

Perception of and Adaptive Capacities to Climate Change Adaptation Strategies and Their Effects on Rice Production: A Case of Pabna District, Bangladesh

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Abstract: Bangladesh is one of the most sensitive hotspot for climate change and climate-related extreme events which significantly affect agricultural production. As a result farmers' try to minimize the adverse affects by various adaptation strategies. The aim of the study is thus, perception of and adaption capacities to climate change adaption strategies and their effects on rice production in a moderate level of drought severity and groundwater depletion but greater cropping diversity area (Pabna District). To find out the actual trend of climatic variables (e.g., temperature and rainfall) forty two years of climate data on temperature and rainfall (1972-2013) from the Bangladesh Metrological Department (BMD) for Ishwardi weather station were collected and analyzed using non-parametric Mann-Kendall test. The adaptive capacities of rice farmers were estimated quantitatively and categorized into high, moderate and low adaptive capacities. Double logarithmic regression model of Cobb-Douglas production function was used to quantify the effects of adaptive capacities of farmers on rice production. The data was obtained by conducting direct collaboration with 200 rice growers of Pabna District in the periods of July, 2015. The results of Mann-Kendall test revealed that an increase in annual temperature of +0.014°C and decrease in annual rainfall -1.152 from 1972 to 2013 has been recorded for the Ishwardi station of Pabna District, Bangladesh which is similar with the farmers' perceptions. Result of adaptive capacities revealed that on the average the farmers' interviewed are moderately adaptive to climate change. The results of Cobb-Douglas production function identified that the degree of adaptive capacities, labour, use of fertilizer, farm size, education and extension contact have significant effects on rice production. It also indicates that the more a farmer has the ability to adjust to climate change strategies the more the rice output he or she obtain. Therefore, rice farmers should be empowered through better extension services for obtaining more rice output. Strengthening agricultural research and support services including information accessibility, education and training for improved crop culture practices, and expanded and efficient surface-water irrigation infrastructure are critically important for increasing the adaptive capacities of the farmers.

Keywords: Adaptive Capacities, Adaption Strategies, Climate Change, Cobb-Douglas, Rice, Bangladesh

1. Introduction

Climate is commonly as the weather over a long period of time [3]. The standard averaging period is 30 years [9]. If the averaging period is very lower than the standard it would be threatened to the globe. Now-a-days the period is smaller resulting the climate change, has become most complex and

challenging issue in the globe. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. Individuals research [1], and institutions such as the Inter-Governmental Panel on Climate Change [24], the United Nations Development Program (UNDP) [43], the World Bank (2010) and Food and Agriculture Organization [18] have demonstrated that climate change is a reality and a primary

environmental threat to sustainable development in the 21st century. From 1906 to 2005 the global average surface temperature increased by 0.74 [0.56 to 0.92]°C. The linear warming trend over the 50 years from 1956 to 2005 was 0.13 [0.10 to 0.16]°C per decades is nearly twice that for the 100 years from 1906 to 2005 [24]. IPCC has estimated that by 2100, average temperatures will increase by between 1.4° and 5.8°C. IPCC also reported sea levels would rise by an average 0.09 to 0.88 m between 1990 and 2100.

The global climate has changed and these changes are shown by more frequent and intensity as well as irregular changes of disasters such as floods, droughts, storms and Tsunami within and over years. These changes have largely impacted on social, economic and environmental systems and shaped prospects for sustainable agricultural and rural development [17]. However, the impacts of climate change will not be uniform across the globe and considerable differences are expected among different regions [33]. Surprisingly, the poorest countries, who are the least contributors to global climate change, are amongst the most vulnerable to climate change. Poor communities are not only located in high-risk areas, but their lack of economic and social resources means they are ill-equipped to adjust to the long-term changes in climate [40, 42, 15] where half of the world's seven billion people take rice as staple food where more than 90% of its produced and consumed in Asia. So, the effect of climate change has already shown off its vulnerable effect to the rice production. Since a temperature increase of 0.5°C is projected to reduce rice output by 5.91% [44].

Agriculture is an important sector of the Bangladesh economy. Despite a declining share in the gross domestic product (GDP), agriculture remains the pillar of the Bangladesh economy. It represents the critical source of income for the majority of the population and directly employing about half of the total labour force [22]. Furthermore, rural communities, that represent the vast majority of the population, will continue to depend on agriculture even with structural change in the economy (World Bank, 2013). Rice accounts for 90% of the total food production in Bangladesh and occupies nearly four-fifths of the gross cropped area. As a crop, it is sensitive to changing climate related extreme events, such as flood, drought, cyclones [35] and groundwater depletion.

