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Competitive Research Grant

Sub-Project Completion Report
on

Development of a Business Model on Crops and Cattle for Low Carbon Farming Technique: An Initiative for Farm Level in Coastal Region of Bangladesh

Project Duration

May 2017 to September 2018

Bangladesh Agricultural University Research System (BAURES)
Bangladesh Agricultural University, Mymensingh-2202

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Acronyms

AEZ	=	Agro-Ecological Zone
AR4	=	Assessment Report 4
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BDT	=	Bangladeshi Taka
BLS	=	Bacterial Leaf Steak
BMDC	=	Bangladesh Meteorological Development Corporation
BRRI	=	Bangladesh Rice Research Institute
CEGIS	=	Center for Environmental and Geographic Information Services
CH_4	=	Methane
DAE	=	Department of Agricultural Extension
DSSAT	=	Decision Support System for Agro Technology Transfer
FAO	=	Food and Agricultural Organization
IPNS	=	Integrated Plant Nutrient System
LCF	=	Low Carbon Farming
GDP	=	Gross Domestic Product
GHG	=	Green House Gas
GOB	=	Government of Bangladesh
IDCOL	=	Infrastructure Development Company Limited
IFDC	=	International Fertilizer Development Centre
IPCC	=	Inter-governmental Panel of Climate Change
MOFE	=	Ministry of Forest and Environment
NGO	=	Non-Government Organization
RCBD	=	Randomized Complete Block Design
SAARC	=	South Asian Association for Regional Co-operation
SMRC	=	SAARC Metrological Research Centre
SRES	=	Special Report on Emissions Scenarios
UNDP	=	United Nations Development Program
WB	=	World Bank

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Executive Summary

Cultivation of rice releases significant amounts of GHG into the atmosphere, thus contributes to climate change. Fortunately, there are techniques for reducing GHG emissions from rice cultivation. The many of which can also directly benefit the small-holder rice farmers who are the primary producers of rice in Bangladesh. The study on development of a business model on crop-cattle integration for low carbon emission technique was therefore aimed to address two urgent global priorities: (1) reducing emissions of greenhouse gases (GHGs) far below their business-as-usual trajectory by modifying existing rice paddy field management practice and (2) enabling poor and near-poor rice farmer populations to integrate cattle in rice farming system using cattle manure-based unconventional enterprise. To mitigate climate change, the role of low carbon farming (LCF) practice by bio-gas production and manure management for organic fertilization was also assessed under this study. The study was conducted in the Greater Khulna region of Bangladesh.

By reducing chemical fertilizer and pesticide/herbicide, farmers were able to reduce both input costs and the release of two separate GHGs (methane and nitrous oxide) by soil carbon storage. The study found that the organic carbon sequestration would increase from 0.95 % to 1.25% by LCF. The reduced cost of farm inputs significantly improved farm profitability. The estimated farm income after new business model was BDT 4,73808 which was 185-fold higher than the traditional business as usual practice without integration. And by rigorously quantifying GHG emission reductions, LCF will generate “carbon credits” that can then be sold to offset GHG emissions elsewhere, generating funds that are returned to participating farmers, thereby increasing their incomes in future. The scores of the adaptation dummy provide strong significant evidence that the adaptation strategies undertaken by farmers were correlated with returns to land and ensured 10 percent higher income. After reviewing contemporary literature it was also found that the application of single mitigation practices like improved feed quality and improved animal health can result in reductions of emission intensity ranging from 36% to 3%, depending on the intervention and production system. LCF would be a viable model to improve the livelihoods of rice farmers and to build community capacity.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project:**
   Development of a Business Model on Crops and Cattle for Low Carbon Farming Technique: An Initiative for Farm Level in Coastal Region of Bangladesh

2. **Implementing organization:**
   Bangladesh Agricultural University Research System (BAURES), Bangladesh Agricultural University, Mymensingh-2202

3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s):**

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4. **Sub-project budget (Tk):**
   4.1 Total: BDT 25000000
   4.2 Revised (if any):

5. **Duration of the sub-project:**
   5.1 Start date (based on LoA signed): 8 May 2017
   5.2 End date : 30 September 2018

6. **Justification of undertaking the sub-project:**

   The adaptation of farming to climate change is gaining importance in policy and scientific debates as almost all farm activities and production depend on weather and, therefore, are climate sensitive. Recently, the adverse impacts of climate variability and change on traditional farming are visible in developing countries. This bio-physical change in the production environment has directed farmers towards strategic alternatives for farming practices. In fact, Bangladesh is ranked number five in world vulnerability index (Kreft and Eckstein, 2014). The country‘s coast is one of the longest in the world (5107 km), and the area is ecologically sensitive and climatically vulnerable. The erratic weather events drastically reduce milk yields and fish production. Crops like rice, wheat, pulses and rape seeds are also susceptible to infestation of pests and diseases in weather under the effects of climate change (Rashid and Islam 2007).

The Master Plan for Agricultural Development in the Southern region of Bangladesh was prepared by the Ministry of Agriculture (MoA) and FAO in 2013. The National Plan for Disaster Management (2010) was prepared by the Ministry of Disaster Management & Relief (MoDM&R) to reduce the risk of people, especially the poor and disadvantaged, from the effects of natural, environmental and human induced hazards. The national-level strategic plans such as the Five Year Plans and Perspective Plan have been formulated by the General Economic Division (GED) of Planning Commission. More recently, the 17 Sustainable Development Goals with 169 targets, is a new global agenda and Bangladesh is highly committed to meeting these goals. However, the challenge lies in integrating these sectoral, national and global targets and plans into long term coherent strategies taking climate change and future demands into account, as well as in effective implementation of the needed interventions in a well-coordinated manner. Due to the large uncertainties with respect to climate change and socio-economic development, planning is being enriched with adaptive and mitigation strategy making in several deltas in the world. Rather than providing linear recipes, robust and flexible strategies and measures have been taken, with strong institutions and a good knowledge base that allows policy makers and stakeholders to anticipate and decide on the most appropriate investments. Learning from these international experiences, BDP 2100 has been similarly developed in light of the many possible future paths that are possible, and is designed to be changed over time as new information becomes available or policy priorities change.

Moreover, in developing countries, environmental pollution and access to energy sources still represent challenges, especially in relation to human and environmental health and economic development (Ahuja and Tatsutani, 2009). Energy influences the status and pace of development; hence, a current challenge for the developing world lies in the available supply of affordable and sustainable eco-friendly renewable energy (SDG-7). Energy poverty is exhibited by a lack of access to electricity and clean cooking facilities, which are two elements that are essential for meeting basic human needs (Roubík *et al.,* 2018). The demand and supply of energy is greatly imbalanced and creates an anarchic atmosphere in Bangladesh society. Fossil resources are often used to mitigate the current imbalance of demand and supply of energy. But fossil fuels are being rapidly depleted in Bangladesh due to over-exploitation for the purpose of mitigating existing difficulties (Kabir *et al*., 2013). In this situation, the renewable energy portion of total energy production should play a significant role in Bangladesh along with global development but is far behind its potential.

