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Economics of Sustainable Intensification and Adaptation Practices for Low Carbon Farming in Bangladesh

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Abstract: *This paper sets out the economic implications of sustainable intensification and farmers' motivation toward adaptation. Economic rationality implies the cost-effectiveness of coping mechanisms, and the cost of GHG emission in farm activities. All of these effects are important for the successful adaptation of farms from an economic viewpoint. Only a few studies have been conducted to analyze farm-level performance focusing on the global climate change perspective. This study tries to identify merits of coping mechanisms Among the available options using traditional farm management analytical tools and descriptive statistics. It is based on the survey of three hundred farms prone to the effects of climate change in Bangladesh. An effective way of reviving the farm income to the threshold level is to reduce the cost and increase productivity, widening the scope of agricultural adaptation. It is shown that a combination of several farming practices; like crop management, fertilizer application, and rainwater harvesting provide three benefits. These are low-resource use to ensure productivity, earn high farm net income at the same time reduce GHG in production, and farm operation under adaptation to changing climatic conditions. The results suggest that farmers' pathway to low-carbon farming under different adaptation practices may reverse the negative climate change impacts for future generations.*

Keywords: Sustainable intensification, climate change, net farm income, adaptation and mitigation

1. Introduction

Alternative agro-climate and eco-system services are new challenges for the farm economy. The community faces climate change and may change production practices and existing management. A coping mechanism that uses ecological, social,

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and economic systems in response to climate stimuli and their effects is defined as adaptation. More specifically, farm-level adaptation may refer to process, action, or outcome in a farming system for better adjustment to climatic stress, hazard, risk or opportunity (McCathy et al. 2011, Smit and Wandel 2006). An adaptation strategy may involve cost appreciation, cost reduction, input or output substitution and reduction in net earnings from threshold earnings. Farmers maximize their objectives in such a complexity of choices under uncertainty, risk, and volatility of investment benefit. These are the main economic implications of adaptation on farming for sustainable intensification.

The economic implications of climate change and adaptation at the farm level are not yet well understood. Farming is a risky business and impacts of climate variability cannot be easily separated from it. The slow and gradual effects of climate variability threaten the economic outcome of farming activities. It is essential that an assessment of climate change should comprise all its associated costs and benefits. When the cost of climate change and the net benefits of adaptation options are well understood, strategies and priorities can be defined for an effective combination of mitigation and adaptation measures for farming.

Nordhaus (1994) states adaptations could be realized up to a point where their marginal benefits equal to the marginal cost of adaptation. The straight-forward approach in economic valuation is to estimate costs of climate change impacts and to assess the costs and benefits of alternative adaption options. Valuation techniques can be based on: (i) directly observed market behavior, or (ii) hypothetical market behavior (AGHGO 2004). The first approach addresses direct market pricing of costs and benefits and indirect market or surrogate market, pricing of cost and benefit of climate impact. The second category is applicable where value is not directly observable in the market. The common framework for costing the impact of climate change is given by welfare economic theory. It addresses the externalities, uncertainties, and equity with a monetary value of the impacts of climate change and provides methods and tools. Welfare economics typically applies partial equilibrium analysis and general equilibrium analysis. Partial equilibrium analysis assesses the impacts of climate change on a single sector, while general equilibrium analysis deals with economic effects through the whole economy.

Therefore, for an economic analysis of climate change impacts and adaptation options, impacts have to be identified first. These bottom-up studies may assess impacts under the assumption that climate change impacts will not be large or indirect (AGHGO 2004).

2 Analytical framework and tools

Climate change impacts indicate the difference between conditions of a system with and without climate change (Ahmad and Warrick 2001, Adams et al. 1998).

This analysis includes all the potential impacts of climate change from the direct bio-physical impacts to the indirect ecological and social ones. Climate change adaptation is the adjustment that helps to reduce the susceptibility of a community to the effects of climate change and can be both behavioral changes as well as technological adjustments. The aim is to cope with climate change with tactical as well as strategic adjustment (Frankhauser, Tol and Pearce 1997). The assessment of adaptation impacts includes the gross benefit of adaptation. This can be quantified by referring to the extra cost and extra benefits of the coping mechanism. By assessing the efficiency of resource use within different adaptation options and the mitigation potential, farm management decision-makers can decide which adaptation option offers the greatest benefits relative to threshold or non-adapted productivity.

