

Impact of Climate Change on Agriculture Especially in Jessore and Sathkhira Districts According to Farmers' Mitigation Strategies to Climate Change; Evidence from Farmer Level Data

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Abstract

This study studies the adaptation of farmers to demeaning environmental situations likely to be caused or exacerbated under global climate change. It examines four central components: (1) The rate of self-reported acceptance of adaptive instruments (coping plans) consequently of changes in climate; (2) Ranking the potential coping plans based on their apparent importance to agricultural initiatives; (3) Documentation the socio-economic factors related with adoption of coping plans, and (4) Ranking potential limitations to adoption of coping plans based on farmers' reporting on the grade to which they face these restraints. As a preliminary matter, this paper also hearsays on the perceptions of farmers in the study about their involvements with climatic change. The study area is included of fifteen villages in the coastal region (Jessore and Sathkhira districts), a topographical region which climate change works has decorated as prone to accelerated degradation. Five hundred (500) farmers take part in the project's survey, from which the data was used to compute biased indexes for positions and to achieve logistic reversion. The rankings, model results, and expressive statistics, are stated here. Results showed that a common of the farmers self-identified as having involved in adaptive behavior. Out of 15 adaptation policies, irrigation ranked first among farm adaptive measures, while crop assurance has ranked as least utilized. The logit model clarified that out of eight factors surveyed, age, education, family size, farm size, family income, and involvement in collectives were meaningfully related to self-reported adaptation. Notwithstanding different support and technical interferences being available, lack of available water, lack of cultivable land, and random weather graded highest as the respondent group's restraints to coping with ecological poverty and change belongings. These results deliver policy makers and advance service providers with vital awareness, which can be used to better mark interventions which build endorse or facilitate the adoption of coping appliances with potential to build resiliency to altering climate and subsequent ecological effects.

Keywords: Farmers' adaptation; Climate change; Bangladesh; Jessore; Sathkhira

Introduction

This study asks how farmers adjust to changing climatic conditions, particularly drought. Agricultural lists first perceive the opposing effects of climate change at the farm manufacture level and then take adaptive actions to silent these adverse effects [1] as adaptive actions are able to reduce susceptibility [2]. Therefore, impact and adaptation are interlinked. It was evident that farmers incurred significant amounts of production losses due to climate change. This is focused on what mitigation strategies have been practiced by farmers in the study area to reduce their food production losses due to climate change.

The specific inquiry questions investigated in this part are: (a) What are farmers' perceptions of climate change in a very severe drought-prone area of Bangladesh? (b) What are the major mitigation strategies in the study area? (c) What are the determinants of farmers' mitigate choices? And (d) What are the barriers to effective mitigation to climate change? These four study questions will be addressed using micro data at the farm level. The organization of this part is as follows. Section 2 provides a brief overview of the literature. The theoretical framework is outlined in section 3. The methodology is presented in section 4. Section 5 reports and discusses the results while section 6 concludes the part.

Change and agriculture: A short-term overview of the literature

Climate change affects crop agriculture badly, particularly in countries in the lower latitudes of the world [1,3]. Alteration is seen

as an essential policy option as compared to mitigation to limit the negative effects of climate change [4-6]. This is because mitigation has an insignificant impact on the current stock of greenhouse gases in the short run and, moreover, it requires collective and global actions [4].

There have been several studies examining the potential effects of climate change on agriculture globally [7-11]. The earlier studies assumed either no or little adaptation at an aggregate level. However, farmers' mitigation has been under researched especially at the farm level. Furthermore, an analysis of the determinants of adaptation strategies is limited in the climate change impact literature. Nevertheless, agro-economic rationality implies that addressing climate change requires mitigate strategies and farmers usually make adjustments in their production processes to overcome any negatives experienced. Adaptation is very important if farmers are to counter the potential unfavourable impacts of climate change [4,10,12]. Adaptive measures

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are able to protect the livelihoods of poor farmers and ensure food security by reducing the potential negative impacts and reinforcing the advantages associated with climate change [1,2,13-15].

There is a growing number of study on farm level mitigation strategies and their determinants globally [5,1] However, mitigation in agriculture varies across countries. Different mitigation strategies are practiced by farmers depending on the climatic conditions, farm types and other conditions such as political, economic and institutional factors [2,16,17]. More precisely, mitigation choices are context specific and change from area to area and over time [18]. Therefore, country or area specific studies of climate change mitigation are required. In this context, research studies for Bangladesh are very limited [19-23].

Paul [19] documented some adjustment measures such as crop replacement, irrigation, gap filling and the inter-cropping of wheat and kaon (a local food crop). Ali [20] identified some adaptive measures such as the construction of embankments and cyclone shelters, and the introduction of new rice varieties suitable to higher salinity levels and temperatures. Rashid and Islam [23] identified drought, flood, soil salinity and cyclones as the major extreme climatic events which adversely affect agricultural operations and production. Changes in behavioural patterns, human practices and international actions are suggested as anticipatory adaptive measures. Based on focus group discussions and key informant interviews, Ahmed and Chowdhury [21] and FAO [22] identified the excavation of DTWs which facilitated irrigation, the excavation of ponds, switching to mango farming, the cultivation of short-duration and drought-tolerant crop varieties and home stead garden in gas major adaptation strategies for the Jessore and Sathkhira districts of southwest Bangladesh. However, none of these studies analyzed the determinants of farmers' adaptation strategies alongside the farmers' perception of climate change and the barriers to adaptation which are crucial for devising effective adaptation policies. Moreover, farm level adaptation strategies in the Jessore and Sathkhira districts have not been studied. Therefore, the objective of this chapter is to examine, using a detailed farm level dataset, farmers' perception of climate change, barriers to adaptation and factors affecting adaptation choices in rice production systems by using the case of farmers in greater Jessore, a severely drought-prone district of Bangladesh.

