring the soil analyses results from bi-weekly AESA of the control and	Key trainers Support team

		treatment sub-plots as examples for the discussion. How soil characteristics changes when applying biochar; 5. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 6. Discuss with participants to prepare for the next session	
Session 7 (morning or afternoon)	- Registration; - Review previous lesson; - Rice field agro-ecosystem analysis; - Rice farming a "business"; - Evaluation of the session; - Plan for session 8.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Field exercise to collect data about plant growth, insect, water control, observation on soil property changes, etc.; 4. Facilitators should start by asking questions to participants why they think rice should be a business? If yes how could we make this business prosperous? 5. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 6. Discuss with participants to prepare for the next session.	Key trainers Support team
Session 8 (morning or afternoon)	- Registration; - Review previous lesson; - Rice field agro-ecosystem analysis; - Post-harvest management and losses; - Post test; - Evaluation of the session; - Plan for session 9.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Field exercise to collect data about plant growth, insect, water control, observation on soil property changes, etc.; 4. Facilitator should try to provoke the discussion by allowing them to form small groups to discuss and present their results to plenary. What post-harvest technologies they are using? What are looses they could thin off? What would be the measures to prevent looses? 5. Same folders with same questions of pretest are used for the post test. Same process as use for the pretest; 6. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation; 7. Discuss with participants to prepare for the next session.	Key trainers Support team
Session 9 (morning or afternoon)	- Registration; - Review previous lesson; - Review all sessions; - Presentation of post test results; - Plan for session 10 - Preparation for Field Day; - Evaluation of the session.	1. Record participants; 2. Give the chance to participants of best they remember from previous session; 3. Facilitators/trainers should have important topics already listed in the flipcharts then during the session; participants are asked of what they could remember/learn best for each	Key trainers Support team

		topic; 4. Facilitators/trainers present post test results written in the flipcharts. Best participants from 1-3 (but they should be suggested and agreed by participants) will be given a souvenir during the Field Day. Their performance to be selected is based in the result from test, participation, performance of work at their animal farms, etc.; 5. Field Day is important for participants to show their performance and results of their work to other invited community members. This can be for the morning session of which all field school participants should be present and also invite other community members to participate and learn from this experience; 6. Ask farmers in the plenary session to assess facilitator/trainers, knowledge, practice, training place, time, environment and participation.	
Session 10 (morning or afternoon)	- Registration; - Welcome invited and distinguished guests; - Harvest rice; - Present outputs/outcomes of the demonstrations/FFS; - Group photo; - Visit posters and the demonstration sites; - Remarks from participants representative; - Welcome remarks from distinguished guest; - Closing; - Group lunch.	1. Record participants; 2. All team should work together to produce a series of posters for presentations which could include pictures of the activities during the demonstrations and FFS. Appoint a representative to present the outputs/outcomes to the distinguished guests and participants; 3. Cameraman will be invited to take video clips for TV and possible newspaper; 4. The master ceremony of project should guide the participants to the posters and assigned farmers to present each of the posters then to the demonstration sites. Owners of the demonstration should be the presenter of her/his activities to the guests; 5. Assign a representative from the group to give a speech of the overall impression of being of part of the project and their commitment for future; 6. After field visit, master ceremony invites the distinguished guest/representative of the donors/project to give the remarks and closing of the Field Day; 7. Master ceremony invites all participants including guests for the lunch jointly by the group and project at the site.	Key trainers Support team

e) Field days and exchange visits

FFS participants often enjoy organizing a field day for their local community to display and discuss the skills they have gained through involvement in the field day. This is a good opportunity for the community to gain a better understanding of what happens in an FFS and what the benefits and problems of operating this approach are. The field day could be mid-season or combined with the closing ceremony.

Exchange visits between FFS in different areas are often great opportunities for joint learning and it is interesting to ask the participants to document what they learnt from the visit to improve future FFS operations as well as field visits. Farmers find it stimulating to see the enterprising skills of other farmers and are always eager to then try them out on their own fields. Farmers tend to feel a sense of pride in organizing and being involved in field visits.

f) Evaluation of the FFS

During the design of the initial FFS curriculum time for evaluation exercises should be timetabled. In order to identify the strengths and weaknesses of the FFS, an evaluation exercise focusing on the results, process and impact can be conducted.

- **Results:** What were the results of applying the FFS approach and conducting experiments in the field?
- **Process:** How effective were the FFS activities in helping participants learn about rice production and its ecosystem when applying biochar?
- **Impact:** What can participants accomplish by implementing the demonstration and FFS during FFS in their own fields?

g) Outcomes of the FFS and Demos

The outcomes of proposed activities include:

- Yield of selected crops will be increased by at least double of the present yield per hectare;
- Production cost of selected crops will be decreased to a minimum point;
- Gross annual income will be increased by double;
- Environment sound in terms of healthy soil, insect;
- Biochar awareness is well adopted amongst farmers.

5. WORK PLAN, IMPLEMENTATION ARRANGEMENTS

There are three demonstrations intended to be implemented in the districts of Tramkak in Takeo and Chhouk and Dang Tung in Kampot. CEDAC will implement rice and vegetable demonstration in Chhouk and Dang Tung as they are working there, while the DAEng will implement three demonstrations on rice, vegetable and maize in Tramkak district in collaboration with the provincial Department of Agriculture.

It is aimed to begin the demonstration in the 2013-2014 dry seasons and 2014 wet season. In the 2013 dry season, rice and vegetable demonstration will be started in 10 villages in Tramkak and the study team suggests 5 villages in Chhouk district and another 5 villages in Dang Tung district.

As indicated in Section 3 'RECOMMENDED PILOT INVESTMENT - OUTPUTS, ACTIVITIES, DEMO PLOT PLANS and PERFORMANCE INDICATORS,' the demonstrations on rice and vegetable can begin in December 2013 in which vegetable demonstration will end in the last week of January 2014, while rice will end in the second week of April 2014.

The implementing agency should have assigned staff or recruited 2-3 staff to be based 5 days a week at the target villages during the period of the demonstration. As these are short assignments, intensive is required in order to get the demonstration implemented efficient and effectively.

The implementing agencies should coordinate on some kind of collaboration for the concerned institutions, particularly the district agricultural offices, which allow the knowledge sharing to be optimized and it is expected later, that they will join effort in promoting the use of biochar in farming.

There are several rice mills in Takeo (two rice mills – one in Daun Keo district and one in Tramkak district) and Kampot (CEDAC gasifier) of which biochar are available from gasifiers and paddy drying plants. It is important to start communicating with the owners for supply of biochar for these demonstration purposes but also important to bridge farmers to these sources of biochar for their future uses. The negotiation with owners of these rice mills should be done in early December 2013.

As these demonstrations required intensive work, the production of biochar by farmers using kilns produced by DAEng would keep it as an option for future development work. And this will have to propose another project aiming at the use of the remaining rice straw in the paddy field as biomass for biochar production. The use of rice straw as biomass for biochar would have great potential as it is available and accessible by farmers.

6. MONITORING AND REPORTING

Monitoring is an important part of this demonstration effort which allows capturing changes or modification after verification to ensure that: a) the learning process of farmers, demonstration collaborators and researchers / extension workers are well captured; b) what are the changes of the plants during the development process in terms of height, leaves, or diameter of the plant in case of maize and finally the yield; c) impact on soil and soil fertility arising from biochar utilization; and d) the community perception and adoption of biochar into their farming activities.

a) **Learning process:** field team including 1 field officer and 1 experienced trainer should coordinate with key demonstration farmers to regularly conduce the monitoring and the need to undertake monitoring in order to further knowledge and provide information on techniques that can be employed more widely. The stability, fate and impacts of biochar will need to be monitored at long-term demonstration and benchmark sites.
b) **Changes in plants:** The changes in plants in terms of height, number of leaves and / or diameters of the plants by comparing control sub-plots and the treatment plots and try to collect the data and information in the participatory manner involving demonstration farmers and other interested farmers as much as possible. Then, use the results from the monitoring to discuss with farmers their reasons. The progress of plants will be monitored from the start of the demonstration to the harvest of crops. The total biomass will also be measured at the end.
c) **Impact on soil and soil fertility:** Changes in soil structure should also be monitored. This monitoring can be done through field observation, but soil samples can also be taken from the start before applying biochar and at the end of the demonstration for laboratory analysis. Soil moister and soil pH can also be monitored. The present of earthworms on the control and treatment sub-plots.
d) **Community adoption and perception on biochar:** This is an important factor to be monitored for future large scale investment. We need to hear what farmers or villagers think about biochar in term of its usefulness, availability and accessibility of biomass for biochar production. The good sign to be monitored whether there are other villagers including those invested farmers to training take own initiative to try biochar.