Bio-gas is one of the potential renewable energy sources in Bangladesh. As an agro-based economy Bangladesh is endowed with plentiful necessary resources that could be used for generating clean and renewable energy in the form of biogas through anaerobic decomposition. Cow-dung has often been applied as a raw material into biogas digesters to produce the biogas, which results in not only gas and bio fertilizer production but also provides other social, economic and environmental benefits including improvement of women's and children's health, improvement of soil fertility, reduction of CO_2 emission, income generation, reducing deforestation, better sanitation, reducing air and water pollution and reduction of imported fuels (Ni and Nyns, 1996; Chapagain, 2011).

Current climatic condition in seeking to end climate change impact in all its forms at farm level adaptation and low carbon farming techniques are required with respect to multi-disciplinary business model development. This research project was undertaken to introduce climate stress tolerant rice varieties and cattle production technique through community-based approach by bio-gas plant and utilization of residues from livestock waste for cropping. The deficiencies and policy options were identified so as to inform the development of robust measures.

7. Sub-project goal:

Crop-cattle integration business model development for sustainable low carbon farming (LCF) technique using cattle manure for bio-gas and bio-solid production

8. Sub-project objective (s):

i. To document the low carbon emitting farming techniques and determine soil carbon sequestration by low carbon farming (LCF) in rice production.
ii. To develop business model on crop-cattle combination for economic and environmentally sustainable farming through bio-gas production, marketing and use of bio-solid as soil amendment with IPNS fertilization.
iii. To formulate climate change mitigation policy for improving farm adaptation capacity.

9. Implementing location (s):

Bagherhat, Khulna and Sathkhira

10. Methodology in brief:

(a) Approach

This research was conducted with the joint collaboration of two Departments of Bangladesh Agricultural University namely, Department of Agricultural Economics and Department of Environmental Science. There were two research components of the study. The Department of Environmental Science basically examined and analyzed field agronomy of soil carbon sequestration of LCF from the experiments in field. The Department of Agricultural Economics performed socio-economic analysis based on farm survey. The sample farmers were selected from the coastal districts of Bangladesh that included Bagherhat, Khulna and Sathkhira on the basis of mixed crop-cattle farming system and climate change prone area. From each district at least one upazila was selected purposively and the study locations were considered as the concentration of rice-cattle farming and having bio-gas plant under IDCOL management. The IDCOL is a renewable energy extension related company which is selling the bio-gas plant in rural areas.

A multistage sampling technique was used for selecting the sample farm households. In the first stage, two villages from each upazila (Mongla from Bagherhat, Dumuria from Khulna and Sadar from Sathkhira) were randomly selected. The farmers were selected from the 6 villages that had adapted to climate change and participated in the different program for climate adaptation. From each village, 100 adapted farm households were randomly chosen for better representation of the population. In total, 600 adapted farm households were selected for the baseline study that would be considered for core trainees of the LCF technology transfer. The similarities in the socio-economic, agro-ecological zones, production environment and the sample size were considered to be the valid representation of the whole population.

The selected samples were consisted of 300 motivated lead farmers for business model development from 600 core trainee farmers. Participatory community based (CBO) groups were formed to provide knowledge of judicious use of their animal excreta, bio-gas production management and bio-solid production and marketing. Finally, 100 farmers got entrepreneurial assistance for developing and piloting LCF by cattle-crop mix farming out of 300 motivated farmers from the period of July 2017 to June 2018. These 100 farmers were the basis of business model development.

(b) Analytical Framework

(i) Lab-field based research activities

Experimental design and treatments

Different LCF based experiments were carried out at the Department of Environmental Science of BAU under the supervision of Co-PI. The experimental field soil and water sample were collected at specific rice growth stages. In addition, samples were collected before and after rice harvest. All the soil and water samples were analyzed at BAU Central Lab and Environmental Science Lab following stated method. The experiment measured emission of different low carbon farming (LCF) options mostly rice field that used bio-solid for saline soil amendment. Table 1 depicts treatment description for emission trails for different LCF options for crops.

Table 1. Soil amendments and practices

Treatment	Low carbon farming (LCF) options	Rice Boro
T_1	Recommended NPKSZn with no amendments	BINA 8
T_2	50% Recommended NPKSZn with bio-solids amendment (IPNS)	BINA 8
T_3	No NPKSZn, 100% bio-solid amendment	BINA 8

(ii) For field-based research

LCF demonstration and supporting field experiments

At the beginning of research LCF trials were set up at BAU and then the farms were selected (farmers' field) in coastal areas of Bangladesh. The cattle residues were converted into bio-gas and bio-slurry by community management. The bio-gas production was demonstrated at BAU and then by product i.e. bio-slurry was collected and analyzed. After that the business model of low-cost cattle production management was disseminated using the dried bio-solid in crop field. In addition to this, supply chain of stress tolerant seed variety and indigenous cattle rearing inputs were provided to maintain techniques.

The experiments were conducted in dry season (Boro), December 2017 to June 2018 at 3 locations under the districts of Bagherhat (Mongla), Sathkhira (Sadar) and Khulna (Dumuria). The experimental treatments were T_1: recommended 100% NPKSZn no amendment, T_2: 50% NPKSZn+ remaining NPKSZn from bio-solids (IPNS) and T_3: no NPKSZn + bio-solids amendment (100%). There were five replications and treatment combinations were 3×5=15. In each site there were 15 plots, in which treatments were distributed following RCBD.

Investigation of soil chemical properties

Soil redox potential (Eh), pH, EC, TDS, iron (Fe) conc. and DO conc. were measured at every fortnight interval during rice cultivation. Soil organic carbon (Walkley and Black method; Allison 1965), total-**N%** (Micro–Kjeldahl method, Keeney and Nelson, 1982), available P (Colorimetric method, Watanabe and Olsen, 1985), available S (by the calcium chloride (0.15%) extraction method, Williams and Steinbergs, 1959) were determined following standard methods. Exchangeable calcium (Ca), sodium (Na) and potassium (K) were extracted from soil using 1M CH_3COONH_4 solution (Jackson and Barak, 2005) and their concentrations in the extract were directly determined by flame photometer. Exchangeable magnesium was extracted by Diethylene Tri amine Penta Acetate (DTPA) solution and its concentration in the extract was determined directly by an atomic absorption spectrophotometer (ASS). At the harvesting stage, soil bulk density was analyzed using cores (volume 100 cm3, inner diameter 5 cm), filled with fresh moisture soils. The collected soil core samples were oven dried at 105°C for 24 h and then measured the weight of dried core samples. Soil porosity was calculated using the bulk density (BD) and particle density (PD, 2.65 Mg m^{-3}) according to the equation: Porosity (%) = (1 – BD/PD) *100.