Climate change in Bangladesh is especially a serious concern since agriculture is the most vulnerable sector to the climate change. German watch released the 2016 Global Climate Risk Index which indicates a level of exposure and vulnerability to extreme events that countries should understand as a warning to be prepared for more frequent and more severe events in the future and according to this index Bangladesh ranked sixth [49] and at the same time it indicates how serious the problem is for Bangladesh. Moreover, according to an estimation of Intergovernmental Panel on Climate Change [18], due to change in rainfall patterns associated with increasing temperatures, flooding, prolonged droughts and salinity by sea level rise could cause decline in rice production in Bangladesh by 8% in the year of

2050 against 1990 as the base year [35]. Hussain [24] has predicted that due to the effect of high temperature, crop production of two most important rice varieties (*Aus* and *Aman*) will be declined by 1.5-25.8% for *Aus* variety, and 0.4-5.3% for *Aman* variety (*Aus* and *Aman* rice varieties are cultivated during monsoon season in Bangladesh) respectively in the year of 2050. Since rice is very sensitive to climate, environmental and soil conditions, any unfavorable changes in climatic factors (temperature, precipitation, relative humidity and bright sunshine duration) are expected to affect rice yield adversely. Despite these serious climates-related difficulties, Bangladesh may be able to develop adaptive responses that could mitigate these effects.

Two ways to get rid of climate change vulnerability: mitigation and adaptation. Since mitigation is the time consuming process; so adaptation, the adjustment strategies is only the way get rid of climate change vulnerability. Adaptation is a policy option for limiting the negative effects of climate change [30]. This policy option can reduce vulnerability both to slow-onset climate change (e. g. sea level rise and salinization) and to extreme climatic events, such as droughts and floods [11]. And vulnerability could be reduced by altering exposure, reducing sensitivity, and improving the adaptive capacity of the system [50, 39]. IPCC [18] defines adaptive capacity as the ability or potential of a human or natural system to respond successfully to climate variability and change so as to moderate potential risks or cope with consequences of extreme events such as, floods, heavy hail/snow events, heavy wind and dust storms, droughts and dry spells, heat waves and warm spells, cold spells. Farmers have many different options available to cope with climate change; some of the options are able to increase soil fertility and moisture, therefore being suitable for improving adaptation capacity; most options can sustainably increase crop yields. The most common adaptation options include changing crop varieties, irrigation, planting trees, crop and livestock diversification, soil conservation, early and late planting, increasing plant spacing, use of clay soil, and adjusting the level and timing of applying fertilizer [10; 14, 30, 37, 38, 51] Traditional and newly introduced adaptation practices can help farmers to cope with both current climate variability and future climate change [8]. In Bangladesh, Ghosh et al.[12], Masud et al. [53], Sarker et al. [54] and Alauddin. M and Sarker A. R., [2] found that changing planting dates, early maturing rice varieties, drought tolerant rice varieties, use of chemical/organic fertilizers, farming near water bodies, mixed cropping, improved irrigation, set up shallow tube well in pond, building of embankments, integration of trees in rice farms, crop rotation, short duration species selection, little pond digging to conserve rain water etc. are the common adaptation strategies to climate change. But there are many barriers to adaptation include lack of information, lack of access to credit and land, and water shortages [46, 51, 14].

Taking into consideration the combined effects of climate change on rice-intensive countries such as Bangladesh, an

investigation of perception of and adaptive capacities to climate change adaptation strategies and their effects on rice production is necessary to find out or understand how the degree of adaptive capacities of farmers among existing adaptation strategies affects rice production appears essential. Farmers' perceptions of the long-term changes in climate variables and extreme weather events are important because farmers first perceive the changes and then, based on their perceptions, they make decisions about adaptation strategies. This research advances the existing literature in two important ways. First, it uses farm-level survey data and quantitative analysis (to focus specially on rice farmers' adaptive capacities to climate change adaptation strategies and their effects on rice production in moderate drought severity and groundwater depletion areas in Bangladesh). Second, adaptive capacity varies from farmer to farmer that's why degree of adaptive capacity among climate change adaptation strategies also varies and of course it affects rice output. So, it is very essential to estimate the adaptive capacity to climate change adaptation strategies. But no studies have been done on adaptive capacities to climate change adaptation strategies and their impact on rice production in Bangladesh using micro data till now. Thus, the present study is an effort to improve our understanding about the rice farmers' perceptions, adaptive capacities to climate change adaptation strategies and their effects on rice production. It is very important for policy makers and technocrats to improve the farmers' adaptive capacities to climate change adaptation strategies as well as increasing rice productivity.

Section 2 reviews the relevant empirical evidence, while section 3 presents and discusses the methodology. Section 4 presents and discusses the empirical results of the study. Section 5 discussed the conclusion and policy implications of the findings.

2. Literature Review

Three bodies of literature are relevant to this study: (1) Perception of the climate Change; (2) Adaptive capacities to climate change adaptation strategies and (3) their impact on rice production. Apart from research undertaken on Bangladeshi farmers, which is reviewed in section 2.2 the bulk of the existing research that has investigated farm-level adaptation to climate change has been mostly in in Africa countries (Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe) and to a lesser extent in Sri Lanka, Australia, Malaysia, China, Nepal, Philipaine, and India. The result from this body of research is examined first.