This pilot demonstration of biochar should be able to document evidence for the expansion of this initiative in the future. The main goal is to establish long term biochar utilization by the farming community. Tested data gathered will be the solid evidence for future investment. The key elements for monitoring are the changes to soil structure, carbon content, fertility, productivity, and biodiversity. Soil moisture and changes in soil and plant ecology will also be monitored.

Continuous feedback from monitoring throughout the life of the activities ensures that the quality of the activities is sufficient to provide good results. Before Participatory Monitoring begins, the community must understand why they are monitoring. Information should keep everyone informed of progress (or lack of progress) towards planned objectives and activities.

Participatory Monitoring provides an ongoing picture that allows the community to determine whether activities are progressing as planned. It may also show when activities are not leading to objectives, so that early adjustments can be made. Participatory Monitoring provides an "early warning" which identifies problems at an early stage. Solutions can then be sought before the problems get out of hand. This is especially important with new technologies that may have negative effects after introduction.

The methods used for motoring biochar demonstration are a) laboratory test of soil before and after the demonstration; b) participatory M&E using focus group discussion; and c) field observation. While Participatory Monitoring can be introduced at any stage of activities, it is best introduced at the beginning stage, before activities are implemented. At this stage, preparations are made for how and who will do the data collection, and when the periodic analysis will take place. After implementation, when the activities have begun the recording begins. At set periods, which can be either daily, weekly, monthly, or seasonally, the information that is being recorded is analyzed.

Monitoring steps

- It is important that the team takes the time to prepare and plan monitoring. It helps everyone know why they are monitoring, and how it will be done. The first meeting is to plan for monitoring that can include all those directly involved in the biochar demonstration activities as well as other interested groups (those who wish to learn from the demonstration). But it will be concentrated on those directly involved or those selected by the groups who will be responsible for monitoring. Planning for monitoring can use a framework much like those used for Participatory Baselines and Participatory Evaluation. This framework is explained in the following steps;
- The team organizes meetings to review objectives and activities with the demonstration participants. The demonstration participants have to make their own objectives and activities and simple questions can be used to provoke the discussion and brainstorm (what are you expected to get by participating in the demonstration using biochar? What should we do together to realize your expectation?). Sometimes the demonstration implementing team (outsider) and demonstration farmers (insiders) might have different objectives and therefore it is necessary to clarify them at the early stage of preparing the monitoring plan;
- After objectives and activities are reviewed, discuss the information needed to help know if activities are going well. Focus on the questions "What do we want to know?" and "What do we monitor that will tell us this?" The facilitator can write (or draw), on large sheets of paper or a blackboard, monitoring questions generated around each objective and activity. There should be an agreement by the group on each monitoring question. If many questions are generated they can be ranked in order of importance.

As during the implementation of the demonstration on the use of biochar, the training using Farmer Field School approach will be conducted then it is also important to monitor the training events as follows:

- Number of participants at events is a simple indicator of effective outreach and successful events;
- Training participants should make own assessment after training events and this feedback would help the trainer to do better in responding to participants needs;
- A success measure is the number of farmers who participate in the training take own initiative of using biochar.

7. SUMMARY OF PILOT COSTING AND DETAILED COSTS BY IMPLEMENTING AGENCY

The budget is calculated by the type of demonstration crops. Rice and vegetable demonstrations will be conducted in the dry season of 2013-2014, except maize which the demonstration will be conducted in the wet season of 2014. The estimated budget is a standard calculation which includes staff/personnel cost, travel, training, materials and supplies, equipment and analysis and overhead costs (5%) (Table 12, Table 13 and Table 14).

Explanation of proposed budget for demonstration in dry season 2013-2014 for rice and vegetable and wet season 2014 for maize:

- The budget for staffing includes salary and per diems. The experienced field staff with the ability to manage, design of the demonstration / trial, record data, coaching, etc. will have a salary of US$600-700 and estimated per diem of US$400 per month. The project coordinator will spend 45% of his/her time on this project, while 2 experienced field staff / researchers and a trainer will be employed full time during the period of 4 months starting from December 2013 to May 2014.
- The budget for travel will cover the cost of motorcycles and car rental for the scheduled visit (M&E) by the project coordinator. The proposed budget of motorcycle rent includes the cost of fuel and maintenance.
- Recruited staff will join a training/meeting for 3 days before allowing them to go to the field work – responsibilities/tasks are made clear on these 3 days. Although they have different responsibilities and tasks, they should work together in order to coordinate an effective field work. Framers' training will be organized per target villages and each training session will have the participation of 5 demo farmers plus 20-25 invited villagers to attend and learn. A cross-visit will be organized by selecting a village with best demonstration to share with other demo farmers. A Field Day at the end of the demonstration is organized with the participation of 100 people from inside and outside of the selected villages and the local authority. A professional video camera will be hired to document the processing demonstration from start to the end. A workshop will be organized jointly with other biochar demonstrations and this workshop can be done at the central level (example at MAFF) or at provincial level.
- The project will provide seeds, fertilizer and biochar to demo farmers while farmers have to pay for others including land preparation, labor cost for transplanting, etc. Soil pH meters are needed for field work and soil from 5 randomized locations of the target demos are sampled for laboratory analysis.

Table 12: Detailed estimated cost on rice demonstration dry season 2013-2014

No	A. Staffing	Descriptions	Unit cost ($)	Cost ($)
a.1	Project coordinator - package including per diem	1ps x 4 months x 45%	652.5	2,250.00
a.2	Field Officer - package including per diem	1ps x 4 months	1050	4,200.00
a.3	Trainer - package including per diem	1ps x 4 months	1050	4,200.00
	Sub-total			10,650.00
	B. Travel			
b.1	Motorcycle - rent plus fuel	3 motors x 4 months	150	1,200.00
b.2	Car - PC project M&E	2days x 4 trips	75	600.00
	Sub-total			1,800.00
	C. Training			
c.1	Staff inception workshop and training	5ps x 3dyas	50	750.00

c.2	Farmer training	10villages x 16 weeks	35	5,600.00
c.3	Crossed visit	1visit x 50 ps	10	500.00
c.4	Field Days	1FD x 100ps	7	700.00
c.5	Video documentation and TV broadcast	LS		1,200.00
c.6	Workshops and meetings	1time x 50 ps	25	1,250.00
	Sub-total			10,000.00
	D. Materials and supplies			
d.1	Seeds/seedlings	2.5kg x 50demos	0.68	85.00
d.2	DAP	2.5kg x 50demos	0.68	85.00
d.3	Urea	3.5kg x 50demos	0.58	108.75
d.4	KCL	2.5kg x 50demos	0.65	81.25
d.5	Biochar	250kg x 50demos	0.0065	81.25
d.6	Transportation of biochar	LS	65	65.00
	Sub-total			506.25
	E. Equipment and analysis			
e.1	pH meter	2 pH meters	75	150.00
e.2	Soil	5samples x 2times	45	450.00
	Sub-total			600.00
	F. TOTAL DIRECT COST			23,556.25
	ADMINISTRATIVE COST - 5%			1,177.81
	GRAND TOTAL			24,734.06

Table 13: Detailed cost on vegetable demonstration in dry season 2013-2014

No	A. Staffing	Descriptions	Unit cost ($)	Cost ($)
a.1	Project coordinator - package including per diem	1ps x 2 months x 45%	562.5	1,125.00
a.2	Field Officer - package including per diem	2ps x 2 months x 60%	630	2,520.00
a.3	Trainer - package including per diem	1ps x 2 months	1050	2,100.00
	Sub-total			5,745.00
	B. Travel			
b.1	Motorcycle - rent plus fuel	3 motors x 4 months	150	900.00
b.2	Car - PC project M&E	2days x 4 trips	75	300.00
	Sub-total			1,200.00
	C. Training			
c.1	Staff inception workshop and training	5ps x 3dyas	50	750.00
c.2	Farmer training	10villages x 16 weeks	35	5,600.00
c.3	Crossed visit	1visit x 50 ps	10	500.00
c.4	Field Days	1FD x 100ps	7	700.00
c.5	Video documentation and TV broadcast	LS		1,200.00
c.6	Workshops and meetings	1time x 50 ps	0	-
	Sub-total			8,750.00

	D. Materials and supplies			
d.1	Seeds/seedlings	2.5kg x 50demos	0.68	102.00
d.2	DAP	2.5kg x 50demos	0.68	170.00
d.3	Urea	3.5kg x 50demos	0.58	116.00
d.4	Biochar	250kg x 50demos	0.25	32.50
d.5	Transportation of biochar	LS	65	30.00
	Sub-total			450.50
	E. Equipment and analysis			
e.1	pH meter	2 pH meters	75	150.00
e.2	Soil	5samples x 2times	45	450.00
	Sub-total			600.00
	F. TOTAL DIRECT COST			16,745.50
	ADMINISTRATIVE COST - 5%			837.28
	GRAND TOTAL			17,582.78