2.1 Adaptation appraisal

(a) Farm performance analysis

Both commercial and subsistence farmers are suffering economic losses due to climate shocks. These losses can be measured as the increased resource inputs and the loss in the value of the output when referring to productivity (AGHGO 2004). Choosing the approach depends on the anticipated response of producers' impact. There are a number of tools and indicators available with which production cost, productivity or farm net income can be measured. These are:

Gross margin analysis: This method refers to the units of output and the estimated change in output due to climate change or adaptation impact.

Agricultural land assessment: These method estimates changes in land value with and without climate change and the impacts may indicate variability of productive capacity. Comparing, the unit costs of resource inputs; such as water requirements before and after changes and adaptation.

The total budgeting approach: It may help to estimate the difference between net incomes (the value of gross output minus gross resource inputs) with and without climate change or adapted or non-adapted conditions.

The partial budgeting approach: It can be used to estimate the marginal change of output or farm net income due to alternative production practices for adaptation to climate change. It is a tool to analyze change in farm business by input substitution, output substitution or technology adoption.

All methods are popular appraisal techniques for estimating the net benefit of adaptation to specific climate change impacts for the purpose of choosing between different adaptation alternatives. These estimates focus on the economic implications of climate change and adaptation options for optimizing farm goals at alternative bio-physical changes and ecosystem services.

The study uses most of the analytical tools described for appraising adaptation techniques and the impacts of climate change. On the basis of the estimated indicators, the impacts of climate change and adaptation options were compared with a base line (or reference) scenario to visualize the net effects.

Descriptive statistics of adaptation practice are presented for the two main rice growing seasons, *Boro* and *Aman*. To get an overall idea of impact and adaptation, this study used all the indicators. The analysis of impact of farm management strategies on per hectare productivity (yield, gross margin, net margin, and returns to land) uses the mean variance method (Just and Pope 1979). The variance of the productivity in a specific season indicates production risk. The comparison of mean productivity for threshold to non-adapted periods and non-adapted periods to adapted periods reveals the impact of climate change and adaptation efficacy.

(b) Cost-Benefit Analysis

The appraisal of adaptation options is also done using one of the CBA techniques BCR. This is an economic decision support instrument that compares benefits of adaptation with the cost of the implementation of an adaptation option. Some adaptations have investment costs at the initial stage and resource maintenance costs each year in addition to production costs. For these investments, the undiscounted full costs are used in the BCR analysis to assess the financial performance of rice farming after adaptation.

(c) Cost-Effectiveness Analysis

This is an economic decision-support instrument widely used to determine least-cost pathways to advise on economic or environmental goals (AGHGO 2004). In the study, CEA provides the estimated benefits in kind (for example, quantity of rice) for adaptation options that are likely to be achieved for 100 BDT spent on adaptation as a given cost. For simplification, the assumption is to revive production up to the threshold level. In the first step, the method identifies the cost of each option. Then, the benefits as incremental outputs that are achieved by each alternative option are quantified. Finally, the cost-effectiveness of an adaptation option is calculated by determining the amount of BDT necessary to cover the rice production towards thresholds under climate shocks. This also indicates how much incremental rice could be produced for 100 BDT spent on an adaptation option.

2.2 Data sources

The study uses the data from the field survey and, thus, a total of 300 farm households prone to the effects of climate change. Part of the 13th agro-ecological zone that the study covers, where production is considered to have medium potential, is of tidal flood plains. The three sample coastal districts, Khulna, Sathkhira and Bagherhat, were purposely selected in consideration of the farm income vulnerabilities in the regions. Selection was also based on the existence of GO and

NGO-supported projects for climate change adaptation and GHG mitigation. Three Upazila were purposely selected for the same attributes of representation.

Detailed cost and production information was collected for 2006 (provided by the farmers' records in association and memory). This period of production is considered the threshold level. There was no severe effect of climate variability on production in the area up to 2006. The next three years, 20007, 2008 and 2009, are considered the climate shocks period. After two devastation sea storm *Sidre* (2007) and Aila (2009) the production system, the farmers claim, underwent severe changes. This period is assumed as production without coping strategies under adverse climate variability or the non-adapted period for the sample farmers. From 2010 to 2013 the sample farmers adopted alternative production systems in their fields; this period is the adapted period aiming of sustainable intensification. Farmers' bench mark data on different thresholds was recorded by the farmers when they joined the farmers club. Hence, data of inputs and outputs were cross-checked with bench mark records kept by the farmers' club.