2.1. Evidence Excluded Bangladesh

The role of the human perception is one of the most important questions. If we understood how a human - perceives information and operates it - we would more precisely make the future forecasts and increase our efficiency". That's why Deressa *et al.* [14] consider

perceiving climate variability is the first step in the process of adapting agriculture to climate change. A better understanding of farmers' concerns and the manner in which they perceive climate change is crucial to design effective policies for supporting successful adaptation of the agricultural sector. Further, it is also important to have precise knowledge about the type and extent of adaptation methods being taken up by farmers and need for further advances in existing adaptation setups. Hence, understanding how farmers perceive changes in climate and what factors shape their adaptive behavior is useful for adaptation research [33, 48]. Bewket [7] found that increased temperature and decreased rainfall are widely held perceptions; all respondents stated that they had observed increase in temperature and decrease in annual and seasonal rainfall amounts.

In America Brechin, [12] found that between 1989 and 2003, 24 percent to 40 percent of the respondents worried about greenhouse effects as a great deal, where 52 to 72 percent have felt this way for a number of years and worried about a fair amount. In another research, Leiserowitz [31] contended that since the year 2000, large majorities (92 percent) of Americans were aware of global warming. Moreover, 74 percent of them argued that climate change was real and already underway. Meanwhile, 76 percent of the total population already viewed climate change as a somewhat very serious problem. Namafe (2009) also highlights that even Barack Obama, the incumbent president of USA by the time this research was conducted, never considered climate change as a major pressing environmental issue compared to terrorism and others.

Oxfam (2008) surveyed two of Vietnamese provinces, Ben Tre and Quang Tri in May 2008 to take a snapshot of Vietnam, how poor families were experiencing climate change. The perception of many villagers and local leaders in these provinces was that climate was changing. In Uganda Okonya J. S., Syndikus K. & Kroschel J. (2013) revealed weather-related events such as prolonged dry seasons, floods, storms, mudslides, extreme rainfall, and delayed/early rains have become more frequent. Ninety nine percent of all households interviewed had observed a change in the climate in the last 10 years. The highest impact had on crop production.

Wang *et al.* [47] also find that climate change indirectly affects crop production as farmers react to changes in market signals. Second, the economic research accounts for the ways in which changes in trade flows and prices (which are direct consequences of climate change effects in other countries) will impact China's agricultural sector. To recover this react they have already attempted to take adaptive strategies. They have different adaptive capacities.

Gupta, J. *et al.* [23] found out the question: How can the inherent characteristics stimulate the capacity of society to adapt to climate change from local through to national level is assessed? This can help to assess if the adaptive capacity to respond to climate change; and to focus on whether and how institutions need to be redesigned. This paper also briefly

demonstrates the application of this Adaptive Capacity Wheel to different institutions.

G. A. Glwadys et al. [19] estimated that climate has changed and farmer's perceptions are in the line with the climatic data record. The study tries to examine the determinant of adaptation to climate change. However, only approximately half of the farmers have adjusted their farming practices to account for the impacts of climate change. Lack of access to credit was cited by respondents as the main factor inhibiting adaptation. So the adaptive capacities are also very poor. The analysis highlighted that household size, farming experience, wealth, and access to credit, access to water, tenure rights, off-farm activities, and access to extension are the main factors that enhance adaptive capacity.

Mabe, F. N. et al. [57] estimate the adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the northern region of Ghana. The adaptive capacities of rice farmers categorized into high, moderate and low adaptive capacities. On the average, the farmers interviewed moderately adaptive to climate change. He founded that farmers with high adaptive capacities obtained higher paddy rice more than moderate and low adaptive farmers. Rice farmers should be empowered through extension services in order to attain high adaptive capacities status so as to help them obtain more rice output. Another studies performed by Mabe F. N., Sienso G. & Donkoh S. [32] revealed different effects of the factors on farmer's choice of adaptation strategies. Farming experience, farm income, access to phones, mixed farming, farmers' perception on reduction in rainfall amount and access to weather information significantly and positively affects the choice of at least five climate change adaptation strategies. But lack of agricultural extension service, adult education programs, and agro climatic information centers may weak the adaptive capacities.

Okonya J. S., Syndikus K. & Kroschel J. [40] revealed weather-related events have become more frequent and intense in Uganda. This has left most of the rural poor farmers' food insecure and their livelihoods threatened while gender of the household head and size of land owned significantly affected adaptation. Coping strategies towards extreme events included storing food, income diversification and digging drainage channels. Other strategies were planting trees; high-yielding, early-maturing, drought-tolerant, disease and pest-resistant varieties; planting at onset of rains; increased pesticides application among others. But there are available a very few number of strategies and the farmers experienced low adaptive capacities of the strategies.

2.2. Evidence from Bangladesh

Most studies that have examined adaptation to climate change in drought prone areas of Bangladesh without focusing their adaptive capacities and their impact on rice production. Only one study used quantitative method, using non parametric mann-kendall test and sen's slope [21].

Rakib, M. and Anwar, S. M. H. [42] examined the determinants of farmers' perception on climate variability in

different specifications of household characteristics. The sample was adult farmers with at least 20 years of farming experience in the area. The research revealed that more than 80% of farmers believe that temperature in the district had become warmer and over 90% were of the opinion that rainfall timing had changed, resulting in increased frequency of drought.