Table 14: Detailed cost on maize demonstration for wet season 2014

No	A. Staffing		Unit cost ($)	Cost ($)
a.1	Project coordinator - package including per diem	1ps x 3 months x 45%	562.5	1,687.50
a.2	Field Officer - package including per diem	1ps x 3 months	1050	3,150.00
a.3	Trainer - package including per diem	1ps x 3 months	1050	3,150.00
	Sub-total			7,987.50
	B. Travel			
b.1	Motorcycle - rent plus fuel	2 motors x 3 months	150	900.00
b.2	Car - PC project M&E	2days x 3 trips	75	450.00
	Sub-total			1,350.00
	C. Training			
c.1	Staff inception workshop and training	5ps x 3dyas	50	750.00
c.2	Farmer training	10villages x 12 weeks	35	4,200.00
c.3	Crossed visit	1visit x 30 ps	10	300.00
c.4	Field Days	1FD x 100ps	7	700.00
c.5	Video documentation and TV broadcast	LS		1,200.00
c.6	Workshops and meetings	1time x 50ps	0	-
	Sub-total			7,150.00
	D. Materials and supplies			
d.1	Seeds/seedlings	1.5kg x 30demos	0.5	22.50
d.2	DAP	1.63kg x 30demos	0.68	33.25
d.3	Urea	8.7kg x 30demos	0.58	151.38
d.4	KCL	7.6kg x 30demos	0.65	148.20
d.5	Biochar	250kg x 30demos	0.0065	48.75
d.6	Transportation of biochar	LS	65	35.00
	Sub-total			439.08
	E. Equipment and analysis			

e.1	pH meter	2 pH meters	75	150.00
e.2	Soil	5samples x 2times	45	450.00
	Sub-total			600.00
	F. Total Direct Cost			**17,526.58**
	Administrative Cost - 5%			876.33
	Grand Total			18,402.91

8. SUMMARY POVERTY REDUCTION AND SOCIAL STRATEGY (SPRSS), AND INDIGENOUS PEOPLE ASSESSMENTS

8.1. POVERTY ANALYSIS AND STRATEGY

8.1.1. Country Strategies on Poverty

Cambodia's GDP has quadrupled, increasing from US$216 per capita in 1992 to US$945.99 per capita in 2012. From 1994 to 2011, Cambodia experienced an average growth rate of 7.7 percent. Between 2004 and 2007, the economy grew above 10 percent annually[13]. The Cambodian economy is based upon four main pillars of growth: agriculture, industry (garments), tourism and construction. The share of agriculture in 2012 is estimated to be 4.3% or 3.3-5.7% between 2006-2012. The agriculture sector still has a high potential in rice as well as other crops, if effective irrigation systems are improved and expanded. The GDP of agriculture declined to 26.7 percent in 2007 but increased to 27.5% in 2012. Within the agriculture sector, crops including rice shares 54.8%, fisheries with 25.4%, livestock with 14.19% and 5.7% with forestry (MAFF 2013). Looking at the share of sub-sectors between 2007 and 2012, except forestry which is gradually declining from 7.3 percent in 2007 down to 5.7% in 2012, the other three subsectors are quite consistent.

Although the progress in reducing poverty is attained (from 30.1% in 2007 to 25.8% in 2010), the rural poverty rate remains high. Furthermore, the gap between the rich and the poor, especially urban-rural inequality remains a challenge. Land concentration and landless people are on a rising trend, adversely impacting on the equity and efficiency of land use. Large areas under economic land concessions have not been utilized efficiently. Illegal claim of state land and protected areas as privately owned and unlawful logging are still taking place. Rehabilitation and reconstruction of the national road network across the country were on great progress but quality was the concern. Energy and electricity tariffs remain high compared with Thailand and Vietnam, and this is one of the obstacles preventing competitiveness as well as attracting investments and improving livelihoods. Irrigation system has not been fully developed and utilized to its potential, requiring more efficient management and investment. Financing, management, and technology are the major challenges for SMEs in Cambodia. Institutional capacity of the Government is still limited due to low salary and incentive schemes. The cooperation between government agencies is still inadequate, while some legal and regulatory frameworks contain loopholes, and there is a shortage of resources to carry out policies.

The National Sustainability Development Strategy (NSDS Vision 2030) is a new government ambition looking forward to 2030 for sustainable development of people's wellbeing and social development. The proposed goals of NSDS Vision 2030 are 1) Poverty alleviation; 2) Good health; 3) Well educated people; 4) Gender equity; and 5) Zero victims of landmines and UXOs. However one major prerequisite for sustainable development is 'good governance', which requires reducing dramatically the level of corruption, speeding up decentralization and ensuring the participation by all major groups. A government action plan based on the NSDS should be proposed and implemented in three interval periods; short-term (2008-2010), medium term (2008-2015) and long term (2008-2030). The proposed indicators reflect the objectives and targets in the NSDS and are divided in four sections: 1) Indicators for People's Wellbeing and Social Development; 2) Indicators for Sustainability of Natural Resources and the Environment; 3) Indicators for Sustainable Economic Sectors and Infrastructure; and 4) Indicators for Good Governance and Implementation of Sustainable Development.

With the ambitious millennium development goal of halving the number of Cambodians living in poverty by the year 2015, the government recognized the critical importance of the agriculture

[13] *RGC 2012. The Cambodian Government's Achievements and Future Direction in Sustainable Development*

sector, but specifically rice as being the one sub-sector that could make this happen, particularly, for rural people. Thus, the policy to promote paddy rice production and export set 2015 as the target year to export at least one million tons of milled rice. The government's vision is to bring Cambodia into the world market as a key milled rice exporting country. There are existing policies and strategies which have the direct support for this new policy initiative such as:

1. Phyto-sanitary Inspection Sub-decree 2003;
2. 2) Law on Crop Seeds Management and Right of Breeders 2008;
3. 3) Law on Management of Quality and Safety on Products, Goods and Services 2000;
4. 4) SAW 2009-2013;
5. 5) ASSDP 2009-2013;
6. 6) the Sub decree on Economic Land Concession 2005;
7. 7) Sub decree on Social Land Concession 2003;
8. 8) the Cambodia Trade Integration Strategy (CTAS) and Trade Sector Wide Approach (SWAp) 2013-2018;
9. Sub decree on Contract Farming 2011 etc.

The Agricultural Land-use Management Law is being drafted with the aim to regulate farming land for the purpose of agricultural development.

Paddy production reached 9.3 million tons in 2012 (MAFF 2013) however the remarkable surplus has been recorded since 2008. In 2012 the surplus of paddy rice was 4.73 million tons or 3.03 million tons of milled rice but has the potential to almost double the present yield when key inputs' such as irrigation facilities, high quality rice seed, fertilizers, appropriate technologies, and provision of micro credit with affordable interest rate to rice producers are in place. There is a trend to cultivate the early rainy season rice (9.6% of the total rice cultivated areas in 2012 compared with 7.3% in 2011) as to ensure that they could get some rice for home consumption and sale if the yield of main wet season fail to harvest due to the effects of climate change. The areas planted dry season rice 2012 has also increased 2% compared with 2011. The wet season rice is commonly dependant on rainfall and because of the low inputs such as fertilizer and pesticide, yield per hectare is usually lower than the dry season (2.8 tons per ha of wet season versus 4.3 tons of the dry season in 2012).

8.1.2. Poverty Analysis

i) Key issues

Although progress in reducing poverty is attained (from 30.1% in 2007 to 25.8% in 2010) the rural poverty rate remains high. Furthermore, the gap between the rich and the poor, especially urban-rural inequality remains a challenge. It is believed that enhancing the productivity of the rice sector could improve the living standards of poor people, especially in rural areas.

MAFF's Agriculture Sector Strategic Development Plan 2009-2013 goes in parallel with other major government development plans and strategies. The ASSDP 2009-2013 has five strategic objectives (i) Food security, productivity, and diversification, (ii) market access for agricultural products, (iii) Institutional and legislative development framework, (iv) fisheries reform and (v) forestry reform. MAFF has translated the strategic objectives into three policy objectives: a) to increase productivity and diversification to ensure an annual increase of 10% of all important crops, 3% in livestock production, b) to ensure the proper demarcation of the fishing lots for community fisheries; and c) to ensure the coverage of forest on 60% of total land by 2015.