Detailed information on adaptation practice, production stages, labour endowment, land preparation, fertilizer use, irrigation efficiency and variety status was collected. Data was available for the years 2006 to 2013- 8 years of the respondent farmers' production status.

3 Results and discussion

3.1 Economic implications of the farmers' perception and climate change impacts

Most of the sample farmers perceive that changes in present climate compared to 20 years ago comprise less rainy days in the dry season, a delay of the rainy season, increased temperatures and more hot days associated with a higher-than-average maximum temperature. They consider 2006 as the last year with a stable climate. Following 2006, the basic climate parameters have not returned to the farmers' normal threshold ranges. After a devastating tropical sea storm named Sidre in 2007, there was significant rising of the sea level around the coast of Bay of Bengal. This created shocks such as salinity intrusion in rice fields and water stagnation. Traditionally, the areas of agricultural land have been marginally salinity-prone, but farmers could wash away the land and remove the problem of salinity with available rain-water. After sea levels, however, problems have increased: water stagnation has worsened average, maximum temperatures risen, and there have been changes in the magnitude of the rainy season. The famers' production systems have faced a new bio-physical and ecological environment that was created by climate variability and the secondary effects of salinity. Interestingly, farmers' perceptions about climate variability are truly reflected in the levels of productivity and farm income. From 2007 rice production per hectare in the Boro and Aman seasons compared to threshold production drastically declined

(Table 1). Farmers are using extra input, water and labor to reach the threshold levels of output or the combinations of inputs that cost the least to ensure productivity resilience. They are faced with continuing climate variability shocks and increasing food insecurities.

Table 1 Comparison of the farm performance in the threshold (2006) and non-adapted (2007-2009) periods relative to climate variability impacts

	Boro season				*Aman* season			
	Yield (Kg/ha)		Gross margin (BDT/ha)		Yield (Kg/ha)		Gross margin (BDT/ha)	
	Threshold period	Non adapted period	Threshold period	Non-adapted period	Threshold period	Non-adapted period	Threshold period	Non-adapted period
Mean	4,113	2,448	53,472	34,985	2,536	1,786	39,066	24,995
Mean difference		1,614.2970 t =.11.5300 (000)		1,8486.9100 t = 10.1773 (000)		750.4596 t = 31.1063 (000)		7,970.5850 t = 27.2055 (000)
Standard deviation	2,514.86	363.13	32,693.21	5,083.84	901.07	569.502	11,722.12	7,973.03
Co-efficient of variation	28	119	28	119	48	54	48	54

Note: t = pair t test value; figures in parentheses indicates provability levels that ensured a high level of significance.
Source: Author's own calculations from survey

Another sea storm Aila hit the study area in May 2009 devastating the rice farming system. In the period of 2007 to 2009, the sample farm households faced severe vulnerability of farm income to climate variability. The variability of yields and of gross margins indicates the impact of climate variability after the threshold climate. Figure 1 represents the relative performance of farm management at the threshold and in the non-adapted period.

The gross returns of Boro rice per hectare were estimated at 53,472 BDT (approximately 535 Euro) under the threshold climate, while this was 39,066 BDT (approximately 400 Euro) for the Aman season. Compared to the threshold, the average gross margin per hectare for both seasons drastically fell in the non-adapted period. This has important implications for farm income and welfare under climate variability, and the significant mean difference in yield and gross margins indicates this impact

3.2 Adaptive response to perceived climate variability and its economic implications

The surveyed farmers have adopted a variety of coping mechanisms in response to climate change shocks. In the aftermath of sea storm Aila an intensive rehabilitation program was initiated by GOs and NGOs in the study area. The perceived knowledge of climate change in non-adapted periods and the agricultural rehabilitation programs of different organizations have directed farmers towards adaptation. Their alternative production practices can be categorized in three distinct management approaches for both growing seasons: soil and crop management practices, best fertilizer management practice, and water management practice. Each of the adaptation categories consists of sub-practice options for environment friendly agricultural activities. There are five specific adaptations for rice cultivation in the *Aman* season and nine distinct categories of adaptation for rice cultivation in the *Boro* season practiced by the sample farmers details described in table 2. Most of the individual practices also indicate that low carbon farming practice was introduced with the climate change adaptation extension program in the study area. The adaptation options are chosen depending on the available resources, growing season, and regional salinity level. The sample farmers rank the adaptation performance according to the net output gain, problems in their application, availability of resources, cost-effectiveness, and sometimes on adaptation and mitigation potential. Interestingly, most of the farmers have great awareness about climate variability and change, because of media reports, GO and NGO campaigns, and extension programs in the study area.