Kamruzzaman, M. [27] explained determines and describe the perception of climate change of farmers. Most of the farmers (69.3%) perceived that climate change started between last 5 to 15 years. They felt that both rainy season and cold season delays to start but ends early. Similarly, they believe that hotness has increased (88.7%) and coldness has reduced (60.0%). Farmers found a reduction in overall rainfall (83.3%) and variation in wind speed, duration of strong wind. They felt the incidence of drought has been increased (73.3%) and flood has been decreased (66%).

Moniruzzaman, M. [36] performed a study on assess the people's perceptions and understanding on climate change to evaluate the awareness level of them on the impacts of climate change in the study area. The study revealed that a significant portions of the society was observing the extreme events of weather like cyclones and storm surges, coastal erosion, and the changes of sea surface i.e. climate change. But they were not aware enough regarding the impacts of climate change and variability; and have hazy knowledge about the climate change.

Islam, M. N. [26] conducted to determine the extent of the farmer's perception and agricultural adaptation to climate change in the severe drought prone area of Rajshahi Division Ishwardi and Lalpurupazila. The findings of the study indicate that the, farmer's perception about climate change was reasonable as majority of farmers claimed that precipitation was decreased, summer season temperature was increased, and winter season temperature was decreased The findings of the study also indicated that majority of the farmers had medium agricultural adaptation capability compare to farmers had low and few farmers had high agricultural adaptation capability.

Ghosh B. C. et al. [21] evaluates rice farmers' perception and climatic variability and adaptive capacities of rice farmers to climate change adaptation strategies were also identified. The results revealed that an increase in annual temperature of +0.04°C. The adaptive capacities of rice farmers were estimated quantitatively and categorized into high, moderate and low adaptive capacities. Result of adaptive capacities revealed that on the average the farmers' interviewed are moderately adaptive to climate change. As high adaptive farmers obtain higher amount of rice therefore, the more a farmer has the ability to adjust to climate change, the more the amount of rice he or she obtain. Rice farmers should be empowered through better extension services in order to attain high adaptive capacity status so as to help them obtain more rice output.

FAO [18] conducted a holistic analysis of the improvement of the improvement of the adaptive capacity in the face of climate variability. Their results showed that rice was the crop

most affected by drought, with recorded production losses up to 70%. FAO [18] identified some major adaptations strategies implemented by farmers, including the excavation of ponds and deep tube-well facilitated irrigation, expansion of mango plantations, the cultivation of short-duration and drought-tolerant crop varieties and homestead gardening.

A research performed by Ghosh, B. C., Mamun, A. H. M. M., Islam, S. M. R., [20] on the climatic effect on rice production. The research founded that need to improve adaptive capacities strongly. The study revealed the significant effects of climatic variables on rice yields and these effects vary among the three rice crops. Increase in Temperature and Relative humidity and decrease in Rainfall have both positive and negative effects on the yield. In that case almost 52% farmers perceive that crop production has decreased.

Although above studies provided useful direction, these studies suffer from two limitations. First, the studies aren't focus on the adaptive capacities to climate change adaptation strategies and their impact on rice production. Second, most of the past cross-sectional studies used county or district level data. But these studies do not allow for the detailed socio-economic and demographic characteristics of farmers that are likely to affect the farmer's perception, their choice of adaptation, and its capacities, thereby, farm productivity.

As the 1st study of its kind on Bangladesh, the current research breaks new ground in analyzing and enhancing farmer's adaptive capacities to climate change adaptation strategies and their impact on rice production. Specifically, this paper has the following research questions:

- a) What are the impacts of climate change on rice production?
- b) How the changes affect the rice production across the study area?
- c) How do rice farmers perceive the impact of climate change on rice production?
- d) How effectively farmers have to adapt to the available adaptation strategies?
- e) What is the degree of farmer's adaptive capacities to adaptation strategies in minimizing the effects of climate change?
- f) Is higher adaptive capacity equivalent to higher rice output and lower adaptive capacity equivalent to lower rice output?

3. Methodology

3.1. Study Area and Sample Selection

Both primary and secondary data were collected to complete the present study. Secondary data for different climatic variables (e.g. temperature and rainfall) was collected from Bangladesh Metrological Department, Dhaka for the *Ishwardi* weather station which covers the period 1972-2014. A cross-sectional survey to collect data by using random technique from farming households in the *Ishwardi Upazila* (also randomly selected) in *Pabna District* was

adopted for this study. The survey ends up with 200 valid observations (excluding missing information). The rationale behind selecting *Pabna District* for the present study is that (i) it is characterized by high temperature and very low rainfall which make it severely drought-prone and (ii) rice farming is the major livelihood-supporting activity. To answer the research questions, the survey sought information on:

- a) Farmers' perception about climate change, climatic variability, adaptation strategies and adaptive capacities to climate change adaptation strategies.
- b) Socio-economic characteristics (e.g. age, gender, education level of the household head, household size)
- c) Farm characteristics (farm size, ownership status production, production cost)