The results from this feasibility study shows that the yield of rice is relative low 2.5 tons per hectare compared with the national average of 2012 of 3.1 tons per hectare and lower than the provincial averages (Takeo was 3.9 tons and Kampot 3.1 tons per hectare). Comparing with Cambodian neighbors Vietnam reached an average of 5.3 tons per hectare in 2012[14], while the average yield of rice in Thailand is similar to Cambodia[15]. There are a couple of factors which effect of the yield of rice which interviewed farmers in these 2 provinces have raised. Firstly, lack of irrigation (89.3%) is the most common in which farmers rely on rain for their crop. As a result, the cultivation is delayed which impacts on the productivity of rice. Secondly, linking with risk management, farmers are not willing to apply fertilizer as recommended and soil commonly has poor fertility. Thirdly, rice seed of different varieties especially traditional varieties are kept through generation without any purification. This poor quality of seed affects the yield of rice. About 88% of the farmers use their paddy rice as seed for generation. Some rice varieties have been introduced by MAFF and farmers' own search for high yielding varieties but they have poor resistance to drought and diseases. Fourth, on average most families (80%) own less than a hectare which common is just enough to produce for family consumption especially in the three targeted districts in Kampot and Takeo. When water is available through intensification, farmers are willing to produce two crops per year – early monsoon and wet season rice.

8.1.3. Design Features

There is a total of 200 families who will directly benefit from the demonstrations of using biochar as soil amendment on rice, vegetable and maize in 32 villages in 13 communes of Tramkak district in Takeo and Dang Tung and Chhouk in Kampot. However it is expected that at least 5,760 farm families in the target villages and communes will indirectly benefit from this effort on introducing new technology not only to increase yield but also contributing to the climate change mitigation.

The investment of pilot demonstration of the biochar technology is geared towards increasing yield, better income, food security and poverty alleviation by introducing biochar from rice husk to crops production including rice, vegetable and maize. The design of this pilot investment is (i) to make biochar available to farming practices. The biochar can be obtained from large rice mills in Takeo and Kampot that already have the gasifier functioning. The cost of biochar is US$0.2 per bag of 25-30 kg; (ii) to introduce the model of kiln to small and medium rice mills in the target villages. They will be encouraged to produce biochar as they have rice husk available to do so. The adoption of the technology will happen when the demand of biochar from villagers increases as they see the result from piloting biochar on rice, vegetable and maize fields; (iii) to identify appropriate technologies for mixing biochar with other nutrients which are needed by plants. Mixing can be biochar together with slurry from the existing biodigester in the target villages; (iv) to further promote the adoption of the technology by private companies or initiative. Experience is shown that technologies are best adopted by users when they become commercialized. For example, gasifier has now been used widely in Cambodia because private sector has adopted the technology and makes it available to users; (v) to improve capacity of service providers (government and NGO staff), private sector and the end users (farmers). About 58% of farmers have primary education, 33.1% at the secondary school, 2% had the high school and only 1.3% studied in the university[16]. For the farmers, it is important to organize on job-training or farmer field school approach which allows them to learn best.

The Department of Agriculture Engineering (DAEng) and CEDAC will each implement 100 pilot demonstrations in 32 villages in 13 communes in Tramkak, Chhouk and Dang Tung districts of Takeo and Kampot provinces. The DAEng will demonstrate the use of biochar in rice, vegetable and maize while CEDAD will only work on rice and vegetable and apply organic principles including SRI in rice production.

8.2. SOCIAL ANALYSIS AND STRATEGY

[14] Vietnam's 2012 output seen steady at about 42 million tons. http://www.reuters.com/article/2011/12/16/vietnam-rice-output-idUSL3E7NG0QS20111216

[15] *FAO 2013. Rice Market Monitor. http://www.fao.org/docrep/017/aq144e/aq144e.pdf*

[16] *Feasibility Study ADBTA7833*

8.2.1. Findings of Social Analysis

The average annual income is US$2,312.2 (GDP per capita is US$464.3 or US$1.27 per day) per family of average 4.98 members. The income sources are 54.3% is from own farm (32.2% from livestock and 30.1% from crops including rice and vegetable) and 45.6% from non-farm (32.9% from garment factory work and 12.7% self-employment including trading). According to ADB 2007 estimate that people who earn less than US$1.25 a day lives under the poverty line. The result from interview people in the 32 villages shows that they just live on the poverty line which can easily fall back. Anything happens to the income generated from the non-farm activities especially the garment work; families in those villages can get an impact on their livelihood. So as rural families they should be able to make their livelihood strongly dependent on what they can do at their farm and these activities would include the improvement of agriculture productivity, diversification from traditional to high value crops. This effort demands better farm management, soil fertility improvement and management, fertilizer inputs, improve farm water control and management, etc. Their GDP per capita in the target is about 50.9% below the national average of 2012 (US$945.99).

All respondents cultivate rice, 70% grow vegetables and 44% plant other crops and a range of rice varieties, vegetable and other crops. In regard to rice, farmers use 15-20 varieties and traditional varieties are more dominant ones and among these varieties Srov Krahorm (red paddy) is the most popular for all target villages. Farmers said that Srov Krahorm is resistant to drought, diseases and insects. Farmers also cultivate many types of vegetables in which cucumber, pumpkin and wax gourd are grown by larger percentage of farmers. In regard to other crops, farmers cultivate maize and beans. Maize in Tramkak, Takeo is commonly for local consumption while in Dang Tung Kampot is more for animal feed (red corn).

8.3. CONSULTATION AND PARTICIPATION

8.3.1. Provide a Summary of the Consultation and Participation Process during the Project Preparation.

The feasibility study is conducted in the period of 8 weeks with the tentative dates to begin in July and the completion by end of September 2013. The study is divided in to 3 stages – the preparation of feasibility study, conduct field work and reporting. At all stages, consultation and participation are used as key instruments for the study. At the preparation stage, the study team met with ADBTA7833 focal point at MAFF and Director of CEDAC for their inputs on the questionnaires and identification of potential villages for the feasibility study and later the implementation of the pilot demonstration.

At stage 2 in the field, the team met with officers of the provincial and district agriculture for their assistance in organizing meetings with local authorities and farmers individually and groups. In each target district in Takeo and Kampot, 2-3 focus group discussions were organized with key informants in the villages in order to understand their views on crops of interest such as rice, vegetables and maize, their views in soil fertility and management and their production inputs, constraints and opportunities. A total of 151 households and 27 small rice mills in 3 districts in Kampot and Takeo provinces were interviewed using questionnaires.

At stage 3, after the data entry, cleaning and analysis, the team members met to review the results and discuss based on individual expertise.

8.3.2. What level of Consultation and Participation (C&P) is Envisaged during the Project Implementation and Monitoring?

☐Information sharing ☐Consultation ☑Collaborative decision making ☐Empowerment

8.3.3. Was a C&P Plan Prepared? ☑Yes ☐No

Key features of the consultation and participation plan for project implementation are as follows:

The project C&P provides the enabling mechanisms for beneficiaries to decide to adopt the introduce technology but service providers (DAEng and CEDAC) should be able to create the environment for decision making process. They make choices through processes inherent in their respective social organization/village.

8.4. GENDER AND DEVELOPMENT

8.4.1. Key Issues

The RGC being one of the signatories to the Beijing conference declaration in 1995 has demonstrated a commitment to addressing gender equality. The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) is another significant international catalyst for Cambodia to mainstream gender. The vision "gender equality in every aspect of socio-economic development" is included in most national development strategies and policies. The Ministry of Women Affairs (MOWA) produced the latest 5 years Neary Rattanak III for 2009-2013 that underscored gender relevance in all spheres of development for Cambodia and the MOWA guides the process of gender mainstreaming in other ministries.

MAFF established a Gender Unit (GU) as the over-arching body to oversee the implementation of the Policy and Strategy for Gender Mainstreaming. This strategy has the vision of "Enhancement of gender equality in the agriculture sector through active cooperation of both women and men for the opportunity to contribute and benefit equally from the activities of all sub-sectors in the agriculture sector".

Cambodia has an active agricultural population of 5,869,633 or 62 percent within the age group 15-64 years old of the overall agricultural population. Seven out of ten members in agricultural households in the country are engaged primarily in agriculture, forestry and fisheries. The total number of agricultural and fishery workers in Cambodia is 3,715,696 of which 1,755,581 (47.3%) are females and 1,960,115 (52.8%) are males[17]. Beside crops, most agricultural households have engaged in raising livestock. About 50% female and 60% male headed agricultural households engaged in cattle raising while 23% female and 30% male headed agricultural households keep pigs. In terms of poultry, the majority of female (70 percent) and male (74 percent) headed agricultural households engaged in chicken farming.

Men and women are engaging with rice, vegetable and maize production although from our interview we did not quantify the commitment of each. Man engagements are land preparation, transportation of rice seedlings and paddy rice home after harvest and threshing while women are preparing the seedlings, fertilization, weeding, transplanting, etc. So this pilot demonstration will equally benefit to both men and women in these selected villages.