Storing carbon in the Soil by LCF

As the climate changes, farmers are facing many challenges: more unpredictable rains, soil degradation by salinity intrusions, and new or different pests and diseases. The low carbon agriculture would help farmers adapting climate change because high soil organic matter content and soil cover help to prevent nutrient and water loss. This makes soils more resilient to floods, droughts, and land degradation processes by salinity intrusions.

The farmers working in LCF system by using cattle residue were hard to operate. But this may substantially increase crop resistance to pests and disease. Maintaining this fertility also helps farmers evolve new cropping systems to adapt climatic changes. The overall, organic fertilization enables farmers to minimize risk, as a result of stable agro-ecosystems and yields, and lower production costs.

(iii) Instruments for economic implication analysis

To examine the economic implications of adaptation strategies and performance of integration, data from the field level were used to analyze different farm management analytical tools such as gross margin analysis, net margin analysis, partial budgeting analysis and productivity capacity analysis of resources using the threshold situation as reference that are terms as business as usual. The after-integration performance is called integration of business model to compare. For measuring the optimum management of manure from cattle, the storage facilities for solid manure and dry slurry in bio-gas tanks and portable bio-gas balloon were utilized. In addition to this, for improving the use of manure for nitrogen, a fall in the use of synthetic fertilizer was assessed that would help to reduce the overall NH_3 emission significantly.

The farm-specific indicators were presented using descriptive statistics such as mean, standard deviation, coefficients of variation and the mean difference for testing whether or not the farm performance changes are statistically significant at different thresholds. The LCF performance model was developed from the Mendelsohn *et al*., (1994) that was used by transforming the standard Ricardian empirical model. That relies of formulation of climate variables and adaptation options as follows:

$$LnV= B_0+B_1F+B_2Z+B_3G+B_4\,LCF+ \mu \qquad (1)$$

Where LnV stands for land value, in this study log of returns to land, *F* is vector of climate variables, Z is the set of soil variables, *G* is the set of socio-economic variables and LCF option dummy, μ is an error term. To capture linear for temperature and precipitation, B's are parameters to be estimated with B_0 standing for the constant term and the rest are coefficients. The introduction reflects the linear shape of the response function between business as usual revenue and after integration of model revenue and climate F.

(iv) Environmental policy implication of GHG emission abatement from farming

In order to evaluate best policy option, the policy tools of Kyoto Protocol like imposition of performance standards, incentivizing best-practice measures for agriculture, subsidies for producing and using GHG-reducing energy sources, carbon taxes and trading scheme were tested according to stakeholder's decision of mitigation by descriptive analysis. Matrix of logic and advantages and disadvantage were analysed for environmental policy options.

11. Results and Discussions

Adaptation of low carbon production practice by soil amendments and its effect on rice yield

Soil amendments with bio-solids increased soil porosity, soil organic carbon content, soil pH, exchangeable K and Ca content in Bagerhat, Satkhira and Khulna region field sites, although exchangeable Na decreased significantly (Table 2). Combined application of inorganic fertilizer (50% of recommended NPKSZn) and bio-solids maximized rice grain yield, which may be due to the higher availability of soil nutrients such as exchangeable K, exchangeable Ca, available P and available S to rice plant. On the other hand, soil EC (electro-conductivity) and exchangeable Na content decreased with bio-solids amendment. Therefore, combined application of inorganic and organic manures could be a feasible option for increasing soil carbon storage, nutrients availability to rice plant and sustaining rice yield, while improving salinity level by decreasing EC values in saline soils. Theint *et al.* (2016) reported that gypsum application under saline conditions showed higher EC values compared to those of non-saline conditions. Singh and Singh (2015) observed that cyanobacteria with gypsum decreased EC values in saline soil. Cucci *et al.* (2012) reported also that electrical conductivity (EC) decreased saline & saline sodic soil with the application of gypsum.

Table 2. Treatment wise yield and soil properties after amendment

Locations	Treatments	Grain yield (kg/ ha)	Soil porosity (%)	EC (dS/m)	Soil pH	Org. C%	T-N%	Avail. P (ppm)	Avail. S (ppm)	Exchangeable cations		
										Ex. Na (meq/100 g)	Ex. K (meq/100 g)	Ex. Ca (cmol^{+}kg^{-1})
Bagherhat (Mongla)	**T1**(recommended NPKSZn with no amendments)	4750	43	6.7	7.3	0.95	0.15	25.6	17.7	3.7	0.35	4.9
	T2 (50% recommended NPKSZn with bio-slids amendment)	5060	44	6.3	7.5	1.15	0.13	29.3	20.3	3.3	0.53	6.6
	T3 (No NPKSZn, 100% Bio-solid amendment)	4470	49	5.9	7.8	1.2	0.09	17.7	13.5	2.9	0.51	5.7
Khulna (Dumuria)	**T1** (recommended NPKSZn with no amendments)	6120	45	4.8	7.1	1.10	0.20	30.8	27.6	3.1	0.43	4.6
	T2 (50% recommended NPKSZn with bio-solids amendment)	6240	48	4.6	7.4	1.25	0.17	39.3	30.5	2.9	0.57	7.3
	T3 ((No NPKSZn, 100% Biosolid amendment)	4690	50	4.3	7.6	1.23	0.10	24.7	25.7	2.7	0.49	5.8
Satkhira (Sadar)	**T1** (recommended NPKSZn with no amendments)	5920	44	5.7	7.1	1.07	0.18	28.6	29.3	3.9	0.45	4.1
	T2 (50% recommended NPKSZn with bio-solids amendment)	6130	49	5.1	7.3	1.18	0.15	36.5	25.7	3.5	0.59	6.7
	T3 (No NPKSZn, 100% bio-solid amendment)	4890	51	4.8	7.7	1.25	0.07	23.7	21.6	3.7	0.47	5.6
	LSD	920	4.3	0.8	0.25	0.25	0.01	6.5	3.7	0.95	0.06	1.2
	Level of sig.	*	**	**	*	**	**	**	**	**	**	*

The increased soil organic C stock under combined organic and inorganic amendments indicates the lower C emissions from paddy rice fields to the atmosphere compared to sole organic or inorganic sources. Rajan *et al*. (2012) reported that maintenance of SOM/SOC in cropland is important, not only for improvement of agricultural productivity but also for reduction in C emission. Tanzia and Ali (2017) reported that combined application of gypsum with cyanobacterial inoculum in soils would be a good practice for reducing methane emissions, improving soil nutrients availability to rice plant and also increasing rice yield attributes even under saline stress condition.