Assumed framework

Crop models or climate impact calculation techniques have been the most frequently used approaches to understanding the relationship between climate change and agriculture. Crop models are used to estimate the potential effects of future long-term climate change scenarios. Farmers' responses to climate variability and extreme climate events in these models are simply hypothetical, and either no adaptation or optimum adaptation is presumed [24]. Furthermore, climate scenarios under these models are inevitably not the scenarios to which farmers are most susceptible. A complementary approach, vulnerability theory, is used to explore the relationship between agricultural systems, the susceptibility to climate change and extreme events and farmers' adaptation explicitly [15]. The term 'vulnerability' generally represents 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes' [13]. The vulnerability of an agricultural system is explained as a function of exposure sensitivity, which indicates the susceptibility of a system to be affected by climate stimulus, and the adaptive capacity of the system [15]. According to the theory, vulnerability is positively related with exposure sensitivity while there is an adverse relationship between vulnerability and adaptive capacity which is the ability of a system, region or community to adapt to the impact of climate change

[15]. More precisely, if exposure sensitivity increases, vulnerability also increases but increased adaptations are possible to alleviate vulnerability. Exposure sensitivity is not homogenous. It will vary from farm to farm as the characteristics of the farms that make them more or less vulnerable to particular climatic changes and extreme events are different. Vulnerabilities to climate change vary also because of socio-demographic, environmental, institutional and social characteristics that are either exogenous or endogenous to the community. Farmers' miigate capacity to climate change is influenced by socio-economic, institutionalandsocialfactors.Socio-economiccharacteristics includeage,education, gender, household size, farm size, farming experience and wealth (i.e., household assets) [25,26]. Institutional factors consist of access to extension services, climate information and credit, and tenure status [1,26]. Finally, social capital includes farmer-to-farmer extension services and the number of relatives living close by [16].These determinants may assist or restrict adaptation choices. In the case of agricultural systems, farmers are the first people confronting climate variability and change. It is thus essential to comprehend farmers' perceptions of and adaptations to climatic changes in order to diminish vulnerability and to enhance the overall resilience of the system [15].

Methodology

Study area

The extenuation part of this study took place in the same villages of Jessore and Sathkhira districts as earlier. District level analysis of climate data in Part 5 reveals that average annual rainfall across greater Jessore varies from 839 mm to 2241 mm. Moreover, the district average total rain fall for the 1964-2009 period is 1505 mm compared to 2408 mm for the whole country. Furthermore, the temperature in the district is as high as 44°C in May and as low as 6°C in January. In terms of extreme climate events, the district is severely drought- affected but is almost free from cyclones and floods [21,22].

Data sources

Micro data from a farm level survey conducted by the researcher is the main source of data for this analysis. The sample comprised the same 550 households who were selected randomly from the 15 selected villages. This part used data on socio-demographic features (age, gender, education and household size), farm characteristics (farm size and tenure status), institutional convenience (access to extension, weather information, credit, subsidy and irrigation facility) and farmers' perceptions about climate change, variation strategies and barriers to mitigation. Moreover, climate data from BMD (2010) is used to make a judgment of climate change in Jessore and Sathkhira with that of Bangladesh. The time period for this analysis is from 1964 to 2009 as climate data for the district is available for only this period.

Theory of chance utility and a micro-econometric model

Providing that various adaptive options are trained by farmers, the selection of the choice model can be either a multinomial probit (MNP) or a multinomial logit (MNL) model. This study uses the MNL model to analyze the determinants that affect farmers' choices of adaptation strategies. This is because this model gives more precise estimation results than the MNP model [27]. Moreover, the MNL model has been successfully and commonly used in some recent studies [5,12,16] while the MNP model is not usually used largely because of the practical difficulty involved in its estimation process.

Farmers' choice of mitigation strategies is a discrete and mutually

exclusive choice. In the context of the current study, a farmer can select a strategy among eight alternatives:

(i) More irrigation, (ii) Short-duration rice, (iii) Supplementary irrigation, (iv) Changing planting date, (v) Agro-forestry, (vi) Use of different crop varieties, (vii) Non-rice crops and (viii) No adaptation. It is assumed that the selection of one of these strategies is independent of the other strategies. The choice of one strategy is categorized by various socio-demographic factors such as age, education, tenure status, access to climate information, extension services and subsidies.

The theoretical underpinning that a farmer chooses among different alternatives lies in the theory of random utility. In this theory, the utility of each alternative is exhibited as a linear function of observed characteristics (farmer and/or alternative specific) plus an additive error term. Furthermore, farmers are assumed to select the alternative that has the highest utility. More particularly, the utility a farmer from alternatives j and k is given by

$$U_{ij} = +\epsilon_{ij}$$

$$= V + \epsilon_{ik}$$

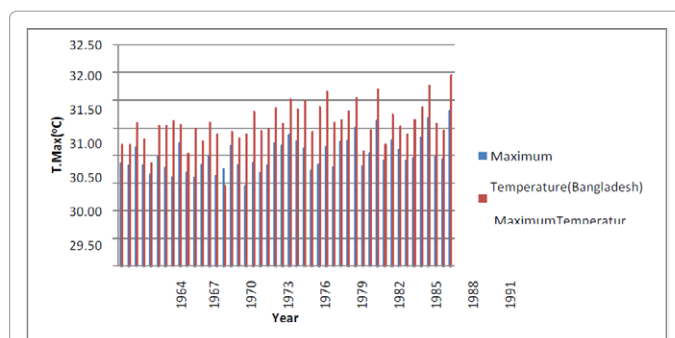
respectively; where V_{ij} and V_{ik} imply the deterministic or systematic component of the utility, and ϵ_{ij} and ϵ_{ik} represent the stochastic component which represents the uncertainty.