8.4.2. Key Actions

☑Gender action plan ☐Other action/measures ☐No action/measures

Although both men and women participate actively in the rice, vegetable and maize cultivations, specific efforts are needed to ensure that women can be involved in decision making process and also attending the training that are organized under this project. Measures included in the design to

[17] FAO/NIS 2010. NATIONAL GENDER PROFILE OF AGRICULTURAL HOUSEHOLDS, 2010

promote gender equality and women’s empowerment are; access to and use of relevant services, resources, opportunities and participation in decision-making processes.

8.5. SOCIAL SAFEGUARD ISSUES AND OTHER SOCIAL RISKS

Issue		Significant/Limited/ No impact	Strategy to address issue	Plan or Other Measures Included in Design	
Labor		Limited impact	Might create job opportunity for the rice mills to produce biochar		Plan
	Employment opportunities				Other action
	Labor retrenchment			X	No action
	Core labor standard				
Affordability		Positive significant	Use locally available resources and will create best synergy with other fertilizer inputs for plant to uptake		Action
				X	No action
Other risk/vulnerability		Non	Non		Plan
	HIV/AIDS				Other action
	Human trafficking			X	No action
	Others (conflict, political instability, etc. please specify				

8.6. MONITORING AND EVALUATION

Are social indicators included in the design and monitor framework to facilitate monitoring of social development activities and/or social impacts during project implementation? ☐ Yes ☑ No

9. INITIAL ENVIRONMENTAL EXAMINATION (IEE) SCREENING MATRIX AND RECOMMENDATIONS

9.1. INTRODUCTION

Fertilizer is an important input for farming which can be organic and/or. The quantity of organic fertilizers (such as compost and animal manure) is normally not available for practicing on organic farming. A full organic rice field would require 13-15 cows per hectare and therefore farmers normally use compost and livestock manure for nursery and vegetable production. Most farmers have applied both animal manure and imported chemical fertilizers on rice, vegetable and crops. The evidence of this study shows that 93%, 19% and 19% of farmers used chemical fertilizer and 76%, 80% and 62% of farmers used cattle manure as fertilizer for rice paddy, vegetable and corn respectively. About ten different chemical fertilizers are available such as DAP, NPK, urea, buffalo head (mixing urea and PK) imported from different countries. The trend of chemical fertilizer application is rising in recent years due to poor soil and farmers get better access to these chemical fertilizers.

The World Bank's World Development Indicators for 2006 reported that fertilizer consumption in Cambodia was only 5 kg per ha of arable land in 2004, whereas farmers in Vietnam and Thailand applied on average 350kg and 141kg of fertilizer per ha respectively. An ADB study reports that in 2008, about 70% of the fertiliser supply was imported from Vietnam and Thailand and estimates that Cambodia's fertiliser demand stood at 130,000 tons (ADB 2008). Low rate use of chemical fertilizer is to mitigate risk. Farmers are worried about the drought and flood and if they put their investment in a basket they might lose everything. MAFF (2011) has also granted permission to 62 companies to import fertiliser and other agricultural inputs. In 2010, 245,854 tones and 100 gallons of fertiliser were imported, along with 2,509 tones, 50 bottles and 146,000 liters of pesticide. According to ADB (2008), farmers use fertilizer at inappropriate times and/or in the wrong amounts. Paradoxically, fertiliser is overused during the dry season when the farm gate price of paddy is lower, raising the question of the economics of fertiliser use. The Cambodia Agricultural Research and Development Institute (CARDI) has disseminated recommendations about fertiliser application by agro-ecological region and soil type, but these are not followed due to the lack of information and knowledge (ADB 2008)[18].

Chemical fertilizers need to be used according to the natural fertility of the soil, to the ecological conditions and the cultivation requirements for nourishing elements. Keeping this in mind, they will not have any negative effects over the surrounding environment. But if the optimal doses are not respected the soil will be polluted. Regarding this matter a study has been made that showed that if the correct dosage is not respected, this could lead to the acidification of the soil to such a level that it won't be suitable for agricultural purposes. Even if excess usage of fertilizers does not cause any changes in the soils texture, it can still contribute to its pure quality. If the correct dosage and the period of administration is respected, then the soil will be improved with nourishing elements, this leading to a better agricultural production (Daniel and Florica 2010)[19].

The biggest issue facing the use of chemical fertilizers is groundwater contamination. Nitrogen fertilizers break down into nitrates and travel easily through the soil. Because it is water-soluble and can remain in groundwater for decades, the addition of more nitrogen over the years has an accumulative effect[20]. According to this study it shows that both organic and chemical fertilizers cost about 36% (18% of chemical and 17.8% of organic fertilizer) of the total cost of US$439 for a

[18] Asian Development Bank (2008), "Issues and Options in Agriculture and Natural Resources Sector in Cambodia" (Manila: ADB)

[19] *Daniel, C. andFlorica, M. 2010. Research regarding the Impact of Chemical Fertilizer upon the soil. http://scientificbulletin.upm.ro/papers/2010/11/Research-Regarding-The-Impact-Of-Chemical-Fertilizers-Upon-T.pdf*

[20] *Sustainable Baby Steps: http://www.sustainablebabysteps.com/effects-of-chemical-fertilizers.html*

hectare of rice. The price of organic fertilizer is calculated as opportunity cost. Most farmers do not sell their cow manure because they know the value of it.

In this pilot investment of biochar, utilization on crops' production is relatively new for Cambodia and probably might also for the Southeast Asia region but it has shown great potential for soil amendment and although not directly of benefit to farmers it is also targeted for carbon sequestration. The optimal biochar combining fertilizer and carbon storage function in soils would activate the microbial community leading to nutrient release and fertilization and would add to the decadal soil carbon pool. The structural and chemical properties of biochars that are driving their decomposition or stabilization in soils still have to be identified (Steinbeiss et al., 2009[21]). There is a huge variability in physical biochar structures depending on the parent material and the conditions present at their formation, which leads to quite different turnover times in soils (Czimczik and Masiello, 2007[22]).

Straw is the only organic material available in significant quantities to most rice farmers. About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity. Removal with 1 tonne of straw, kg/ha 5-8 1.6-2.7 14-20 0.5-1.0 40-70 of N, P2O5, K2O, S and Si respectively (Dobermann and Fairhurst 2002)[23].

Currently, most of this biomass is burned in open air, resulting in air pollution and loss of a potential carbon feedstock for improving soil fertility. Due to air pollution in 2011, straw burning in the field has been banned by the administration of China’s government. Converting rice straw into biochar would benefit in several ways – reducing air pollution, replacing fossil fuel by energy from rice straw and biochar to be used as soil amendment. Biochar is produced within 20-30% of the biomass. The biochar production from rice husk or rice straw varies depending on the producing techniques, the producing process chain, equipment and facilities. This pyrolysis machine can treat without exotic energy wheat or maize straw 400-500kg and produce 120-150kg of biochar[24]. Temperatures of 400–500 °C produce more char (50%), while temperatures above 700 °C favor the yield of liquid and gas fuel components. Typical yields are 60% bio-oil, 20% biochar, and 20% syngas[25]. Slow pyrolysis, for instance, is the most effective means of producing biochar with typical biochar yields of 35-50% of dried biomass weight.

Beside producing biochar, rice straw can be used for energy production which would result in the mitigation of GHG emission from fossil fuel sources and considerable fossil fuel savings[26]. One tonne of the dry-based rice straw is converted to 681 kWh gross electricity (i.e. 0.681 kWh per kg straw) or 0.613 kWh net electricity per kg straw[27]. Life cycle GHG emissions of the straw combustion process chain (logistics and combustion) indicate that 30 kg CO^2eq/t straw(db) or 0.043 kg CO^2eq/kWh would be released into the atmosphere in case of burning the straw in a 10 MWe combustion plant. However, 92-96% of CO^2-eq emission reductions could be achieved; i.e., 0.368 tCO^2eq/t straw (0.496 kg CO^2eq/kWh) and 0.683 tCO^2eq/t straw (0.959 kg CO^2eq/kWh)

[21] Steinbeiss, S., Gleixner, G., Antonietti, M., 2009. Effect of biochar amendment on soil carbon balance and soil microbial activity. Soil Biology & Biochemistry 41 (2009) 1301–1310

[22] Czimczik, C.I., Masiello, C.A., 2007. Controls on black carbon storage in soils. Global Biogeochemical Cycles 21, GB3005.

[23] *Dobermann A. and Fairhurst T.H. 2002. Rice straw management. Better Crops International, Vol. 16, Special Supplement, May 2002*

[24] Genxing Pan, David Crowley, Johannes Lehmann. Burn to air or burial in soil: The fate of China’s straw residues. http://www.biochar-international.org/sites/default/files/Straw_burning_revised0708.pdf

[25] *Bionchar. http://en.wikipedia.org/wiki/Biochar*

[26] Suramaythangkoor T, Gheewala SH, Potential of practical implementation of rice straw based power generation in Thailand, *Energy Policy* 36 (2008) 3193-3197.