3.2. Mann-Kendall Test

By Mann-Kendall test, we want to test the null hypothesis H_0 of no trend, i.e., the observations X_i are randomly ordered in time, against the alternative hypothesis H_1 , where there is an increasing or decreasing monotonic trend. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S. The M-K test statistic S is calculated using the formula:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad (1)$$

The application of trend test is done to a time series x_k that is ranked from $k = 1, 2, \dots, n-1$ and x_j , which is ranked from $j = k+1, 2, \dots, n$. Each of the data point x_k is taken as a reference point which is compared with the rest of the data point's x_j so that,

$$\text{Sgn}(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}$$

It has been documented that when $n \geq 8$, the statistic S is approximately normally distributed with the mean. $E(S) = 0$. The variance statistic is given as,

$$\text{VAR}(S) = \frac{1}{18} \left[n(n-1)(2n+5) - \sum_{p=1}^q t_p(t_p-1)(2t_p+5) \right]$$

Here q is the number of tied groups and t_p is the number of data values in the p^{th} group. The values of S and VAR(S)

are used to compute the test statistic Z as follows

$$Z = \begin{cases} \frac{s-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases}$$

Z here follows a standard normal distribution. A positive (negative) value of Z signifies an upward (downward) trend. To test for either an upward or downward monotone trend (a two tail test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$.

3.3. The Sen’s Estimator of Slope

Some trends may not be evaluated as statistically significant even while they might have practical interest [55]. Linear trend analysis, Sen’s slope method is used in this study to estimate the magnitude of the trend. Here, the slope (Q_i) of all data pairs is computed as [56].

$$Q_i = \frac{x_j - x_k}{j - k} \text{ for } i=1,2,3,\dots,N \quad (2)$$

Where, x_j and x_k are considered as data values at time j and k ($j > k$) correspondingly. The median of these N values of Q_i is represented as Sen’s estimator of slope which is given as

$$Q_i = T_{N+1/2}, \text{ if } N \text{ is odd}$$

$$Q_i = \frac{1}{2}(T_{N/2} + T_{N+2/2}), \text{ if } N \text{ is even}$$

Sen’s estimator is computed as $Q_{med} = T_{(N+1)/2}$ if N appears odd, and it is considered as $Q_{med} = [T_{N/2} + T_{N+2/2}] / 2$ if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1- α)% confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q_i indicates an upward or increasing trend and a negative value of Q_i gives a downward or decreasing trend in the time series.

3.4. Measurement of Farmers’ Adaptive Capacities to Adaptation Strategies

According to Klein [74], adaptive capacity to climate change is the ability of a system or an individual to adjust to climate change or climate variability so as to minimize the potential damages or cope with the consequences. Adaptive capacity varies from farmer to farmer based certain factors that are peculiar to each farmer. Adaptive capacity varies from farmer to farmer based on certain factors that are peculiar to each farmer. It is assumed that farmers are rational and as such they adapt to climate change in order to reduce its consequences. Some farmers have higher ability to adjust to climate change than others. Asante et al. [65] and Nakuja et al. [52] measured adaptive capacities of farmers by considering five attributes such as knowledge, use, availability, accessibility and consultation. The adaptation strategies considered in this research are the use of chemical/organic fertilizer, improved irrigation, farming near water bodies, early maturing rice varieties, drought tolerant rice varieties, mixed cropping, changing planting dates, integration of trees in rice farms, building of embankments, crop rotation and setup shallow tube well in pond. Adaptive capacities of farmers depend on certain factors or attributes such as their knowledge on and number of times they use a particular adaptation strategy. Other factors are the availability and accessibility of the adaptation strategy. Also, the number of consultations that a farmer makes on a particular adaptation strategy affect whether the farmer will be lowly or moderately or highly adaptive to climate change. In measuring the adaptive capacities quantitatively, farmers were asked to indicate their degree of attainment of each attribute. The highest degree of attainment of each of the attributes or factors affecting adaptive capacities was scored 1 where the lowest degree was given a score of 0.25. The score level for a farmer with higher degree of attainment of each attribute is 0.75. Lastly, the score level for high degree of each farmer’s knowledge on each adaptation strategy was sought. In terms of knowledge, the higher the degree, the better knowledge the farmer has on a particular adaption strategy. Table 3.1 summarizes how each attribute was measured.

Table 1. Score Levels of Farmer's Achievement of Attributes.