This is the MNL model (Greene 2003). The MNL model significantly requires the assumption of independence of irrelevant alternatives (IIA) to hold in order to obtain unbiased and consistent parameter estimates. The IIA assumption necessitates that the probability of adopting a particular adaptation strategy by a given farm household requires independence from the probability of selecting another adaptation strategy.

The numerator is the utility (i.e., net benefit) from choice j and the denominator is the sum of utilities of all alternative choices. The probability of selecting a specific adaptation strategy is equal to the probability of that specific alternative being higher than or equal to the utilities of all other alternatives in the set of strategies. The parameters of this model can be estimated using maximum likelihood methods. However, the parameter estimates of the MNL model merely show the direction of the impact of the explanatory variables on the dependent variable. The real extent of changes or probabilities is not represented by the estimates. Moreover, parameter estimates are hard to interpret since they are derived from non-linear estimates (Greene 2003). Therefore, the MNL model parameters are transferred in to relative risk ratios (RRR). This RRR measures the effects on the relative odds of one outcome being selected relative to the base line outcome for a unit change in any of the explanatory variables.

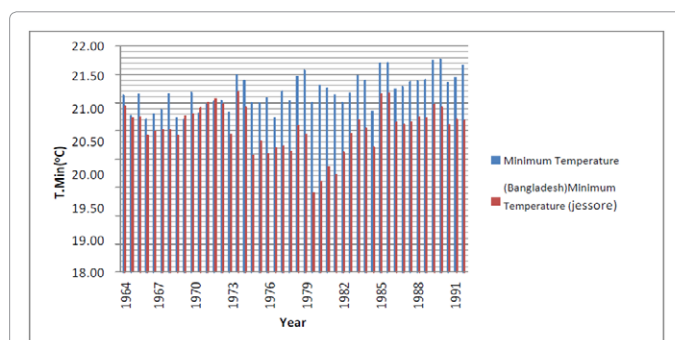
Study outcomes and argument

Overview of climate change in Jessore and Sathkhira districts and comparison to Bangladesh: These Jessore and Sathkhira districts are in the southwestern climatic sub-zone (Zone E) which is characterized by very hot summers and relatively low rainfall [28]. Data on maximum temperature, minimum temperature and rainfall for the 1964-2009 period has been analyzed in this Chapter to assess the changes in these climate variables. A comparison of the Jessore and sathkhira districts with the whole country was also made. Data source was the Bangladesh Meteorological Department. Figure 1 shows that there is an increasing trend in maximum temperature for both the Jessore and sathkhira districts and Bangladesh over the period. The



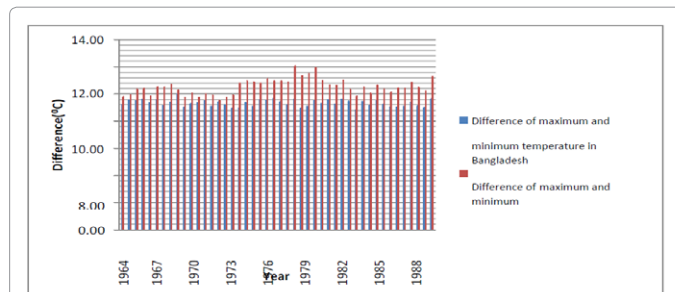
Source: Bangladesh Meteorological Department.

Figure 1: Trends in maximum temperature.



Source: Bangladesh Meteorological Department.

Figure 2: Trend in minimum temperature.



Source: Bangladesh Meteorological Department.

Figure 3: Difference of maximum and minimum temperature.

growth in maximum temperatures in the greater Jessore districts is higher than that for Bangladesh (Figure 2).

Although the minimum temperature in Bangladesh has increased over time, it has decreased in the Jessore and Sathkhira. The difference between maximum and minimum temperature is always higher for the Jessore and Sathkhira districts as compared to the whole of Bangladesh as depicted in Figure 3.

The total mean annual rainfall has increased for Bangladesh while it has decreased for greater Jessore. Annual total rainfall in greater Jessore is far below that of the whole country as illustrated in Figure 4.

In addition to the changes in maximum temperature, minimum temperature and annual rainfall, the frequency and severity of droughts have increased in recent times in the Jessore and Sathkhira districts.

Farmer's perception of climate change: Farmers should perceive first that there is climate change in order to take necessary adaptive

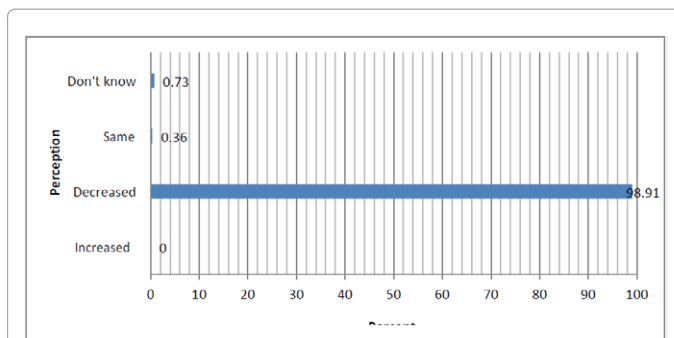
strategies [1]. The surveyed farm household heads were asked about their perceptions of changes in various climate variables over the past 20 years. The major components were yearly temperature, rainfall, drought, and the availability of groundwater and surface water. Perceptions on climatic components were divided into four categories: increased, decreased, remaining same and don't know. Farmers' perceptions on each climatic parameter change are presented below.