In order to assess the impact of a new adaptation management practices on farm production, this study has described the available fourteen adaptation options in detail. The overall economic performance is discussed in the following sections.

3.3 Relative farm performance under different adaptation options

Farm earning performance

A budget approach estimates different performance indicators in farm management analysis. A farmer typically wishes to maximize his farm income subject to the exogenous conditions of the farm. The exogenous conditions are the farm's environment, including climate and ecology. Farmers choose a crop mix and inputs for each unit of land that maximizes the farm net profit.

A number of performance indicators is obtained from a complete budgeting approach according to figure 1. A key indicator is 'returns to land'. In this study, returns to land were estimated for threshold, non-adapted, and adapted periods. This is also the basis for Ricardian theory of land rent, and the basis for further analysis of the impacts of climate 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 1.2 that in return to land all categories drastically decreased by weather variability in the non-adapted period. Adaption impact varies according to the nature of the practice and the seasons.

For the *Aman* season, almost all the adaptation options reap the benefits of reviving production; except in being option number 5 which tried to adapt only by saline-tolerant varieties with fertilizer deep placement. Adaptation option number 2, soil and crop management through relay cropping with khesari (*Lathyrus sativus L.*) and balanced fertilizer application, give the greatest benefits Amang the Aman season options: farmers get double the crops in the same plot at the same time. Option 2 is followed by adaptation option number 3, soil and crop management through relay cropping with khesari (*Lathyrus sativus L.*) including balanced fertilizer application and irrigation management by diversion ditches considering the value of returns to land. Adaptation option 3 also provides double crop benefits as it helps to grow the legume crop in the same plot. Considering the threshold level of the returns to land value, it almost revives the full benefit of the threshold income. In the Aman season options number 1 and 4 moderately increase the value of returns to land but these are significantly lower than the threshold level.

In the *Boro* season, seven out of nine categories of alternative adaptation options had positive impacts on the value of returns to land. Zero tillage with saline-tolerant varieties and best fertilizer management practice were found to not have a positive impact on returns to land. Although both options have merits in mitigation, the farmers claimed there is no positive economic impact. Water management in the Boro season is crucial for reviving the threshold level of productivity. Ensuring the water harvesting and diversion ditches, adaptation option 5 in the Boro season provides the highest returns to land Amang the available options. The second best option in the Boro season is adaptation option number 5 which only ensures irrigation water management with a water reservoir and diversion ditches. Considering the returns to land, the option 5 in the Boro rice growing season is followed by adaptation option 1 which uses soil and crop management practice with climate stress-tolerant seed varieties, including best fertilizer management practice, and irrigation water harvesting.

Table 1 : Returns to land at different climate thresholds under adaptation options

Adaptations	**Returns to land (BDT/ha)**		
***Aman* season**	Threshold period	Non-adapted period	Adapted period
1. Soil and crop management with saline-tolerant seed varieties (Aman-1)	16,240	10,491	12,153
2. Soil and crop management through relay cropping with legume, and balanced fertilizer application (*Aman*-2)	38,485	27,903	32,685
3. Soil and crop management through relay cropping with khesari (Lathyrus sativus L.) including balanced fertilizer application and irrigation management by diversion ditches (*Aman*-3)	30,426	20,953	29,264
4. Integrated pest management with saline-tolerant seed varieties (*Aman*-4)	31,462	21,791	22,685
5. Minimum or zero tillage-based integrated crop management with saline-tolerant varieties and best fertilizer management practice by nitrogen deep placement (*Aman*-5)	14,290	9,519	7,518