Degree	Scores	Knowledge	Use	Availability	Accessibility	Consultation
Highest Degree	1.00	Very well	Several	Very regular	Easily Accessible	Several
Higher Degree	0.75	Well	Twice	Regular	Accessible	Twice
High Degree	0.50	Fairly well	Once	Occasionally	Not easily Accessible	Once
Low Degree	0.25	Not Well	Never	Never	Not Accessible	Never

Source: Modified from Nakuja et al. [52] and Mabe et al. [57]

The adaptive capacity (AdapCap) of an i^{th} farmer to j^{th} adaption strategy is calculated as shown in equation (1) below:

$$AdapCap_{ij} = \frac{K_{ij} + U_{ij} + V_{ij} + A_{ij} + C_{ij}}{N_A} \quad (3)$$

Where AdapCap_{ij} denotes the adaptive capacity of an i^{th} farmer to a j^{th} adaption strategy; K_{ij} , the knowledge of the i^{th} farmer on j^{th} adaption strategy; U_{ij} , the level of usage of j^{th} adaption strategy by i^{th} farmer; V_{ij} , the availability of

innovations on j^{th} adaption strategy to i^{th} farmer; A_{ij} , below
 accessibility of innovations on j^{th} adaption strategy to i^{th}
 farmer; C_{ij} , level of consultation on j^{th} adaption strategies by
 i^{th} farmer; N_A , the sum of applicable attributes.

The average adaptive capacity of farmers to j^{th} adaption strategy, $AveAdapCap_{ij}$ is calculated using the equation (4)

$$AveAdapCap_{ij} = \frac{\sum AdapCap_{ij}}{N} \quad (4)$$

Where, N is the number of Observations.

Table 2. Degree of Adaptive Capacities.

Degree of Adaptive Capacities	Ranges of Indices for AdapCap _{ij}	Ranges of Indices for AveAdapCap _{ij}
Low Adaptive Capacity	$0 < AdapCap_{ij} < 0.33$	$0 < AveAdapCap_{ij} < 0.33$
Moderate Adaptive Capacities	$0.33 \leq AdapCap_{ij} \leq 0.66$	$0.33 \leq AveAdapCap_{ij} \leq 0.66$
High Adaptive Capacity	$0.66 \leq AdapCap_{ij} \leq 1.00$	$0.66 \leq AveAdapCap_{ij} \leq 1.00$

Source: Modified from Nakuja *et al.* [52] and Mabe *et al.* [57]

Based on the adaptive capacities of the attributes, three indices were established. Table 2 shows the categories of adaptive capacities (low, moderate and high) to which each farmer falls within. It also shows the categories of average adaptive capacities (low, moderate and high) of each adaption technology. Farmer i is lowly adaptive to adaptation strategy j if the adaptive capacity calculated falls in the range of $0 < AdapCap_{ij} < 0.33$. The range for moderate and high adaptive capacities are $0.33 \leq AdapCap_{ij} \leq 0.66$ and $0.66 \leq AdapCap_{ij} \leq 1.00$ respectively.

3.5. Empirical Model for Quantifying the Effects of Adaptive Capacities on Rice Output

For quantifying the effects of adaptive capacities on rice output, a Cobb-Douglas production function is employed for this study. A Cobb-Douglas production function shows a technical relationship between inputs and output, specified as:

$$Q_i = \beta_0 K_i^{\beta_1} L_i^{\beta_2} \mu_i \quad (5)$$

Where Q_i is the total output of rice for i^{th} farmer, β_0 is the constant, K_i is the capital input for i^{th} farmer, L_i is the labor input for i^{th} farmer, μ_i is the error term for i^{th} farmer and

$$Q_i = \beta_0 K_i^{\beta_1} L_i^{\beta_2} Fert_i^{\beta_3} Fms_i^{\beta_4} Age_i^{\beta_5} e^{\beta_6 Ext_i} e^{\beta_7 edu_i} e^{\beta_8 LA_i} e^{\beta_9 HA_i} \mu_i \quad (6)$$

Taking natural log of equation (6) above gives the double log equation shown below:

$$\ln(Q_i) = \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + \beta_3 \ln Fert_i + \beta_4 \ln Fms_i + \beta_5 \ln Age_i + \beta_6 Ext_i + \beta_7 edu_i + \beta_8 LA_i + \beta_9 HA_i + \mu_i \quad (7)$$

4. Result and Discussion

4.1. Trend of Climatic Variability

For finding out the trend of climatic variability (e.g.

β_1 and β_2 are the slope coefficients for capital and labor respectively. The unit of measurement for rice output, capital and labour are kilograms, Bangladeshi Taka (Tk.) and man-days respectively.

An augmented Cobb-Douglas production is then specified as shown in equation (6) by including dummy variables such as extension contact (Ext), access to education (Edu), adaptive capacity indicators and continuous endogenous variable inputs such as quantity of fertilizer ($Fert$), farm size (Fms) and age of the farmer (Age). The variable „Extension contact“ is dummied 1 for farmers who have access to extension contact and 0 otherwise. A farmer with at least primary education is dummied 1 and 0 otherwise. La_i and HA_i represent low and high adaptive capacities respectively. A farmer with low adaptive capacity is dummied 1 and 0 otherwise. On the other hand, high adapters are given a score of 1 and 0 otherwise. Quantity of fertilizer, farm size and age are measured in kilograms (Kg), decimals (dc) and years respectively.