Economic implication of crop-cattle integration for climate change adaptation and mitigation

(a) Business model integration performance

Adapting to climate change entails taking the right measures to reduce the negative effects (or exploit the positive ones) by making the appropriate adjustments and changes. Intergovernmental Panel on Climate Change IPCC (2007) defines the adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or effects. It would moderate harm or exploit beneficial opportunities. It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. The adaptation has three possible objectives: to reduce exposure to the risk of damage; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities. In this study, the adaptation and mitigation measures were discussed under crop-livestock integration strategies for LCF. Because, LCF technique mainly based on organic fertilization in crop field instead of synthetic one was well as GHG mitigation from farm operation. The organic fertilization is possible only when cattle components are present in farming system.

Planting of resistant varieties of rice also emphasize on more saline resistant in salinity prone areas that could help in reducing vulnerability to climate change. The solid, dried or vermi-composting are beneficial to soil amendment under salinity. In addition, to this, organic fertilization by solid bio-slurry helps to carbon sequestration in the soil that is a mitigation measure from crop field.

The study found that the use of resistant varieties has been tried by smallholder farmers as adaptation methods to climate change. They also applied mitigation methods using minimum tillage and organic fertilization under community management. These actions are exploiting positive way of remedy from climate change by introducing new business options in farming system of the study area. This would perform business model for profitably operating LCF particularly exploring complementary business enterprise from unconventional by-products of cattle.

In the traditional crop-cattle farming under business as usual model, crops and milk are main products. But, the primary components of LFC based business model are animal excreta utilization for bio-gas and manure marketing. The business model is the value proposition by marketing farm produced bio-gas, vermi-compost and solid bio-slurry. This is a business model of un-conventional farm-based products and the study tests why they are desirable to users. What are the economic implications of LCF based new business model? It is ideally stated in a way that differentiates the products from its merits.

A business model for a new enterprise should cover projected start-up costs and sources of benefits. It targets the base for the business, marketing strategy, a review of the revenues and expenses. Counting costs to the introduction of a product is not enough. A complementary enterprise running until revenues exceeds expenses. Business model may also identify opportunities for partnering with other established businesses. The present study compares business as usual model to new LCF model for partnering by integration. The costs and benefits were calculated in respect of integration of business model in enterprises. The results have been presented in terms of standard income concepts used in farm management analytical tools by Dillon and Hardaker (1980):

Specification and derivation of income measures

The relative performance of enterprises and success of the whole farm business were examined under business as usual situation and new business model case in terms of the following income concepts.

Gross returns:

Gross output was calculated by multiplying the total volume of production of an enterprise by the farm-gate price. For crop enterprise, it consisted of the values of main and by- products. For cattle gross output consisted of the values of main and by-products. Gross returns consisted of the values of main, by-products and net change in inventory.

Gross return = value of main products + value of by-products +change in inventory (closing inventory – opening inventory) closing stock + sold + consumed) -(opening stock + purchased) Dillon and Hardaker (1980)

As mentioned, the income concept used in this study was gross returns. This gross return was estimated for two distinct cases and practices in the study. These are defined as business as usual practice and integration of business model. In the business as usual practice normally three items are observed. They are value of the animals, value of the milk and value of cow dung which are presented in Table 3. In case of business model integration of three items i.e., cow dung stick, vermin-compost and bio-gas were considered as non-conventional by-product. After calculating the gross returns, the value was determined. All the calculations were based on yearly output of five cross bred cows. From Table 3, it could be observed that the value of animals in the opening stocks was BDT 239,281 and closing stock was BDT 383,798. The value of product mainly from milk was estimated to be BDT 4,00,750. The value of milk used for farmer's own consumption was BDT 12,775. From the sale of cow dung, yearly income of the farmer was BDT 8,000 and own use valued at BDT 4,000. The average value of closing stock was to be found BDT 5,800 for the same stock. In the integration of business model, the cow dung stick sold value was estimated at BDT 18,000 per year. Besides, the own use accounted for BDT 14,500 per annum.

Table 3. Gross returns of cattle integration (5 cross- bred milking cows/lactation period)

Items **(BDT /year)**	Business as usual practice			Integration of business model		
	Value of Animals	Value of Product (Milk)	Cow dung (Kg/Year)	Cow dung Stick (KG/Year)	Vermi-compost	Biogas
Opening stocks	239,281	-		-	-	-
Bought	-	-	-	-	-	-
Sold	-	400,750	8,000	18,000	32,500	8,400
Consumed	-	12,775	4,000	14,500	9,500	18,000
Closing stock	383,798		5800	-	-	-
Total net change in inventory	**144,517**					
Gross returns of cattle	1,44,517	4,13,525	17,800	32,500	42,000	26,400
Business as usual practice			5,75,841	Integration of business model		100,900
Total Gross returns						**676,741**

The own used amount of vermi-compost estimated about BDT 32,500 per year under LCF implementation. The integration of bio-gas in business model added BDT 8,400 per year cash income. The imputed benefits after considering own used bio-gas in household would terns about BDT 18,000 per year. It means the new model helps to create income, clean energy and to save fuel by cow dung management.

In addition to this, the bio-gas plant and balloon marketing substantially help to reduce GHG and provide low cost cooking energy in rural areas. The potable bio-gas becomes popular to user. The net change in inventory was estimated to be BDT 1,44,516 for both the cases. The final gross output constitutes by summing up all found BDT 5,75,841 under business as usual model whereas it increased to BDT 676,741 under new business model presented in Table 3.

Gross margin:

Gross margin was derived by subtracting variable cost from the gross output. Sum of the gross margin of the individual complimentary enterprises represented gross margin for the whole farm business. Table 4 indicates that 11% variable cost addition under business as usual practice would help to increase 27 % gross margin by business model integration.