[27] Mitra Kami Delivand, Mirko Barz1, Savitri Garivait, (2011). Overall Analyses of Using Rice Straw Residues for Power Generation in Thailand- Project Feasibility and Environmental GHG Impacts Assessment. Journal of Sustainable Energy & Environment Special Issue (2011) 39-46

could be avoided if rice straw is substituted with the natural gas or coal fuels in the power generation sectors respectively.

Biochar acts as a catalyst in soil amendment and improve soil structure. Thus, biochar will be used as a fertilizer for the plant field. Biochar seems brand new for selected farmers and most of them know the black carbon after burning rice husk. This screening report is completed in respect to the interviewing of 151 individual household representatives in Takeo (Tramkak district) and Kampot (Chhuok and Dang Tung districts). Besides the interviews, the team visited house and field to make cross-checks and also conducted group discussions and meetings to review the impact of the project on environment and other related-issues with villagers and commune chiefs.

This screening report applies to a project to fill the terms of reference of the feasibility study on which a pilot investment project will be demonstrating and testing the production and use of biochar as a soil amendment in cropping systems directly incorporated into soil or through its addition to other biomass products and biofertilizers in Cambodia.

9.2. DESCRIPTION OF THE PROJECT

As part of the support to the Greater Mekong Sub-region (GMS) regional cooperation program in agriculture implemented by the GMS working group on agriculture (WGA) ADB support the Capacity Building Technical Assistance (TA) 7833: REG Capacity Building for Efficient Utilization of Biomass for Bioenergy and Food Security in the GMS. The TA provides support for activities in Cambodia, Laos PDR, and Viet Nam with an expected impact of “the improved use of biomass” through the “efficient operation of pilot biomass utilization projects”. Terms of Reference for ADB TA7833 – Feasibility study for a Pilot Investment to Demonstrate the Use of Biochar Enhanced Products in Two Provinces of Cambodia.

The proposed project will be implemented in Takeo (Tramkak) and Kampot (Chhouk and Dang Tong). These 2 provinces are represented in 2 different characteristics of agro-ecological regions (AEZs) of Cambodia (Takeo in floodplain versus Kampot in Coastal). The population of Tramkak, Chhouk and Dang Tung is 34,138 households (152,170 people), 12,178 households (54,261 people) and 22,650 households (99,587 people) (Census 2008). The most important farming activities are rice, vegetable, livestock and other crops.

Rice husk (1.8 million tons per year) and rice straw (26.2 million tons per year) have a huge potential for the production of biochar in Cambodia. If a minimum 20% biochar can be obtained after gasification, Cambodia would have 5.6 million tons of biochar and 3.4 million kWh net electricity.

The scope of this project will be limited to testing low cost kiln and gasifier to produce Biochar for the inclusion in cropping systems linked to existing organic rice and vegetable production, SRI rice production, and maize.

Biochar supply technologies:

a) To speed the implementation of the pilot demonstration, biochar will be purchased from large rice mills in Takeo, Kampot and Kandal provinces. Size of each plot from the 330 demonstration will be calculated using a minimum of 10 metric tons per hectare. A total of 130 tons of biochar would be needed – 100 tons for 100 rice plots of 500 m^2 of rice, 15 tons for 50 plots of 200 m^2 of vegetable and 15 tons for 30 plots of 500 m^2 of maize.
b) Currently, the Department of Agriculture Engineering (DAEng) has technology from Japan - the Kuntan kiln, and has copies of the low cost Laos technology and the oil drum model from Viet Nam. DAEng has been producing biochar from rice husk using the Kuntan Kiln, and has concurrently added some of the Kuntan kiln technology into the Viet Nam drum kiln. The cost of each adapted unit is US$1,000. The DAEng will (i) continue development work on local biochar kiln designs, (ii) provide training of trainers for the Kuntan Biochar Kiln – a total of 30 trainers will be trained, and (iii) make the

contract for the construction of 10 biochar kilns for the distribution to participating end users.

Biochar soil amendment products:

a) DAEng will work on technical input to specify formulations for bio-products to be included in the demo plots and to review the bio-fertilizer sector and enterprises involved in the import, purchase and manufacture of bio-fertilizer. The potential to label, and distribute products more widely through such channels will be assessed. It is envisaged that biomass related by products including biochar and treated bio-slurry would be tested and evaluate the results and adaption.

Farm Demonstrations:

a) DAEng Tramkak District: Rice, vegetable and maize. DAEng in collaboration with PDA Takeo will implement pilot demonstrations in 10 villages of 3 communes in Tramkak district, Takeo province. The three selected communes have a large number of bio-digester units already installed with the support from SNV Netherlands Development Organization in Cambodia. The slurry from the bio-digester will be mixed with biochar for rice, vegetable and maize. A total of 100 rice demonstration (500 m^2 each) plots, 50 vegetable demonstration plots (200 m^2 each) and 30 maize demonstration plots (500 m^2 each) will be organized in these 3 selected communes in Tramkak district. A total of 20 kilns will be produced by DAEng of which 10 units will be distributed to rice mills of the target villages of CEDAC for the same purpose.
b) CEDAC will implement pilot demonstration in 21 villages of 10 communes in Chhouk and Dang Tung districts. CEDAC will implement 100 demonstration plots (500 m^2 each) of SRI rice and 50 demonstration plots (200 m^2 each) of organic vegetable. A total of 10 units of kiln will be distributed to rice mills in the two selected districts for the production of biochar.

9.3. DESCRIPTION OF THE ENVIRONMENT

There is not much different in terms of soil types in the 3 different districts. However, respondents prefer to divide in 3 main categories of soil types for rice paddy: Firstly, sand (17%) covers many paddy rice field and cash crop such as water melon and corn. It classifies as very poor fertility of soil type. Rotation is applied between rice paddy and cash crops due to low land size for cultivation. It needs to add more fertility when the time of cultivation. Secondly, silt (54%) covers most of the field of agricultural activities (rice paddy, vegetable and crops). It classifies as medium soil fertility. It needs to add less fertilizer when cropping is applied. Thirdly, segment (30%) covers mostly the cultivated land close to home in the villages and the paddy with deeper than other land around. It classifies as very good soil type. For rice cultivation, if there is enough water, the yield will be good with no need to add any fertilizer. Clay-in somehow clay soil type is very few only vegetable fields and no for rice paddy in the area.

The application of fertilizer varies in terms of amount and method of use. The amount of using depends on the:

i) distance of the rice paddy;
ii) types of soil; and,
iii) affordability of family.

It tends to use both animal manure and chemical fertilizer if the paddy is close to the village and use only chemical fertilizer if the paddy far from villages. The application is 1.4 t/ha and 0.12 t/ha in average animal manure/compost and chemical fertilizer respectively. The amount of chemical fertilizer application in this study is similar to Vietnamese farmers apply 0.122 t/ha which is much lower in China was 0.24 t/ha. It is good for farmer practices at the study area by using both types of fertilizer-animal manure/compost and chemical fertilizer together for being supplementary to each other.

Pesticides/Herbicides application is not the top priority of farmers' concerns due to the study areas it doesn't have many farmers use it for rice paddy. Only one case found during the study using the herbicide on the rice paddy. They don't use any insecticide or pesticide for rice, except for vegetables. However, the using doses and methods are not clear that needs to be considering for further observation.

Most of households in the studying area drink water from drilled tube wells or hand dug open wells situated near the household. There is no problem with drinking water. One of the top priorities of the farmers' issues is rice paddy irrigation. Rice paddy irrigation totally depends on rain water in case of the studying areas. The proposed project is no affected on this case.

100% of respondents are involved in rice cultivation. The production is used mainly for home consumption plus save small amount for replanting in the next season (75%) and for sale (25%). Cattle manure/compost which they save during the dry season was transported to the rice paddy close-by the villages in the early wet season, spreading as basal fertilizer before the first plowing was applied. The paddy was plowed at least twice before planting the rice seedlings. There was 2 types of chemical fertilizer applied in 2 different periods of time, using DAP as basal and urea or other types fertilizer as top dressing.

There are 70% of respondents planting vegetables (more than 10 varieties) for home consumption (30%) and extra cash income (70%). Vegetables were planted on the upper land such as around the house, on the bank of pond and some cases on the rice paddy land after rice was harvested. Animal manual/compost was mostly applied much more than chemical fertilizer. It experiences little use of insecticide/pesticide for vegetables.

Approximately 44% of respondents are involved in corn, 26% cultivation for home consumption and 74% sale. Except the red corn, all of its yields were for sale. When corn grains were sold, the plant biomass was left over on the field as residues. This residue is waste because it is not effectively managed by the farmers. Approximately 50% of the weight of the total corn plant is residue, consisting of stalk, leaf, cob and husk. About 4-6 t/ha is left over the field. It is a huge potential to use this kind of residue for gasification to produce syngas and biochar with sound friendly to environment.