***Boro* Season**			
1. Soil and crop management practice with climate stress-tolerant varieties including best fertilizer management as well as irrigation water harvesting (*Boro*-1)	37,93]	13,612	21,493
2. Soil and crop management through saline-tolerant varieties and balanced fertilizer application by nitrogen deep placement with water harvest (*Boro*-2)	31,534	14,588	16,738
3. Crop management by saline-tolerant varieties, balanced fertilizer application with nitrogen deep placement as well as irrigation management by water reservoir and diversion ditches (*Boro*-3)	26,975	11,697	13,934
4. Minimum tillage-based integrated crop management with salt-tolerant varieties (*Boro*-4)	35,164	14,281	16,105
5. Best fertilizer management practice by balanced fertilizer, nitrogen deep placement including water reservoir and diversion ditches (*Boro*-5)	40,912	17,787	29,350
6. Irrigation water management with water reservoir and diversion ditches (*Boro*-6)	33,850	16,919	26,427
7. Soil and crop management practice with saline tolerant varieties associated with irrigation water management with water reservoir and diversion ditches (*Boro*-7)	21,492	12,868	12,893
8. Zero tillage-based integrated crop management with saline tolerant varieties with water reservoir and diversion ditches (*Boro*-8)	31,490	16,162	16,005
9. Best fertilizer management practice applied by balanced fertilizer (Boro-9)	17,261	10,418	9,396

Source: Author's own farm survey

Interestingly, options 3 and 7 in the Boro season is used most of the available components, but the restoration performance was low. The reason behind this is the higher costs of inputs involved in implementing an integrated approach which reduces farm returns to land. At the same time, some regions salinity levels exceed the tolerance level in crop growing and, as a beginner; it will take time to fully adjust to the new practices.

Adaptation options 2 and 4 moderately increase the land value from the non-adapted period, but compared to the threshold level, the performance is low. Nevertheless, all adaptation options for the sample farmers have monetary as well mitigation merits. Compared to threshold levels, the returns to land indicator of the non-adapted periods significantly decreased. The hope is that the diminishing trends of such indicators for the sample farmer stops with successful coping mechanisms of the adaptation options.

3.4 : Marginal impact of adaptation by partial budgeting approach

Partial budgeting evaluates the consequences of changes in farm methods which affect only part rather than the whole system of the farm (Dillon and Hardaker 1980). In the case of adaptation, farmers use a new technology package that affects performance.

Table 2 Marginal impacts of adaptation options using a partial budgeting approach in the Aman season

Options	Aman-1	Aman-2	Aman-3	Aman-4	Aman-5
A. Benefit forgone					
Gross margin forgone	33,408	39,144	41,129	41,784	39,144
New extra cost	18,945	23,011	18,846	20,531	18,668
Subtotal	52,353	62,155	59,975	62,315	57,812
B. Benefit gained					
Gross margin due to change	36,753	45,695	66,443	48,807	45,695
Cost no longer incurred	19,658	19,920	20,451	23,433	18,898
Subtotal	56,411	65,615	86,894	72,240	64,593
C. Net change = (B-A)	4,057	3,460	26,919	9,924	6,781

Source: Author's calculations based on the farm survey.

By comparing situations with and without the new alternative practices, the net effect on the whole farm performance can be estimated. This is also described as the marginal impact of change by production method substitutions. In the first step, the performance change as a result of adaptation is calculated based on the benefit forgone and the benefit gained. The benefit forgone has two sub-components: the gross margin forgone by introducing the new method (the gross margin without adaptation), and the extra cost for the new production practice. In other words, the benefit received under the present farm system would no longer be received for alternates systems (tables 3 and 4).

The benefit gained has two sub-elements: the gross margin due to change (that is, the gross margin after adaptation) and the cost no longer incurred for alternatives. Finally, the net change in farm profits associated with alternative adaptations can be calculated as benefits gained minus benefit forgone. If, after the calculation, the benefit gained is greater than the benefit forgone, the adaptation option is considered a feasible alternative. If the converse is true, the adaptation is not sustainable from an economic point of view.

Tables 3 represent the figures for adaptation options in the Aman season. The highest possible net change occurs with adaptation option 3 in the Aman season. Interestingly, if water management is absent in this adaptation option of the Aman season, the net gain drastically falls to the lowest level as indicated in case of option 2. Therefore, irrigation is an influential factor, which greatly affects the results, for this option. The soil and crop management practice only by saline-tolerant rice varieties marginally changes in gross margin. Farmers have potential for greater gain if they include integrated pest management to the varieties change. The marginal effect of adaptation option number 5 in the Aman season accounts for 6,781 BDT per hectare.