Table 4. Income indicators of business model (5 cross- bred milking cows/lactation period)

Indicators (BDT /year)	Business as usual practice*	Business model**				Incremental benefit or cost (%)
		Cow dung & stick (kG/year)	Vermi-compost	Bio-gas	Total	
Gross output	5,75,841	6,08,341	6,17,841	6,02,241	6,76,741	18
Variable cost	3,53,087	3,58,524	3,67,274	3,74,055	3,93,679	11
Gross margin	2,22,754	2,49,817	2,50,567	2,28,186	2,83,062	27
Fixed cost	56,553	56,553	81,553	1,12,053	1,37,053	142
Net margin	1,66,200	2,61,663	2,27,913	3,16,632	4,73,808	185
Net farm income	1,66,200				4,73,808	185
Operator's labour and management income	84,431	1,79,894	1,44,913	2,32,132	3,88,077	360
Management income	30,431	71,894	39,913	1,24,132	1,75,077	447

**The traditional practice of mono-crop rice farming; **The practice prescribed by the study for LCF, mainly integration of non-conventional cow dung use procedure.*

Net farm income

Net farm income is represented by return to the farm operator for contribution of labor, capital and management. It was calculated by subtracting the selected fixed cost items such as cost of land use, payment for the annually hired labour and depreciation of farm buildings and equipment's from sum of the gross margin for the whole farm business. The new business model needs capital investment for verimi-compost making shed and other structures. Moreover, the bio-gas plant also required one-time investment for at least five-year life span. The net farm income of business model became BDT 4,73,808 from 1,66,200 by increasing fixed cost 185 percent compared to business as usual practice presented in Table 4.

Operator's labour and management income

Operator's labor and management income was derived as the difference between the value of net farm income and imputed opportunity cost of family operating capital. Thus, operator's labor and management income = net farm income-opportunity cost of family operating capital. Table 4 shows that the estimated operator's labor and management income was BDT 84,431 under the business as usual practice which substantially increased to BDT 4,73,808 under new business model consisting all un-conventional components in the system. The table also focused on the proportionate change of operator's labor and management income under business model adaptation.

Management income

Management income representing the final residual income was calculated by subtracting opportunity cost of operator's labor from operator's labor and management income presented in Table 4. The new business model also substantially increases this performance indicator of integration that was BDT 30,431 in business as usual practice and turns to BDT 1,75,077 under business model.

(b) LCF adaptation performance analysis:

A key indicator, returns to land used for LCF performance analysis, is depicted in Figure 1. The mathematical formulae of returns to land could be derived as follows from the farm income indicator:

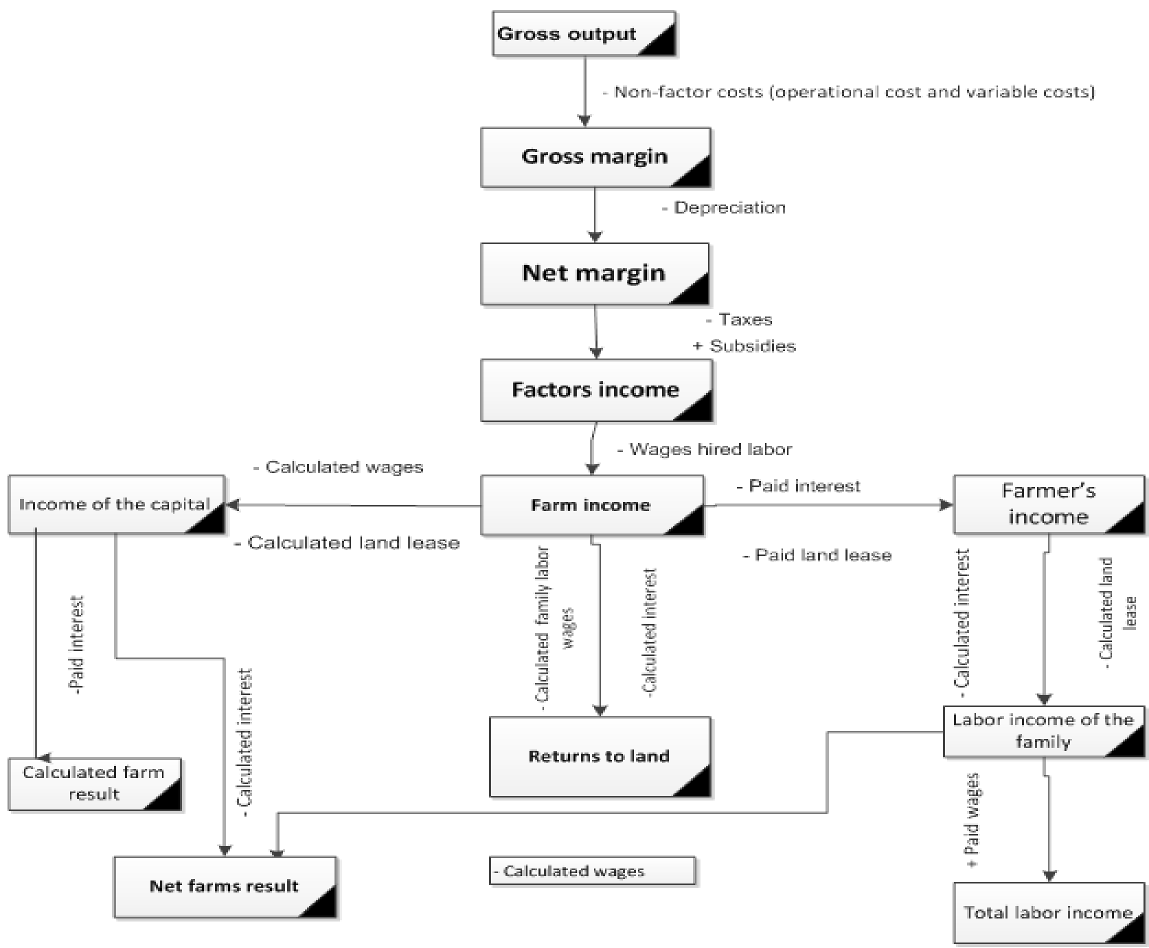
$$Returns\ to\ land = Farm\ income - (calculated\ family\ labor\ wage + calculated\ interst)$$

Van Huylen broeck and Calus (2008)

In this study, returns to land were estimated of baseline period and compared to adapted period. This is also the basis for Ricardian theory of land rent, and the basis for further analysis of the impacts of climate variability and adaptation performance change on farms.

The 'returns to land' indicator effectively represents farm earnings and the impact on land under conditions of endogenous factor endowment for profit maximization subject to exogenous climate stimuli and adaptation dynamics. It is evident from Table 5 that the return to land always moderately high for all district compared to threshold.

Figure 1: Indicators of performance analysis for crop enterprise



Source: Adapted from Van Huylenbroeck and Calus (2008)

Table 5 represents the estimates of the empirical analysis describing the impacts of the climate variability and LCF adaptation on farm returns to land. The crop enterprise profit indicator returns to land depends on climate factors (maximum temperature and precipitation), LCF adaptation and some farm specific socio-economic variables (age of farm owner, education, variety dummy, ratio of fertilizer budget to balance dose).