According to Onumah *et al.* [76], the Cobb-Douglas production function restricts the return to scale to one. Even though, this is a limitation, Cobb-Douglas production function had been used by Battese (1997) for its simplicity. Therefore, following Battese [75], we use an augmented Cobb-Douglas production function for this study, which is specified as:

temperature and rainfall) we use Mann-Kendall test. The Mann-Kendall test requires time series to be serially independent. The presence of serial correlation in the time series makes trend tests too liberal, i.e. the null hypothesis of no trend is rejected too frequently, specifically, if there is a positive serial correlation [62, 63]. For this, von Storch and

Navarra [64] suggest that the time series should be ‘pre-whitened’ to eliminate the effect of serial correlation before applying the Mann–Kendall test. This study incorporates this suggestion and thus possible statistically significant trends in climatic observations (x_1, x_2, \dots, x_n) are examined using the following procedures:

- a) Compute the lag-1 serial correlation coefficient (designated by r_1).
- b) If the calculated r_1 is not significant at the 5% level, then the Mann–Kendall test is applied to original values of the time series.
- c) If the calculated r_1 is significant, prior to application of the Mann–Kendall test, the ‘pre-whitened’ time series may be obtained as $(x_2 - r_1x_1, x_3 - r_1x_2, \dots, x_n - r_1x_{n-1})$ [66]

So, we remove the effect and analysis the trend. In the trend, annual temperature displays significant changes, with an upward trend identified for the *Ishwardi Upazila*. The average trend calculated for the study area has a Sen slope of +0.014, implying that an increase in annual temperature of +0.014°C from 1972 to 2013 has been recorded for the *Ishwardi Upazila* which is consistent with Chowdhury and Debsharma [59] and Mia [58] pointed out that temperature has been changed by using historical data of some selected meteorological station. Paratha sarathy et al. [60] and Divya and Mehritra [61] reported mean annual temperature of Bangladesh has increased during the period of 1895-1980 at 0.31°C over the past two decades. Karmakar and Shrestha [73] using the 1961-1990 data for Bangladesh projected that annual mean maximum temperature will increase to 0.4°C and 0.73°C by the year of 2050 and 2100 respectively.

Table 3. Trend of Annual Temperature and Rainfall for *Ishwardi Upazila*, 1972-2013.

Statistics	Temperature	Rainfall
Mann-Kendall Statistics	279.00	-216.00
Kendall’s Tau	0.340	-0.263
Sen’s Slope	0.014	-1.152
P-value	0.002	0.015
Alpha	0.05	0.05
Test Interpretation	Reject H_0	Reject H_0

Note: H_0 : There is no trend in the series, H_A : There is a trend in series

Table 4. Farmers’ Perception of Various Climatic Parameters over last 10 years.

Farmers’ Perceptions	Temperature (%)	Rainfall (%)	Drought (%)	Availability of Ground Water (%)	Availability of Surface Water (%)
Increased	95	1.8	96	2	1.5
Decrease	2.7	96	1.13	96	96
Don’t Know	2.3	2.2	2.87	2	2.5
Total	100	100	100	100	100

Source: Computation from Field Survey, 2015

Table 4 indicate that 95% of the surveyed farmers have observed increasing temperature while only an insignificant 2.7% noticed a decreased in temperature, and for 2.3% of the respondent can’t perceive. In case of rainfall 96% household heads observed a decline in yearly rainfall. 1.8% household

From the above table we see that annual rainfall displays significant changes, with a downward trend identified for the *Ishwardi Upazila*. The average trend calculated for the study area has a Sen’s slope of -1.152, implying that decrease in annual rainfall of 1.152 mm. 1972 to 2013 has been recorded for the *Ishwardi Upazila* which is consistent which is consistent with the study of Roy [78] and Zakaria [79], they also observe a significant downward trend for annual rainfall in the northern region of Bangladesh. So, climate of this region may change significantly. This decreasing trend of total rainfall may have the relationship to the decrease of water in rivers of this region, less evaporation as well as its consequences.

4.2. Farmer’s Perceptions of Climate Change

As Ban and Hawkins [4] define ‘perception’ it is the process by which we receive information or stimuli from our environment and transform it into psychological awareness. It is interesting to see that people infer about a certain situation or phenomenon differently using the same or different sets of information. Knowledge, interest, culture and many other social processes that shape the behavior of an actor who uses the information and tries to influence that particular situation or phenomenon [68, 67]. Saarinen [69] talks about perception as an extremely complex concept and confines ‘social perception’ which is concerned with the effects of social and cultural factors on cognitive structuring of our physical and structural environment. This varies with the individual’s past experiences and present sets or attitudes acting through values, needs, memories, moods, social circumstances, and expectations [69, 70] Farmers should perceive first that there is climate change in order to take necessary adaptive strategies [51]. The surveyed households were asked for any observed changes in temperature, rainfall, and drought, availability of ground water and availability of surface water over the past 20 years in order to ascertain their level of perception. Perceptions on climatic components were divided into three categories: increased, decreased, and don’t know. Farmers’ perceptions on each climatic parameter are presented below in Table 4.

heads perceived an increase in rainfall while don’t know to 2.2% respectively. Almost 96% households noticed that frequency of drought has increased over the last 10 years while 1.79% households had no idea about the drought. In case of availability of ground water and availability of

surface water 96% of the household heads perceived that availability of ground and surface water has decreased while 2.5% had no idea and 1.5% said that it has been increased.