Temperature changes: The results in Figure 5 signify that 97% of household heads have noticed rising temperatures while only an insignificant 0.55% noticed a decrease in temperature. Temperature remained unchanged for 1% of household heads while another 1% of household heads had no knowledge about it. Most of the farmers' perceptions are in accordance with the analysis of official data in the previous section.

The results in Figure 6 indicate that 99% of household heads observed a decline in total yearly rainfall. No household heads perceived an increase in rainfall while rainfall remained the same to 0.36% of households. Analysis of official rainfall data in Unit is consistent with the perception of the majority of household heads.

Changes in droughts: The study area is a drought-prone area. Other extreme events such as cyclone and floods are almost non-existent. Accordingly, farmers' perception of droughts is reported in Figure 6. Nearly 100% of households noticed that frequency of drought has increased over the last 20 years.

Changes in other climatic parameters: Other important climate parameters include groundwater, surface water, heat waves and colder



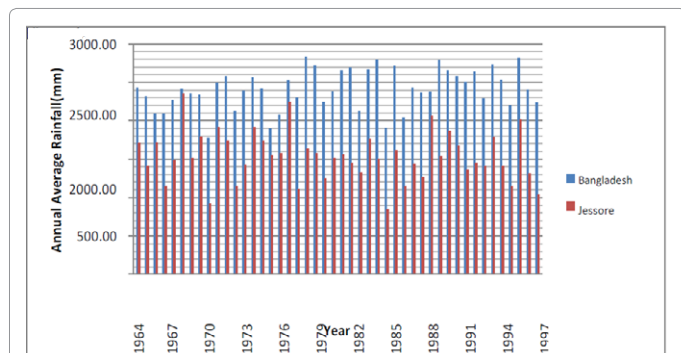
Source: Bangladesh Meteorological Department.

Figure 6: Farmers' perceptions of yearly rainfall changes over the last 20 years changes in droughts.

Farmers' perception	Other climate parameters (yearly)			
	Availability of ground water (%)	Availability of surface water (%)	Severity of heat wave (%)	Severity of colder weather (%)
Increased	0	0	98.9	43.45
Decreased	99.64	98.9	0.36	40
Remained same	0.36	1.1	0.37	8
Don't know	0	0	0.37	8.55

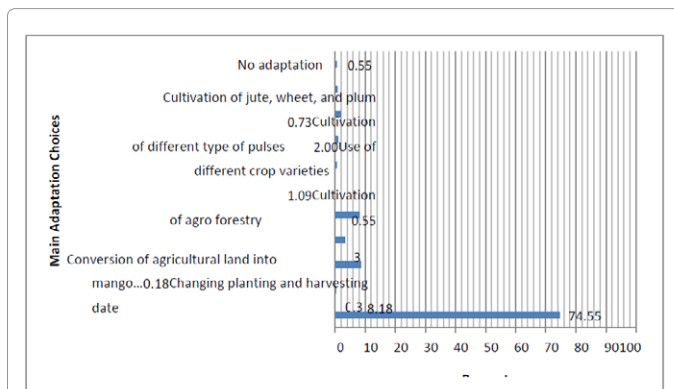
Source: Bangladesh Meteorological Department

Table 1: Farmers perceptions of other climate parameters over last 20 years.



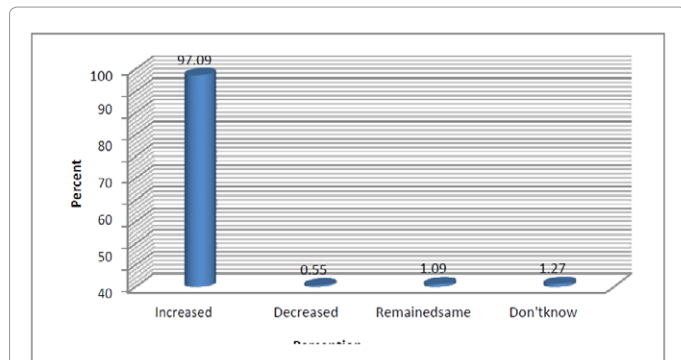
Source: Bangladesh Meteorological Department.

Figure 4: Trend in annual average total rainfall.



Source: Bangladesh Meteorological Department.

Figure 7: Farmers' main adaption strategies.



Source: Bangladesh Meteorological Department.

Figure 5: Farmers' perceptions of yearly temperature changes over the last 20 years rainfall changes.

weather. Farmers were also asked about these over the past 20 years. Farmers' views on these parameters are shown in Table 1. Almost 100% of the household heads perceived that availability of both groundwater and surface water had decreased. The severity of heat waves had increased for nearly 100% of household heads while the perception on the severity of colder weather is diverse.

Farm-level adaptation strategies: It is useful to discover adaptation strategies in order to obtain an understanding of an agricultural system's mitigate capacity [15]. Farmers in the study area were asked to reveal their major adaptive strategies in response to changing climate. These are summarized in Figure 7.