Table 5 Returns to land at threshold and LCF adaptation (BDT/hac)

Region	Threshold period (baseline 2017)	LCF adapted period (2018)
Khulna	15356	17032.07
Sathkhira	15484	16871.11
Bagerhat	14472	16438.12

The estimates for climatic variables are statistically significant for model specification with log-linear form and fixed-effect equation. The scores of the adaptation dummy provide strong significant evidence that the adaptation strategies undertaken by farmers are correlated with returns to land and responsiveness to climate shocks. Among the farm-specific socio-economic variables the age of the farmer is negative and strongly significant for model. Interestingly, the variety dummy was positive and statistically significant for the *Boro* season. The logic behind the significance in the *Boro* season dummy is that the *Boro* production system applies a high-yielding package including fertilizer and BINA-8 rice variety that is one of the popular salt tolerant rice seed.

Table 6. Variables explaining impacts of climate variability and adaptation options on returns to land using a fixed-effect model

Variables	**Boro Season**
Returns to land per hectare (dependant variable)	
Climate/weather factors	
Temperature Boro season	-0.25***
Precipitation Boro season	0.01***
Adaptation	
LCF adaptation dummy (0/1)	0.10***
Socio-economic factors	0.001
Age of owner	0.0793326*
Education	0.000072
Soil type	0.000098
Variety dummy (0/1)	0.1569749***
Ratio of fertilizer budget to balance doze	0.008***
Constant	16.82***
Goodness of fit indicators	
R^2 Within Between Overall	 0.99 0.93 0.60
F-value (dependable variables, no. of observations-Panels-dv)	229.94 (8, 2091)
Corr. (u_i, Xb) Prob > F	-0.8208 (0.000)
sigma_u sigma_e	0.98 0.0095
rho (fraction of variance due to u_i)	0.98
F test that all u_i=0: F(panels-1, observations-no. of panels-no. of variables) Prob > F =0.0000)	1358.11 (9, 111) (0.000)

****Significant at 1 percent level, ** Significant at 5 percent level, *Significant at 10 percent level*

However, in *Boro* season high-yielding varieties significantly increased the returns to land. The ratio of fertilizer budget to balanced doses showed negative impacts on returns to land, the estimated co-efficient was highly significant. Lastly, age, education and soil type showed insignificant impact on returns to land. From the estimated coefficients of equation 1 marginal impact of climate variables can be observed. In the same way, marginal impacts of LCF adaptation can be calculated. Table 6 shows these marginal impacts of climate variability and adaptation of LCF on rice farm's returns to land based on the empirical models. According to the log-linear model results, an average *Boro* season maximum temperature increase by 1-degree Celsius results in a decrease in returns to land per hectare by 25 per cent from its threshold level for all farms in the sample.

Conversely, for an average precipitation increase of 100 mm, returns to land will increase by 10 percent in the *Boro* season. The season is comparatively susceptible to the climate variability. Therefore, when farmers adopt coping mechanisms with climate change, the marginal impact of the adaptive strategies with LCF may be higher. In fact, the marginal impact of LCF adaptation as measured by the adaptation dummy the empirical model is 10 percent of returns to land which can be achieved by succeeding in *Boro* season. The results of the analyses of the marginal impacts of climate variability and adaptation options suggest that proper coping mechanisms and LCF adaptation strategies can protect farmers from losses from climate shocks.

(i) Environmental policy implication of GHG emission abatement from farming

This part of the study provides policy recommendations on why and how to provide public support to LCF and extension. It outlines options for providing this support, followed by abatement benefits, challenge and feasibility as shown in Table 7. Sources for LCF innovation and climate change mitigation policy support are the key to increase the sustainability, productivity and competitiveness of farming systems under climate variability and conversion to organic fertilization in farming, the crop-cattle integration is a solution to specific local agronomic problems in saline prone coastal areas of Bangladesh. It is one of the main bottlenecks of farmer to convert the traditional rice farming under climate change. Recognition of the benefits of LCF (both by consumers and by policy makers) requires scientific evidence of the positive externalities associated with its production methods and products.

Policy approach

Out of 2.83m ha land in the 13 coastal districts of Bangladesh, about 0.84m ha are affected by varying degrees of soil salinity (Karim & Iqbal, 2015). Agriculture is of great importance for both economy and nature of Bangladesh. The intensification of agricultural production in the country was partly successful due to a substantial increase in the use of fertilizers and pesticides. A range of low-cost mitigation options exists to mitigate emissions coming from agricultural by imposition of performance standards. However, they are mostly restricted to a proportion of the emissions (e.g. methane emissions from cows) and are limited by institutional, social, educational and economic constraints (Knopf *et al*., 2010; Smith *et al*., 2009).

Table 7. Environmental policy matrix of GHG emission abatement by LCF

Policy instruments	Abatement benefits	Challenge &feasibility
Imposition of performance standards	Diversified way of crop-cattle integration & co-benefits	Difficult to design regulatory systems
Incentivizing best-practice measures for agriculture	Adoption of lower emission methods of crop or livestock production	Best solution for developing countries
Subsidies for producing & using GHG-reducing energy sources	Agriculture subsidies would be channelized, home supplied fertilization with manure.	Farm level mitigation possible
Carbon taxes	Benefits will be under risk	Not feasible for agriculture
Trade schemes	Farmers & nation would be benefitted	Feasible is subject to strong monitoring

Emissions and emission intensities from dairy production

The national dairy population is estimated to be 23.44 million cattle and 1.45 million buffalo; with dairy cattle producing 4.7 million litres of milk and buffalo producing 0.08 million tonnes (Khan and Martin 2016). The subsistence dairy cattle production system produces the largest share of milk production, contributing 77 percent of total milk supply from cattle. In the buffalo dairy sector, the extensive and semi-intensive systems contribute 41% and 59% of total 0.08 million tons of milk, respectively. The dairy cattle sector in Bangladesh is responsible for about 52.2 million tons of CO_2 equivalent emission. The GHG profile is dominated by methane (79%) while the contributions of nitrous oxide (N_2O) and carbon dioxide (CO_2) are almost 3% and 18% of the total respectively (FAO, 2017).

The milk production from buffalo adds another 1.3 million tonnes of CO_2. At national level, the emission intensities of milk produced from dairy cattle and buffalo in Bangladesh are 11.1 and 3.2 kg CO_2 eq/kg fat-and protein corrected milk (FPCM), respectively; the highest values were found for the subsistence and extensive systems. The emissions were on average 12.7, and 5.6 kg CO_2 eq/kg FPCM for the subsistence and commercial dairy cattle systems and 4.4 and 2.3 kg CO_2 eq/kg FPCM for the extensive, and semi-intensive dairy buffalo system respectively (FAO, 2017).