Table 3 Marginal impacts of adaptation options using a partial budgeting approach in Boro season

Options	Boro-1	Boro-2	Boro-3	Boro-4	Boro-5	Boro-6	Boro-7	Boro-8	Boro-9
A. Benefit forgone									
Gross margin forgone	45,893	38,865	40,096	41,258	39,310	34,820	41,357	39,534	35,781
New extra cost	27,063	26,942	28,252	26,867	32,974	32,167	25,267	25,417	36,943
Subtotal	72,956	65,807	68,348	68,125	72,284	66,987	66,624	64,951	72,724
B. Benefit gained									
Gross margin due to change	76,676	63,978	57,878	77,374	65,022	54,711	71,220	64,037	62,123
Cost no longer incurred	26,764	23,573	27,936	26,157	20,678	21,471	25,288	22,018	23,791
Subtotal	103,440	87,551	85,814	103,531	85,700	76,182	96,508	86,055	85,914
C. Net change = (B-A)	30,484	21,744	17,464	35,405	13,416	9,195	29,884	21,104	13,180

Source: Author's own calculations based on the farm survey.

The five options assessed all have positive effects on the net change but the range is very high. Some options are reducing costs and some are increasing the gross margin. The farmers apply the practice according to their affordability and availability of resources. They claim their new adaptation knowledge is a first step to climate-resilient farming.

In the case of the *Boro* season, the highest possible net change occurs with adaptation option 4 because it is an option which notably reduces tillage cost and contributes to reducing production cost. If irrigation water is applied with the best fertilizer management as adaptation option 1 in the *Boro* season, cost increase, and the net gain decreases compared to option 4 under minimum tillage. Option 1 is the second best option in *Boro* season. Therefore, irrigation and fertilizer are influential factors in gross margin increase; however, the net change is less and cost is high compared to option number 4. Options 2, 3, and 8 provided moderate changes in net income after adaptation. Farmers have some potential for greater gain if they include soil and crop management with the saline-tolerant seed varieties. The marginal effect of adaptation option number 7 in the *Boro* season accounts for 29,884 BDT per hectare, which is the third best option in the *Boro* season. Adaptation options number 5 and 9 provided low changes in net income compared to the other available options. The marginal impacts of options 5 and 9 on net income change accounts for 13,416BDT and 13,180BDT per hectare of land respectively. Adaptation option 6 in the *Boro* season use only irrigation water and diversion ditches which effects marginal changes in the gross margin.

The nine options assessed all have positive effects on the net change but the range is very wide. Some options reduce costs and some increase the gross margin to the same degree as that of the *Aman* season. The farmers apply the practice according to their affordability and availability of irrigation water resources. For long-term adaptation options they have to invest for an extended period of time and keep land resources for rain water reservoir which has opportunity costs. The financial analysis and economic appraisal can better present the implications of adaptation options as it accounts for such resources and the opportunity cost.

3.5 Appraisal of the adaptation options of the Boro and Aman rice growing seasons on the basis of the farm survey data

The farmers that are prone to the effects of the climate change have specific goals, including the resilience of farm productivity and returning revenue up to the threshold level. The goals relate to family food security and better livelihoods as a result of a stable farm income (Ramasamy 2012). According to the views expressed in the study survey, traditional and subsistence farmers are very rigid in their professional mobility even when vulnerability of income and opportunity costs is higher. They want to survive by changes within the farming system, and this makes adaptation options worthwhile. However, any adaptation or investment decision has to be economically assessed in view of available options. In the following CBA (using benefit cost ratio BCR indicator) and CEA are used for assessing the most valuable adaptation options in rice farming. BCR is one of the CBA tool indicates the financial performance of adaptations, while CEA indicates the total benefit for a given amount of money. Table 5 represents both the BCR and CEA of farm-level selected adaptation options. These analyses were considered only for the adaption options that need initial investment cost, pay-back periods and, benefits comes over an extended period of time.