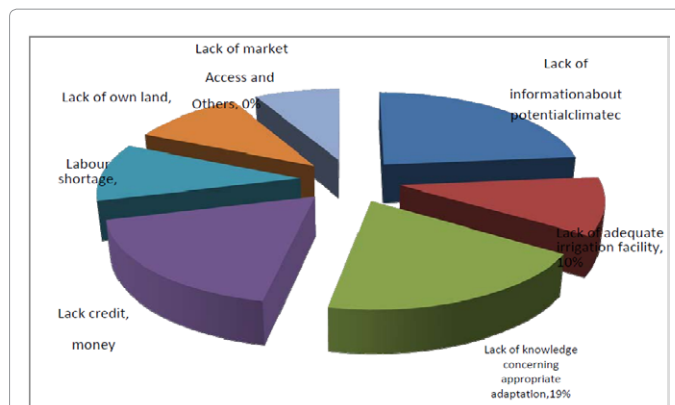
Farmers have adopted a variety of adaptation strategies including irrigation, direct seeded rice, greater emphasis on Aman rice with supplementary irrigation, short-duration rice varieties, changing planting and harvesting dates, the conversion of paddy land into mango

or chards, agro-forestry, using different crop varieties, the cultivation of various pulses and the cultivation of jute and wheat. Irrigation is the most commonly used method (75%). Other main adaptive choices are changing the planting date and supplementary irrigation for Aman rice. In addition to the main mitigation strategies farmers were asked about their secondary adjustment measures which are presented in Figure 8.

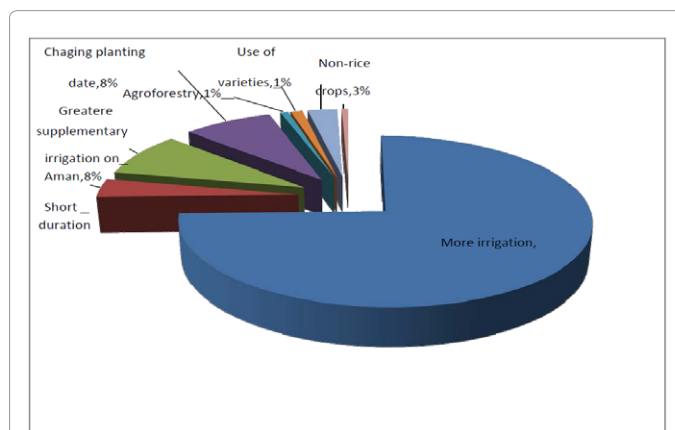
Farmers' secondary mitigation measures Changing planting date, cultivation of short-duration rice, using different crop varieties and supplementary irrigation for Aman rice are important secondary adaptation strategies. The main and secondary mitigation choices mentioned by farmers are very similar to those found in other studies for adjacent districts [21]. The adoption of these adaptation strategies implies that the farmers in the study area are risk-averse.

Adjust to the alleviation

Farmers take other adjustment measures after adaptation has taken place. This is because mitigation incurs costs. Mitigation strategies might resolve one problem but they sometimes create other problems which necessitate an 'mitigate to mitigations' [19]. Farmers in the study area do take other adjustment measures after mitigation (Figure 9). The results reveal that 28% of households took loans from rural usury lenders and relatives, 26% sold their livestock and nearly 17% used their previous savings in order to undertake mitigation measures.



Source: Bangladesh Meteorological Department.
Figure 10: Barriers to adaptation.



Source: Bangladesh Meteorological Department.
Figure 11: Farmers' main mitigation choices.

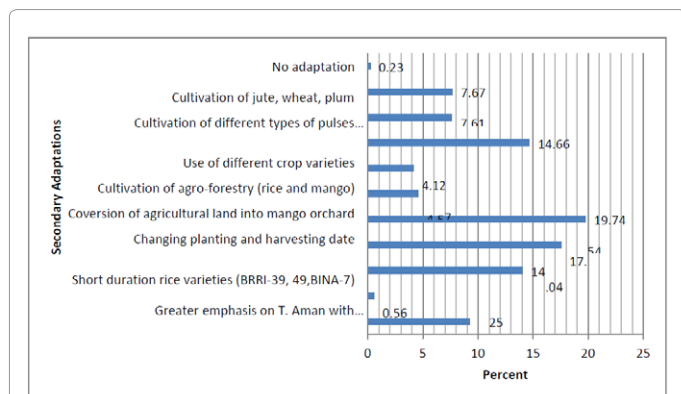
Other adapt to mitigation measures included the sale of other assets, mortgaging of land, borrowing institutional micro-credit, and family members migrating to urban areas in search of additional income sources.

Obstacles to mitigation

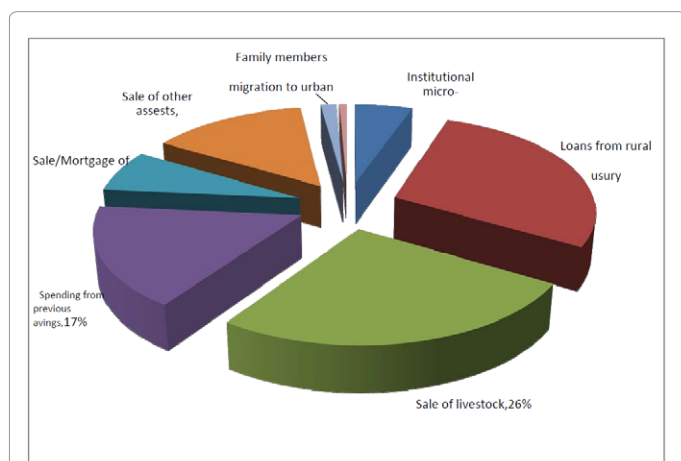
Issues such as accessibility and usefulness of climate information, the institutional environment and the socio-economic situation of households affect farmers' capacity to adapt to climate change [29-31]. Farmers perceived barriers to the adoption of various mitigation strategies (Figure 10). Farmers outlined the most important barriers as a lack of weather information, a lack of knowledge on appropriate adaptation strategies and a lack of credit (money or saving). Other important barriers are lack of own land, a lack of irrigation water and labour shortages.