It is clear that farmer don't have much rice husk at the household level because i) they sell the rice and the whole rice grains and ii) they take the rice to mill at the rice millers' place and not bring any rice husk back. The rice husk is left over at the rice millers'. Few rice millers usually sell the rice husk to the neighboring clients while other rice millers just burn it out in the open air. The rice milling neighbors used to complain to the millers on the smoke and dust from the piles of open burning rice husk. It is enough to say the rise husk is not used effective and in efficient manners. Besides the complaints of the neighbors, the burning of rice husk is fragile to the environment by causing the pollution and greenhouse gas emissions. There are no local (small, medium and large scale) producers and/or providers of biochar are found in this study.

Approximately 15% of the respondents experienced practicing in burning rice straw with the main purpose for being easy to plough (61%) for the next cycle of cultivation and getting the mineral for paddy (9%). Actually, it is not getting the benefit from this burning in contrast it is a bad effect because i)-produces smoke and ii)-after burning the ask flies away due to the wind. It will leave the paddy empty. As the result, it is smoky and dusty. The bottom part of rice straw leaves at the field. A couple cases, farmers cut and collect rice straw (bottom part) from the paddy for being used in mushroom cultivation. In general, this kind of rice straw leaves on the paddy field for cattle grazing. Some parts of this kind of rice straw fly away by the wind power when it is decayed as small pieces of its proportion. It is very few decaying and returning to the soil. So, it is a kind of waste for this residue.

9.4. SCREENING OF POTENTIAL ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

Simply put, biochar is the carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air. In more technical terms, biochar is produced by so-called thermal decomposition of organic material under limited supply of oxygen (O^2), and at relatively low temperatures (<700°C)[28]. Four complementary and often synergistic objectives may motivate biochar applications for environmental management: soil improvement (for improved productivity as well as reduced pollution); waste management; climate change mitigation; and energy production, which individually or in combination must have either a social or a financial benefit or both. As a result, very different biochar systems emerge on different scales (see Chapter 9). These systems may require different production systems that do or do not produce energy in addition to biochar, and range from small household units to large bioenergy power plants.

The proposed pilot demonstration is to introduce the biochar as soil amendment on rice, vegetable and corn production aiming at improving crops' productivity, improving soil fertility and better utilization of existing farm resources. Generally there is a great positive impact of using biochar for crop production rather than negative impact.

The rice husk biochar, increased yields of rice grain and straw by 30% and 40%, respectively; but there were no differences between biochar produced in a downdraft gasifier compared with that from a rice dryer, nor between urea and biodigester effluent as N fertilizer. Biodigester effluent increased rice grain yield more than urea in the absence of biochar, but there were no differences between the two fertilizers when biochar was applied. Biochar increased soil pH, water holding capacity and cation exchange capacity. These criteria were not affected by the source of N fertilizer, nor by the source of the biochar[29].

A number of trials conducted by CelAgrid team showed that when increasing the application of biochar from 0 to 5 kg/m^2 led to linear increases in biomass DM yield of 39, 100, 300 and 350 % for Water spinach, Chinese cabbage, Celery cabbage and Mustard green, respectively. Soil quality was improved after the 35 day trial (pH 6.82-7.13; OM 22.6 - 25.7%). The chemical composition of the biomass DM showed average increases in crude protein from 13.7 to 18.1% for leaves and from 7.23 to 9.16 for stems. By contrast, crude fiber in leaves decreased from 14.5 to 9.27% in DM while in stems it fell from 15.6 to 10.7%[30].

Farmers using diluted human urine as a replacement for chemical fertilizer. In plain soil, it was found that a 15% solution of sanitized urine and water added to soil produces a sorghum yield of 205kg/acre, 51% less than the yields observed with chemical fertilizer. On its own, sanitized urine is not a viable replacement for chemical fertilizer. When this same urine treatment was applied to soils amended with biochar (at a rate of 6,000 kg/acre), we recorded a sorghum yield of 1,025 kg/acre.[31] This represents a 144% increase relative to chemical fertilizer.

The majority (62–66%) of these GHG emission reductions were realized through C sequestration within the soil. Gaunt and Lehmann (2008)[32] found that when biochar was applied to agricultural land, the potential reduction in GHG emissions was between 2 and 5 times greater than when it was burned to offset fossil fuel usage. These potential reductions in GHG emissions following

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[28] Johannes Lehmann and Stephen Joseph 2009. Biochar for Environmental Management. Science and Technology

[29] Huy Sokchea, Khieu Borin, Preston, T. R. 2013. Effect of biochar from rice husks (combusted in a downdraft gasifier or a paddy rice dryer) on production of rice fertilized with biodigester effluent or urea. http://www.lrrd.org/lrrd25/1/sokc25004.htm

[30] Chhay Ty, Vor Sina, Khieu Borin and T R Preston 2013. Effect of different levels of biochar on the yield and nutritive value of Celery cabbage (*Brassica chinensis var*), Chinese cabbage (*Brassica pekinensis*), Mustard green (*Brassica juncea*) and Water spinach (*Ipomoea aquatica*). **http://www.lrrd.org/lrrd25/1/chha25008.htm**

[31] Jason 2013. The Longterm Impact of Biochar in Soil (Season 2). http://www.re char.com/2013/01/24/the-longterm-impact-of-biochar-in-soil-season-2/

[32] Gaunt, J.L., Lehmann, J., 2008. Energy balance and emissions associated with biochar sequestration and pyrolysis bioenergy production. Environmental Science & Technology 42, 4152e4158.

biochar application to soil are primarily due to the sequestration of carbon (C) within the soil (Roberts et al., 2010)[33], with other potential reductions due to savings in fertiliser requirement, reductions in fossil fuel usage, and reductions in soil emissions (Gaunt and Lehmann, 2008). Biochar application to agricultural soils has the potential for long-term C sequestration, due to the stability of biochar in soil environments. Biochar is composed of a range of different forms of C, from recalcitrant aromatic ring structures, which can persist in soil for millennia, to more easily degradable aliphatic and oxidized C structures, which mineralize to CO^2 more rapidly through degradation by biotic and abiotic oxidation (Liang et al., 2008)[34].

Both the mineral and the organic components of soil influence water holding capacity. Although higher levels of soil organic matter increase water-holding capacity and can be deliberately managed, changes will be temporary unless a regime is maintained. Glaser et al. (2002) reported that water retention in terra preta was 18% higher than in adjacent soils where charcoal was low or absent, and likely a combined consequence of higher biochar content and higher levels of organic matter that appear to be associated with charcoal in these soils. As biochar is broadly stable in soil, it has the potential to provide a direct and long-term modification to soil water holding capacity through its often macroporous nature, reflecting cellular structures in the feedstock from which it is typically produced.

Although Pyrolysis or other biochar production methods should not raise any unique health and safety issues and the Health and Safety Executive (HSE) does not anticipate that expanded use of such technologies requires much change to regulatory practices (HSE, 2006)[35]. Under certain conditions, and if the feedstock has a high silica content, pyrolysis might result in the formation of crystalline particles. Inhalation of crystalline silica is associated with silicosis and relevant precautions would be required to minimize exposure. Consideration of human health impacts from inhalation of small particulates would also be required during handling, transport and application (Collison et al., 2009)[36].

9.5. INSTITUTIONAL REQUIREMENTS AND ENVIRONMENTAL MONITORING PLAN

This project, in fact benefits to a positive environmental effect and therefore it is necessary to plan for the environment assessment after this initial environment assessment.

9.6. PUBLIC CONSULTATION AND INFORMATION DISCLOSURE

During the group meeting, participants were given an opportunity to ask questions and exchanged their common concerns about the proposed project. However the most positive impact is when using remained rice straw in the field for the biochar production as they normally burn it in the open air.

9.7. FINDINGS AND RECOMMENDATION

No major concern of negative impact on the environment of using rice husk and rice straw for biochar production. The availability of rice husk might be a concern as reported earlier that farmers mill each time a small quantity of paddy for just 7-10 days consumption. Although most expressed their positive attitude in using straw remained in the field for biochar there are farmers who still

[33] Roberts, K.G., Gloy, B.A., Joseph, S., Scott, N.R., Lehmann, J., 2010. Life cycle assessment of biochar systems: estimating the energetic, economic, and climate change potential. Environmental Science &Technology 44, 827e833.
[34] Liang, B., Lehmann, J., Solomon, D., Sohi, S., Thies, J.E., Skjemstad, J.O., Luizao, F.J., Engelhard, M.H., Neves, E.G., Wirick, S., 2008. Stability of biomass-derived black carbon in soils. Geochimica et Cosmochimica Acta 72, 6069e6078.
[35] HSE (2006). The Health and Safety Risks and Regulatory Strategy Related to Energy Developments: An expert Report by the Health and Safety Executive Contributing to the Government's Energy Review, 2006. Health and Safety Executive. London
[36] Collison, M., Collison, L., Sakrabani, R., Tofield, B., and Wallage, Z. (2009). Biochar and Carbon sequestration: A Regional Perspective. Low Carbon Innovation Centre, UEA, Norwich.

think that removing the remaining straw from paddy fields might have a negative impact on the soil fertility. Therefore, it is important to consult again with farmers and get those with real interest to pilot the demonstration. It is recommended that this project proceeds for the pilot demonstrations in the selected villages.