Options for improving productivity and enteric methane mitigation

Improving animal and herd productivity is one of the key pathways to reduce enteric CH_4 emissions per unit of product. Reducing enteric CH_4 via increasing productivity is economically viable in most situations; several activities that reduce methane emissions have low or negative economic cost when considering the increase in production. Research findings claimed that there are several technologies that could work for emission abatement. If they are applied comprehensively throughout the sector, they would make a rapid and important contribution for improving technical performance and profitability of dairy production while reducing GHG emissions. Improved practices and technologies like strategic supplementary feeding, and improving the diet quality, improved animal husbandry practices by excreta management using bio-gas plant can improve dairy productivity and reduce emission intensity.

In the assessment of technical abatement options for the main dairy cattle production system, the following criteria were used:

- Interventions had to have potential for improving productivity while at the same time reducing enteric CH_4 emissions per unit of output.
- Interventions had to be feasible in the short or medium term. Feasibility was first determined by sectoral experts and selected interventions had to have already been implemented or in use at least at farm level in Bangladesh.
- A team of national experts to identify key areas to address low productivity in dairy systems should include: (i) improving the quality and availability of feed resources; (ii) strategic feeding and supplementation to address the feed seasonality constraints; and (iii) improved herd management and animal health interventions.

Mitigation of enteric methane can play an important role in food security and climate strategies. This work shows that significant reductions in methane emission intensity can be realized through the adoption of existing and proven technologies and practices. The application of single mitigation practices (e.g. improved feed quality, improved herd health, etc.) can result in reductions in emission intensity (CO_2/kg) ranging from 36% to 3%, depending on the intervention and production system. Deworming in commercial dairy systems increased emission intensity by 1% compared to the baseline. This increase is explained by the reductions in mortality rate and a resulting increase in animal numbers. The impacts achieved are modest because a cautious approach was adopted in the applicability of the interventions. Given the resource constraints faced by the sector, many of the interventions were applied to a subset of the animals (i.e. lactating animals). All interventions returned a positive productivity outcome with increases in production ranging between 4% - 15%. Applying a combination of interventions aimed at improving fertility and reproductive status of the herd; improving feed availability and quality and herd health can potentially result in a reduction potential of 17.5% and 17% in emission intensity relative to the baseline emission intensity. With these combinations of technologies, an increase in milk production of 24% and 27% (in subsistence and commercial system, respectively) can be achieved compared to the baseline situation.

In prioritization of interventions for enteric methane, a preliminary ranking of interventions per production system to identify those with high reduction potential, increased production and high economic return was undertaken to provide an indication of what is workable. Out of the 7 interventions assessed, 4 were considered relevant for the dairy cattle system including supplementation of diet with urea and molasses, feeding a balanced feed ration, fodder cultivation and udder health management. Balancing feed rations based on available feed resources returned the highest impact on all three criteria in both subsistence and commercial dairy systems.

Measures to overcome these barriers are crucial for a LCF. Emission reduction in agriculture could be driven by policy instruments like the EU Nitrate directive and make it an integral part of the wider approach for promotion of the best available practices in agriculture and rural development. Incentivizing these best-practice measures for agriculture is related to public spending that would bear by the nations who are not responsible for the emission. The abatement cost for the incentivizing this practice must come from the Kyoto protocol commitment under Clean Development Mechanism (CDM) that means financing carbon reduction measures. This is the amicable solution and best policy option for developing countries. These measures could bring about a decrease in animal nitrogen excretion, improvement in use of nitrogen in manure and a fall in the use of synthetic fertilizer. All of these have helped to reduce the overall NH_3 emission significantly (Mikkelsen *et. al*., 2014). Some of the measures would be like optimization of manure handling during housing of animals; covering storage facilities for solid manure and slurry tanks that possible by bio-gas plant under business development model; lowering surface spreading and reduction of the time from field application of manure to incorporation; a shorter period of manure spreading has the greatest effect of emissions reductions.

Applying market-based instruments to emissions; the policy issues effort to design and implement market-based policies in the agricultural sector generated two key challenges. The first is to design a policy framework that appropriately aligns the measurement of emissions, the abatement options, and the incentives that would producers face. The second addresses the risk of leakage and economic regrets that arises from unilateral domestic action. The logic for including the agriculture sector in an ETS is two-fold: first, voluntary measures appear unlikely to generate significant emissions reductions and, second, economic theory suggests that exposing all economic activities to a price on emissions can be expected to deliver reductions at optimal long-run efficiency. A possible objection is that beyond some initial low-cost options, the evidence indicates that the potential to mitigate agriculture emissions is low and the abatement costs are high (DeAngelo *et al.,* 2006; Lucas *et al.,* 2007; Beach *et al.,* 2008). Farmers as well as nation would be benefited from this policy options but feasibility of implication depends on strong monitoring.

Although there are many difficulties in the details of mitigation actions in agriculture, a paradigm of climate friendly agriculture based on five principles can be derived from the knowledge about agricultural emissions and carbon sequestration:

- Climate friendly agriculture has to account for trade-offs and choose system boundaries adequately;
- It has to account for synergies and adopt a systemic approach;

- Aspects besides mitigation such as adaptation and food security are of crucial importance;
- It has to account for uncertainties and knowledge gaps, and
- The context beyond the agricultural sector has to be taken into account, in particular food consumption and waste patterns.

Regarding policies to implement such a climate friendly agriculture, not much is yet around. In climate policy, agriculture only plays a minor role and negotiations proceed only very slowly on this topic. In agricultural policy, climate change mitigation currently plays an insignificant role. In both contexts, some changes towards combined approaches can be expected over the next future research agenda.

12. Research highlights/findings:

- The combined application of inorganic and organic fertilizer was found to be a feasible option for sequestration of soil carbon and reducing CO_2 emission in LCF. The organic carbon sequestration was found to increase from 0.95% to 1.25%.

- Combined application of organic and inorganic nutrients increased rice yield. For example, in Khulna sites the highest yield of rice was found with 50% NPKSZn + bio-solids (6240 Kg/ha) compared to other treatments (6120 Kg/ha and 4690 Kg/ha with NPKSZn only and bio-solids only, respectively).

- The practice of organic amendments improved salinity level by decreasing electro conductivity (EC) values in saline soils. EC value was found to decrease from 6.7 ds/m to 4.3 ds/m).

- LCF lowered production costs and enhanced yield, thus improving farm profitability. The estimated farm income after new business model was BDT 4,73808 which was 185 fold higher than the traditional business as usual practice without integration.

- The new crop-cattle mix business model provides supplemental farmer income.

- LCF would be viable model that would improve the returns to land of rice farmers.