Determinants of mitigations: Evidence from the MNL model

Model variables: The mitigation MNL model with the 11 choices as exposed in Figure 7 failed to produce realistic results in terms of arithmetical significance of the parameter estimates and on the edge effects. Following Gbetibouo, the model was reorganized by categorizing closely related strategies into the same group. The merging of direct-seeded rice with short-duration rice, the integration of conversion of agricultural land into shirm farm with Agro economy,



Source: Bangladesh Meteorological Department.
Figure 8: Farmers' secondary mitigation measures.



Source: Bangladesh Meteorological Department.
Figure 9: Measures for mitigate to mitigation.

and the cultivation of jute, wheat, plum and different types of pulses were grouped into non-rice crops. Therefore, the options finally included in the MNL model had eight categories: (i) More irrigation, (ii) Short-duration rice, (iii) Greater emphasis on additional irrigation for Aman rice, (iv) Altering planting date, (v) Agro-forestry, (vi) Use of different crop varieties, (vii) Non-rice harvests and (viii) No variation (Figure 11). However, the last category is the reference category in this analysis. The dependent variable of the MNL model is thus the choice of mitigation having eight categories.

The explanatory variables for this study have been selected on the basis of the available literature. They include household, farm and institutional characteristics of gender, age and education of household head, household size, household assets, farm income, farm size, tenure status, farming experience, livestock ownership, access to institutional extension services, farmer-to-farmer extension, information on climate change, access to credit, subsidy, electricity and distance to market (Table 2).

Results from the MNL model and discussions

The MNL model with eight categories of mitigation choices was run and tested for the IIA assumption by applying the Hausman test. The results of the Hausman test are set out in Table 3. All P-values for omitted variables are 1.00 indicating that the model has passed the assumption. If the chi-square value is less than 0.00, the estimated

model does not meet the asymptotic assumptions of the test. Negative test statistics are very common in quantitative work. Hausman and McFadden noted this possibility and concluded that a negative result was evidence that the assumption of IIA had not been violated.

Therefore, the use of the MNL model for adaptation strategies is justified. Probabilities of chi-square values are positive which indicate that the use of MNL model for the dataset is valid.

As most of the explanatory variables are dummies, the RRR can be explained as the relative probability of choosing alternative j to no adaptation which is the base category (or comparison group). Following Yip et al. [32] and Hisali et al. [17], RRR is presented for each adaptation choice (choice j) given a particular characteristic (xi) in Table 4 as well as factors that guide farm household choice of an mitigation choice in the face of climate change. The probability value of LR chi-square implies that all variables are jointly significant though some variables are not individually statistically significant. Following Bryan et al. [1], only the statistically significant variables affecting adaptation choices are discussed here.

Gender of household head: The results show that male-led households increase the chances of more irrigation, the use of short-duration rice and non-rice crops as opposed to using no mitigation. This is probably because male-led households are more informed about new technology than female-led households [1,33].

Variables	Value	Expected sign	Citations
Gender of household head	1=male,0=female	+/-	Nhemacha [12], Deressa et al. [16] Gbetibouo [26]
Age of household head	Years	+/-	Nhemacha [12], Deressa et al. [16] Gbetibouo [26], Hisali et al. [17] Mendelsohn [5]
Education of household head	Years	+	Deressa et al. [16], Mendelsohn [5]
Household size	Number	+	Nhemacha [12], Deressa et al. [16] Gbetibouo [26], Hisali et al. [17] Mendelsohn [5], Bryan et al. [1]
Farm income	Tk.	+	Nhemacha [12], Deressa et al. [16]
Household assets	Tk.	+	Bryan et al. [1], Gbetibouo [26],
Farm/land size/land area	Decimal	+	Nhemacha [12], Deressa et al. [16] Gbetibouo [26], Bryan et al. [1]
Tenure status	1=own,0=otherwise	+	Gbetibouo [26], Bryan et al. [1]
Farming experience	Years	+	Gbetibouo [26]
Livestock ownership	1=Yes, 0=No	+	Deressa et al. [16]
Access to extension (institutional)	1=Yes, 0=No	+	Nhemacha [12], Deressa et al. [16], Gbetibouo [26], Hisali et al. [17], Bryan et al. [1]
Farmer-to-farmer extension	1=Yes, 0=No	+	Deressa et al. [16]
Information on climate change	1=Yes, 0=No	+	Deressa et al. [16], Gbetibouo [26], Gbetibouo [26]
Credit access	1=Yes, 0=No	+	Nhemacha [12], Deressa et al. [16], Gbetibouo [26], Hisali et al. [17], Bryan et al. [1]
Access to subsidies	1=Yes, 0=No	+	Kurukulasuriya [11]
Access to electricity	1=Yes, 0=No	+	Nhemacha [12]
Distance to market	Kilometres	-	Deressa et al. [16], Hisali et al. [17], Bryan et al. [1]

Source: Bangladesh Meteorological Department by Sarker

Table 2: Explanatory variables hypothesized to affect adaptation strategies.