9.8. SUMMARY INITIAL ENVIRONMENTAL EXAMINATION REPORT

The proposed project on which a pilot investment project will be demonstrating and testing the production and use of biochar as a soil amendment in cropping systems directly incorporated into soil or through its addition to other biomass products and biofertilizers in 3 districts of Takeo and Kampot.

There is a huge potential residue of fibrous biomass from rice of both rice husk and rice straw for gasification to produce the biochar. This is expected that it would help farmers to increase their crop productivity, make efficient utilization of crop residues in terms of environment health and economic return to the family. There is no concern to the negative environmental impact in this proposed project.

10. RISKS AND UNCERTAINTIES

Biochar has the potential to contribute to the climate change mitigation and agricultural productivity improvement. In terms of the sustainability of biochar production and use, the sourcing of the feedstock, manufacture, and application needs to be considered to ensure that there is a net positive impact when environmental, social, and economic perspectives are considered. Another effect would be the unintended adverse agronomic consequences that may occur upon application of biochar to soil, and social injustices that could result from land use changes based on the potential large-scale commercialization of biochar systems[37]. The ability of biochar to inhibit microbial degradation of some organic molecules could have negative effect on the longevity of chemicals in soil. Most agrochemicals are degraded by various mechanisms including natural microbial systems; therefore, those degraded by microbes may remain in the environment for longer period when biochar is present and could have an effect on off-site and non-target impacts associated with using the chemical[38].

10.1. HUMAN HEALTH RISK

The high temperature decomposition of organic matter can result in the formation of polynuclear aromatic hydrocarbons (PAH) and chlorinated dioxins. Both compounds carry health risks to humans and other organisms. Some PAH are known or suspected carcinogens, and dioxins can be toxic at very low concentrations. The health issue caused by the biochar includes lung cancer or respiratory problems, arising from the contact of humans with biochar particles during the production, movement and application processes[39].

It is clearly indicated that the issues around contamination and human health risks includes volatile organic compounds, carbon monoxide or particulates at different points in the process together with the risks of biochar black carbon becoming airborne; for instance while being applied especially if applied to the surface of the soil. There are also fire hazards including spontaneous combustion of biochar that may be provoked by volatiles in the biochar[40]. This could be associated with the reactivity and flammability characteristics of biochar, which can be accentuated by inadequate storage, transportation and application conditions.

10.2. SOCIAL AND ECONOMIC RISKS

Due to the land use change, the same risks that apply to biofuels production apply to biochar production. Large plantations used to produce biochar feedstock, and the substitution of bioenergy crops on land historically used to produce food crops carry social and economic risks. Although biochar advocates may recommend practices to prevent land use change or exploitation of resources that present unintended social or environmental impacts, the financial incentives of biochar manufacture have the potential to motivate project managers to overlook such factors. The potential for biochar is large; there is only a specific area of land available without compromising food production[41]. As the market for these products expands, land use and other resources may be affected. To minimize production and transportation costs, an extensive life cycle analysis must be conducted before wide scale biochar application is considered. This will ensure net benefits in

[37] John Swanson and Daniel Richter 2013: Climate-Change Mitigation Potential of Biochar: A Review and Framework for Carbon Accounting. Masters project submitted in partial fulfillment of the requirements for the Duke Environmental Leadership Master of Environmental Management degree in the Nicholas School of the Environment

[38] Jessica Sparkes and Peter Stoutjesdijk 2011: Biochar: implications for agricultural productivity. Research by the Australian Bureau of Agricultural and Resource Economics and Sciences. TECHNICAL REPORT 11.06 December 2011

[39] *http://biocharbraf.wordpress.com/faqs/*

[40] *http://www.econexus.info/publication/biochar-knowledge-gaps*

[41] Moreira, J 2006, 'Global biomass energy potential', *Mitigation and Adaption Strategies for Global Change 11: 313.*

agricultural productivity and carbon sequestration are realized, while minimizing the effects on global food security.

10.3. SOIL ALBEDO

Due to the ability of biochar to darken the color of soil, especially in soils already low in organic matter, biochar application to soil increases solar energy absorption and decreases soil albedo. Biochar addition may also increase soil temperatures. The increase in soil temperature and decrease in soil albedo could potentially accelerate cycling of nutrients and extend growing seasons in temperate climates; however, with large-scale application of biochar, it also has the potential to decrease the albedo of the earth's surface that potentially contributes to the climate change. The increasing surface albedo has been proposed as a possible mitigation measure for climate forcing[42]. The decrease in soil albedo will have the greatest impact when biochar is applied to light-colored soils with spring cropping regimes, or applied to orchards or vineyards that experience large periods of time with little ground cover[43].

10.4. SOIL RESIDENCE TIMES

Biochar remained in soil with the period of time is another risk that needs to be considered. Evidence suggests that components of the carbon in biochar are highly recalcitrant in soils, with reported residence times for wood biochar being in the range of 100s to 1,000s of years, i.e. approximately 10-1,000 times longer than residence times of most soil organic matter. However, this will depend on the type and quality of the biochar applied in the agricultural soil. Adding biochar to soil can provide a potential sink for Carbon. It is important to note that there is a paucity of data concerning biochar produced from feedstocks other than wood. Owing to the current interest in climate change mitigation, and the irreversibility of biochar application to soil, an effective evaluation of biochar stability in the environment and its effects on soil processes and functioning is paramount[44].

Some researchers calculate a biochar half-life in soil of several hundred to thousands of years. Limited field trials have assessed soil residence times over a range of conditions and biochar types. The limited field studies completed, have found that finely ground biochar slowly disappears from the soil, provided it is not transported from the site through erosion. It is estimated that less than 3% of biochar is lost through mineralization over a 2-year period[45]. They also noted a slow migration rate of biochar to the subsoil and significant loss of fine biochar through erosion during high rainfall events.

10.5. SOIL ORGANIC MATTER

Researchers are concerned that it may lead to accelerated decomposition of plant derived soil organic matter through the biochar addition. Evidence suggested that adding biochar increases soil organic matter decomposition rates and may lead to decreased crop productivity in the long-term. Conversely, adding organic matter and biochar together did not result in faster organic matter mineralization rates[46]. The research was done to verify whether the addition of biochar to the soil affects the degradation of litter and of soil organic matter. The results indicate that the effect of

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[42] Crutzen, P.J., 2006. Albedo enhancement by stratospheric sulfur injections: A contribution to resolve a policy dilemma?. Climatic Change 77, 211-219.

[43] Verheijen, F, Jeffery, S, Bastos, AC, Van Der Velde, M & Diafas, I 2009, Biochar application to soil; a critical scientific review of effects on soil properties, processes and functions, EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg.

[44] Verheijen F, Jeffery S, Bastos A C, van der Velde M and Diafas I 2010: Biochar Application to Soils: A Critical Scientific Review of Effects on Soil Properties, Processes and Functions.

[45] Major, J, Lehmann, J, Rondon, M & Goodale, C 2010: Fate of soil-applied black carbon: downward migration, leaching and soil respiration, Global Change Biology 16(4): 1366–79.

[46] Kimetu, JM and Lehmann, J 2010: Stability and stabilisation of biochar and green manure in soil with different organic carbon contents, *Australian Journal of Soil Research* 48(6–7): 577–85.

biochar on the straw mineralization was small and non-significant. Without biochar, 48% of the straw carbon was mineralized within the 451 days of the experiment. In comparison, 45% of C was mineralized after biochar addition of 1.5 g/kg. The organic matter mineralized more slowly with the increasing doses of biochar. Adding the biochar at 7.7 g/kg reduced soil organic matter mineralization from 6.6 to 6.3%. The addition of 15.5 g/kg of biochar reduced the mineralized soil organic matter to 5.7%. There is no evidence of increased degradation of either litter or soil organic matter due to biochar addition; consequently, there is no evidence of decreased stability of soil organic matter[47].

[47] Bruun, Sander, and EL-Zehery Tarek 2012: Biochar effect on the mineralization of soil organic matter. Journal of Pesquisa Agropecuária Brasileira vol 47.