Table 4 : Cost-benefit and cost-effective analysis of adaptation options in Aman and Boro seasons

Adaptations	BCR	Cost-Effectiveness
1. Soil and crop management through relay cropping with khesari (Lathyrus sativus L.) including balanced fertilizer application and irrigation management by diversion ditches (*Aman*-3)	2.40	100 BDT spent on the adaptation ensures 10kg of rice
2. Soil and crop management practice with climate stress-tolerant varieties including best fertilizer management as well as irrigation water harvesting (*Boro*-1)	2.83	100 BDT spent on the adaptation ensures 8.04kg of rice
3. Soil and crop management through saline-tolerant varieties and balanced fertilizer application by nitrogen deep placement with water harvest (*Boro*-2)	2.37	100 BDT spent on the adaptation ensures 5.7kg of rice
4 Crop management by saline-tolerant varieties, balanced fertilizer application with nitrogen deep placement as well as irrigation management by water reservoir and diversion ditches (*Boro*-3)	2.05	100 BDT spent on the adaptation ensures 4.4kg of rice
5. Best fertilizer management practice by balanced fertilizer, nitrogen deep placement including water reservoir and diversion ditches (*Boro*-5)	1.9	100 BDT spent on the adaptation ensures 2.9kg of rice.
6. Irrigation water management with water reservoir and diversion ditches (*Boro*-6)	1.7	100 BDT spent on the adaptation ensures 2kg of rice
7. Soil and crop management practice with saline tolerant varieties associated with irrigation water management with water reservoir and diversion ditches (*Boro*-7)	2.82	100 BDT spent on the adaptation ensures 8.4kg of rice

8. Zero tillage-based integrated crop management with saline tolerant varieties with water reservoir and diversion ditches (*Boro*-8)	2.5	100 BDT spent on the adaptation ensures 5.9kg of rice

Source: Author's own calculations based on farm survey.

In the Aman season, adaptation option 3 is only long-term investment option and has a BCR of greater than 2 which is quite impressive in financial point of view. The value of BCR higher than one implies that the investment is feasible at given rate of interest as the benefits exceed the cost. The CEA for the same adaptation is also supportive because 100 BDT ensures 10 kilograms of rice, or the cost of 10 BDT/kg of rice. This adaptation option is feasible for its total benefit because the market price of rice is 15 BDT/kg.

In case of the Boro season adaptation option 1, is also a feasible option as the BCR and CEA support application. Boro adaptation 2 is a financially sound adaptation practice and the CEA indicator also supports adopting the technology.

Boro season adaptation option number 3 is a feasible option in view of BCR and CEA indicators, whereas option number 5 is not financially viable provides only 2.9 kilograms of rice for each 100 BDT spent. Similarly, Boro season adaptation option 6 is not-feasible because this adaptation provides only 2 kilograms of rice for each 100 BDT spent; while the market value of two kilograms of rice is only 30 BDT.

Adaptation option 7 for the Boro season usually covers it cost. Finally, adaptation option 8 is also a feasible according to both Indicators.

The alternative production system appraisal helps to set priorities for climate adaptation on farms. The overall assessment suggests that a single sub-component of an adaptation practice alone will not functionally sufficient for facing climate change. An integrated approach consisting of all system components, soil and crop management, fertilizer management, and irrigation option management, will be a feasible adaptation strategy.

4 : Conclusions

This paper presented the economic implications of adaption options in different ways. The assessment indicators of climate change adaptation were analyzed to find the performance of farms at different thresholds. There is not a single criterion to assess economic implications of climate change adaptation for carbon farming as the bio-physical environment and markets determine profitability and viability of farming. The profitability and success of farming depends on many exogenous and endogenous variables. Consequently, the analysis of the economic impacts of climate change adaptation options is challenging because the contributions of influencing factors are difficult to single out. Keeping in mind all the limitations, this study estimated the relevant indicators of farm performance using common economic tools. The basic findings of the study postulate that climate variability has a significant impact on rice production in both growing seasons. The effects are estimated in monetary terms. Results show clear farm income vulnerability from the threshold level due to climate change. As a consequence, farmers operated their farms despite climate shocks for some period and then adopted some alternative practices to build resilience in farm productivity by intensification and improve returns to the threshold level. These adaptations ensured benefits compared to the non-adapted period, minimized the costs of production and economized resource use that ensures sustainability of the farming. In addition to this mitigation potentiality of new practice for low carbon climate smart production merits for sound cultivation. There were 14 common practices of intensification found in the farm survey whose economic implications were assessed for sustainability. Three basic components of adaptation were found to be important for full economic recovery: soil and crop management, nutrition application management and water management. The combined application of the three components can successfully revive the threshold productivity in the study area.

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