Omitted	Chi-square	d.f.	P > chi-square	Evidence for H ₀
More irrigation	0.052	6	1.000	Yes
Short-duration rice	- 82.386	18	1.000	Yes
Supplementary irrigation	- 49.955	13	1.000	Yes
Changing planting date	- 84.181	16	1.000	Yes
Agro-forestry	- 74.813	15	1.000	Yes
Use of different varieties	- 46.435	13	1.000	Yes
Non-rice crops	- 50.571	13	1.000	Yes
No adaptation	- 53.806	15	1.000	Yes

H₀: odds (outcome-J vs. Outcome-K) are independent of other alternatives

Source: Bangladesh Meteorological Department by sarker

Table 3: Hausman test of IIA assumption for the MNL model.

Explanatory variables/ Adaptive strategies	Irrigation		Short-duration rice		Supplementary irrigation		Changing planting date		Agro-forestry		Different crop varieties		Non-rice crop	
	RRR	P level	RRR	P level	RRR	P level	RRR	P level	RRR	P level	RRR	P level	RRR	P level
Gender of household head	6.69e-09 [*]	0.098	5.05e-09 [*]	0.095	8.026	-	1.09E-08	0.109	0.117	1	2.656	0.938	2.85e-09 [*]	0.083
Age of household head	9.725	0.237	37.680 [*]	0.097	18.578	0.157	18.084	0.182	10.947	0.457	53.192	0.139	14.205	0.262
Education of household head	2.577 ^{**}	0.042	1.751	0.283	2.504 [*]	0.061	4.017 ^{***}	0.005	10.506 ^{***}	0.009	3.414 ^{**}	0.039	4.742 ^{***}	0.01
Household size	0.3	0.244	0.148	0.103	0.255	0.213	0.573	0.616	0.524	0.652	0.128	0.128	0.182	0.188
Yearly farm income	12.531 ^{***}	0.001	6.317 ^{**}	0.026	8.559 ^{***}	0.008	4.573	0.069	10.760 ^{**}	0.031	5.304 [*]	0.074	4.649 [*]	0.075
Household asset	0.652	0.356	0.706	0.512	0.7	0.471	0.606	0.322	0.674	0.509	0.280 ^{**}	0.028	0.747	0.599
Farm size	0.377	0.145	0.586	0.495	0.355	0.156	0.358	0.17	1.714	0.643	7.468 ^{**}	0.048	0.532	0.458
Tenure status	4.332	0.133	7.169 [*]	0.081	5.34	0.106	3.171	0.266	1.36E+08	0.998	12.909 [*]	0.096	10.186 [*]	0.073
Farming experience	0.129 [*]	0.053	0.094 ^{**}	0.041	0.116 [*]	0.054	0.156	0.113	0.197	0.335	0.119	0.13	0.164	0.137
Livestock ownership	1.917	0.509	6.78	0.179	3.588	0.292	1.258	0.835	8.48E+07	0.998	0.963	0.976	1.375	0.79
Access to extension	1.676	0.55	1.102	0.923	1.383	0.73	0.274	0.23	7.425	0.112	1.352	0.789	1.516	0.694
Farmer-to-farmer extension	8.078	0.126	1.60e+10 ^{**}	0.003	9.07E+08	0.046	9.169	0.146	17.459	0.167	12.211	0.214	1.42E+10	-
Information on climate change	1.096	0.915	0.881	0.901	0.533	0.506	0.642	0.653	0.937	0.959	1.333	0.814	1.611	0.673
Credit access	3.84	0.124	8.672 ^{**}	0.031	2.204	0.414	1.9	0.531	1.715	0.679	2.689	0.394	3.88	0.198
Access to subsidies	0.172 [*]	0.058	0.247	0.217	0.284	0.242	0.147	0.173	0.183	0.299	0.876	0.918	0.336	0.352
Access to electricity	2.36	0.267	1.254	0.809	2.63	0.262	7.648 ^{**}	0.026	1.04E+08	0.998	7.432	0.154	2.48	0.398
Distance to market	0.389	0.181	0.472	0.35	0.717	0.656	0.973	0.971	1.694	0.598	0.285	0.156	0.251	0.108
Model Summary														
Base outcome	: No adaptation													
Number of observations	: 550													
LRchi-square	:244.32													
Prob>chi-square	: 0.000													
Loglikelihood	:-497.77													
Pseudo-R2	: 0.20													
***Significant at 1% probability level, **Significant at 5% probability level, *Significant at 10% probability level. RRR = Relative risk ratio														
Source: Bangladesh Meteorological Department														
Collected by Rashid														

Table 4: Relative risk ratios of the MNL model for rice farmers' adaptation.

Age of household head: Age of the household head is a proxy for experience and affects mitigation strategies to climate change [1]. Our results reveal that age is significant for short- duration rice and the value of RRR indicates a unit increase in age of household head increases the possibility of the use of short-duration rice. This finding is consistent with Kebede et al. and Deressa et al. [1].

Education of household head: Higher levels of education are positively related to the adoption of improved technologies: farmers with more schooling are expected to adapt better to climatic changes and extreme climate events [1,34-36]. Years of education of household head is a significant determinant or all adaptation strategies excluding short-duration rice. The values of RRR indicate that the education of the household head increases the chances of adopting irrigation, supplementary irrigation, changing planting date, agro-forestry, different crop varieties and non-rice crop relative to the choice of no adaptation.

Conclusion

The study clarified that out of eight factors surveyed; age, education, family size, farm size, family income, and involvement in cooperatives were meaningfully related to self-reported adaptation. Notwithstanding different support and technical intrusions being

available, lack of available water, lack of cultivable land, and random weather graded highest as the defendant group's restraints to coping with ecological poverty and change belongings. These results deliver policy makers and advance service providers with vital awareness, which can be used to better mark interventions which build endorse or facilitate the adoption of coping appliances with potential to build resiliency to changing climate and following biological possessions.