- This pilot business model would be fully replicable and designable for scaling up.

B. Implementation Position

1. Procurement

Description of equipment and capital items	PP target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	1. Executive table -1 2. Executive Chair 3.File cabinate-1 4. Front chair-2 5. Computer table-1 6. Computer chair -1 7. Steel Almira-1	80,500	1. Executive table -1 2. Executive chair 3.File cabinate-1 4. Front chair-2 5. Computer table-1 6. Computer chair -1 7. Steel almira-1	80,300	
(b) Lab & field equipment	1. PVC bio-gas ballon-10 2. Gas Blower-10 3. Gas- Chamber-1 4. Bio-Char oven-1	220,000	1. PVC bio-gas ballon-10 2. Gas Blower-10 3. Gas- Chamber-1 4. Bio-Char oven-1	219,800	
(c) Other capital items	-	-	-	-	

2. Establishment/renovation facilities: N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participants			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	46	14	60	5 days	Inception of LCF
(b)Workshop	NA	NA	NA	NA	

C. Financial and physical progress

Fig in Tk

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	403,740	385,982	372,450	13,532	96.00	delay of fund release
B. Field research/lab expenses and supplies	135,9760	135,9760	1358,000	1,760	99.80	Lower bids
C. Operating expenses	300,000	300,000	298,953	1,047	99.66	Lower bids
D. Vehicle hire and fuel, oil & maintenance	200,000	200,000	198,000	2,000	99,00	Lower bids
E. Training/ workshop/ seminar etc.	60,000	60,000	60,000	0	100	-
F. Publications and printing	90,000	-	-	-	-	-
G. Miscellaneous	6,000	6,000	7,167	-1167	119	Bank charge
H. Capital expenses	80,500	80,500	80,300	200	99.95	Lower bids

D. Achievement of Sub-project by objectives: (tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
To document the low carbon farming techniques & determine soil carbon sequestration by LCF in rice production	1. Baseline survey 2. Field agronomy: physical/chemical data collection from experimental and control plots 3. Laboratory analysis: Analysis of soil & gas samples from test plots to determine GHG emission levels	• The combined application of inorganic and organic fertilizer was found to be a feasible option for sequestration of soil carbon and reducing CO_2 emission in LCF. The organic carbon sequestration was found to increase from 0.95% to 1.25%. • Combined application of organic and inorganic nutrients increased rice yield. In Khulna sites the highest yield of rice was found with 50% NPKSZn + bio-solids (6240 Kg/ha) compared to other treatments (6120 Kg/ha and 4690 Kg/ha with NPKSZn only and bio-solids only, respectively). • The practice of organic amendments improved salinity level by decreasing electro conductivity (EC) values in saline soils. EC value was found to decrease from 6.7 ds/m to 4.3 ds/m).	Reduction of GHG emissions from Bangladesh's agricultural sector; Adaptation options under climate change in farm
To develop business model on crop-cattle combination for economic & environmentally sustainable farming	1. Data analysis and business model of LCF generation 2. Testing economic & environmental viability 3. Dissemination of results to solitary farmers 4. Building capacity of LCF practice	• LCF lowered production costs and enhanced yield, thus improving farm profitability. The estimated farm income after new business model was BDT 4,73808 which was 185 fold higher than the traditional business as usual practice without integration. • The new crop-cattle mix business model provides supplemental farmer income. • Bio-gas marketing system through PVC balloon	Improvement of livelihood and income for small-holder farmers and their communities
To formulate climate change mitigation policy for improving farm level adaptation capacity	Marginalized individuals experience for mitigation policy formulation	Adaptation-and-mitigation policy support level in agriculture would be identified from different policy options that give maximum social welfare	Claiming from carbon market offered by the Kyoto Protocol

E. Materials development/publication made under the sub-project

Publication	Number of publications		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	2	-	-
Information development			
Other publications, if any		1 MS thesis	Multi-functionality of livestock in Bangladesh

F. Technology/knowledge generation/policy support (as applied)

i. Generation of technology (Commodity and non-commodity)

A Business Model for Low Carbon Farming (LCF) developed. This is a farming practice of organic fertilization for salinity amendments in soil using bio-solid from bio-gas plant. The model is only feasible when farmers are operating crop-cattle mix farming through better integration of non-conventional by-product of integrated farm.

ii. **Generation of new knowledge that help in developing more technology in future**

Bio-gas marketing with PVC container & bio-solid utilization for fertilization

iii. Technology transferred that help increased agricultural productivity and farmers' income

None

iv. Policy Support

Climate change adaptation and mitigation in agriculture by Clean Development Mechanism (CDM); financing carbon reduction projects

G. Information regarding desk and field monitoring

I) Desk monitoring (description & output of consultation meeting, monitoring workshops/seminars etc.):

The suggestions came from the workshop held on 05 March 2018 are as follows:

- Detail procedure of comparative study of low carbon farming, mixed farming and cattle rearing was advised to be added in the methodology.
- A detail of experimental design of tillage as well as control plots was advised to be given in consultation with soil scientists or experts.
- More detail justification using contemporary literature review was suggested to add for the business model of low carbon farming, mixed crop, and cattle farming.

- The consultation also gave suggestions for measuring technique of components of greenhouse gas (GHG) should be well designed in the methodology. The experiment of high or low carbon emission from application of slurry should also be conducted through the consultation with expert opinion and in-depth experimental survey.
- The study of economic feasibility of PVC gas container and sustainable marketing of slurry/gas was suggested to incorporate into the project. The monitoring team also suggested for detail analytical procedure regarding production technique, labour use, marketing components and end users should be incorporated in the analysis.
- Finally, the monitoring team advised to add bio-solid and bio-char with the slurry to find the expected result of greenhouse gas.

II) Field monitoring (time & no. of visit, team visit and output):
From 12/02/2018 to 13/02/2018 (10:30 am)

H. Lesson Learned (if any)

1. The LCF technique that was prescribed for 100 lead farmers of the study area ensured three benefits. These were moderately high yield of rice compared to business-as- usual practice, low production cost ensured by farm supplied fertilization and GHG mitigation potentiality by farming activities under climate change perspective by carbon sequestration in soil.
2. The bulk volume of bio-solid transfer and application to field were difficult.

I. Challenges (if any)

1. Saline tolerant rice seed is not available in the market, that’s why farmers could not avail the seeds in time. Sustainability of business model is challenging when there will be no extension services from BINA in this region
2. Drying and making bio-solid from slurry in rainy season is problematic.
3. Availability of labor in farm family for excreta management does not prevail all the time.

Signature of the Principal Investigator
Date ………………………….
Seal

Counter signature of the Head of the organization/authorized representative
Date ………………………….
Seal

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