References

- Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environmental science and policy 12: 413-426.
- Reidsma P, Ewert F, Lansink AO, Leemans R (2010) Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses. European Journal of Agronomy 32: 91-102.
- Liu S, Mo X, Lin Z, Xu Y, Ji J et al. (2010) Crop yield responses to climate change in the Huang-Huai-Hai Plain of China. Agricultural water management 97: 1195-1209.
- Stern N (2006) What is the economics of climate change? World Economics 7: 1-10.
- Kurukulasuriya P, Mendelsohn R (2008) A Ricardian analysis of the impact of climate change on African crop land. African Journal of Agricultural and Resource Economics 2: 1-23.

6. Reidsma P, Ewert F, Oude Lansin A, Leemans R (2009) Vulnerability and adaptation of European farmers: a multi-level analysis of yield and income responses to climate variability. *Regional Environmental Change* 9: 25-40.
7. Adams RM, Rosenzweig C, Peart RM, Ritchie JT, McCarl BA et al. (1990) Global climate change and US agriculture. *Nature* 345: 219-224.
8. Mendelsohn R, Nordhaus WD, Shaw D (1994) The impact of global warming on agriculture: a Ricardian analysis. *The American Economic Review* 84: 753-771.
9. Adams RM, Fleming RA, Chang CC, McCarl BA, Rosenzweig C (1995) A reassessment of the economic effects of global climate change on US agriculture. *Climatic Change* 30: 147-167.
10. Mariara JK, Karanja FK (2007) The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. *Global and Planetary Change* 57: 319-330.
11. Kurukulasuriya P, Ajwad MI (2007) Application of the Ricardian technique to estimate the impact of climate change on smallholder farming in Sri Lanka. *Climatic Change* 81: 39-59.
12. Nhemachena C, Hassan R (2007) Micro-Level Analysis of Farmers Adaption to climate change in Southern Africa. International Food Policy Research Institute, Washington, Washington DC.
13. IPCC (2001) Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
14. Bradshaw B, Dolan H, Smit B (2004) Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. *Climatic Change* 67: 119-141.
15. Reid S, Smit B, Caldwell W, Belliveau S (2007) Vulnerability and adaptation to climate risks in Ontario agriculture. *Mitigation and Adaptation Strategies for Global Change* 12: 609-637.
16. Deressa TT, Hassan RM (2009) Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures. *Journal of African Economies* 18: 529-554.
17. Hisali E, Birungi P, Buyinza F (2011) Adaptation to climate change in Uganda: Evidence from micro level data. *Global Environmental Change* 21: 1245-1261.
18. Smith B, Burton I, Klein RJT, Wandel J (2000) An anatomy of adaptation to climate change and variability. *Climatic Change* 45: 223-251.
19. Paul BK (1998) Coping mechanisms practiced by drought victims (1994/5) in North Bengal, Bangladesh. *Applied Geography* 18: 355-373.
20. Ali A (1999) Climate change impacts and adaptation assessment in Bangladesh. *Climate Research* 12: 109-116.
21. Ahmed AK, Chowdhury EH (2006) Study on livelihood systems assessment, vulnerable groups profiling and livelihood adaptation to climate hazard and long term climate change in drought-prone areas of NW Bangladesh. Rural Development Division, Food and Agriculture Organization, Rome.
22. FAO (2006) Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh. Food and Agriculture Organization, Rome.
23. Rashid MH, Islam MS (2007) Adaptation to climate change for sustainable development of Bangladesh agriculture. Bangladesh Country Paper, APCAEM.
24. Rosenzweig C, Parry ML (1994) Potential impact of climate change on world food supply. *Nature* 367: 133-138.
25. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19: 248-255.
26. Gbetibouo GA (2009) Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. International Food Policy Research Institute Discussion Paper 00849, Washington, Washington DC.
27. Kropko J (2007) Choosing between Multinomial Logit and Multinomial Probit Models for Analysis of Unordered Choice Data. *Pro Quest, Ann Arbor*.
28. Islam T, Neelam A (2010) Climate Change in Bangladesh: A Closer Look into Temperature and Rainfall Data. University Press Ltd, Dhaka.
29. Roncoli C, Ingram K, Kirshen P (2002) Reading the rains: Local knowledge and rainfall forecasting in Burkina Faso. *Society and Natural Resources* 15: 409-427.
30. Eakin H (2003) The social vulnerability of irrigated vegetable farming households in central Puebla. *The Journal of Environment and Development* 12: 414-429.
31. Agrawal A (2008) The role of local institutions in adaptation to climate change. International Forestry Research and Institutions Program Working Paper W08 I-3.
32. Yip, WC, Wang, H and Liu, Y (1998) Determinants of patient choice of medical provider: a case study in rural China. *Health policy and planning* 13: 311-322.
33. Asfaw A, Admassie A (2004) The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agricultural Economics* 30: 215-228.
34. Norris PE, Batie SS (1987) Virginia farmers' soil conservation decisions: An application of Tobit analysis. *Southern Journal of Agricultural Economics* 19: 79-90.
35. Lin JY (1991) Education and innovation adoption in agriculture: evidence from hybrid rice in China. *American Journal of Agricultural Economics* 73: 713-723.
36. Maddison D (2006) The perception of an adaptation to climate change in Africa. University of Pretoria, Pretoria.