4.3. Degree of Adaptive Capacities of Farmers' to Adaptation Strategies

The degree of adaptive capacities of rice farmers to the various adaption strategies is presented in Table 5. The

Table 5. Degree of Adaptive Capacities of Farmers.

Adaptation Strategy	Adaptive Capacities (AdapCap _i)	Rank	Degree of Adaptive Capacities
Use of Irrigation	0.81	1	High Adaptive Capacities
Use of Chemical Fertilizer	0.71	2	High Adaptive Capacities
Early Maturing Rice Varieties	0.58	3	Moderate Adaptive Capacities
Building of Embankment	0.44	4	Moderate Adaptive Capacities
Drought Tolerance Rice Varieties	0.40	5	Moderate Adaptive Capacities
Changing Planting Dates	0.39	6	Moderate Adaptive Capacities
Mulching	0.31	7	Low Adaptive Capacities
Integration of Trees in Rice Farms	0.30	8	Low Adaptive Capacities
Average	0.49	----	Moderate Adaptive Capacities

Source: Computation from Field Survey, 2015

The adaption strategies with moderate adaptive capacities are the early maturity rice varieties, embankment building, drought tolerance rice varieties, and changing planting dates. Out of the eight adaption strategies used, farmers are moderately adaptive to four of them. Among adaption strategies which farmers are moderately adaptive, the early maturity rice varieties had the highest adaptive capacity value of 0.58 while changing planting dates recorded the lowest of 0.39. The adaptive capacities calculated for embankment

respondents interviewed were highly adaptive to use of irrigation and use of chemical fertilizer. This is because their adaptive capacities are within the range of $0.66 \leq AdapCap_{ij} \leq 1.00$. Among these adaption strategies with high adaptive capacities, use of irrigation and use of chemical fertilizer recorded the adaptive capacities of 0.81 and 0.71 respectively.

building and drought tolerance rice varieties are equal with the value of 0.44 and 0.40 respectively. The respondents in the area have low adaptive capacity to the mulching and the integration of trees in rice farms. Mulching has the adaptive capacity value of 0.31. The adaptive capacity value quantified for integration of trees in rice farms is equal with a value of 0.30. Generally, the average adaptive capacity of the respondents is 0.49. This implies that farmers in the study area are moderate adapters to climate change.

Table 6. Percentage of Degree of Adaptive Capacities of Responsibilities.

Adaptive Capacities	Mean Adaptive Capacity	Frequency	Percentage
High Adapters	0.73	30	15
Moderate Adapters	0.57	92	46
Low Adapters	0.30	78	39
Average	0.53	200	100

Source: Computation from Field Data (2015)

Table 6 represents the percentage of the degree of adaptive capacities of respondents. Table 6 indicates that 39% out of 200 farmers interviewed are low adapter to the climate change adaption strategies. Also, 46% of the respondents are moderate adapters. On the other hand, only 15% of the respondents interviewed are high adapters. Though, majority (46%) of rice farmers is moderate adapters to climate change; on the average, the farmers interviewed are moderate adapters. This is because, the mean adaptive capacity calculated is 0.53 which falls within the range of moderate adapters ($0.33 \leq AdapCap_{ij} \leq 0.66$). This implies, averagely the farmers in the area do not have all necessary resources to aid them adapt highly and effectively to climate change.

4.4. Interpretation of Regression Results

Table 7 represents the Ordinary Least Square Method (OLS) regression results on the effects of adaptive capacities on rice production. These results were obtained by the estimating the double logarithmic augmented Cobb-Douglas

production function specified in the equation (5). The Table 7 shown in below.

Table 7. OLS Regression Results: Adaptive Capacities as Determinants of Rice Production.

Variables	Coefficient	Std. Error	t-statistics	Prob.
ln(K)	1.0897	0.783	1.3916	0.1657
ln(L)	0.260	0.144	1.793	0.075*
ln(Fert)	0.298	0.076	3.921	0.000***
ln(FmS)	0.678	0.101	6.049	0.000***
ln(Age)	0.5720	0.615	0.929	0.353
Edu.	0.5172	0.2698	1.916	0.0568**
Ext.	0.087	0.487	1.798	0.073*
LA	-0.1856	0.069	-2.689	0.012***
HA	0.2336	1.002	5.682	0.000***
c	11.2939	3.0305	3.726	0.000***
R- Squared			0.897	
Adjusted R-Square			0.752	
F-Statistics			51.0065	
Prob(F-Statistics)			0.000***	

Note: ***, **, * indicates 1%, 5% and 10% level of significance respectively.

Before interpreting the results we have to first test the basic assumptions of the Ordinary Least Square (OLS) model i.e. Normality, Multicollinearity, Autocorrelation and Heteroscedasticity. After testing, we found that the results are free from multicollinearity, autocorrelation and heteroscedasticity problem and it also normally distributed which are shown in the appendix.

The results of the model are interpreted and discussed in the following paragraph. The results are obtained by estimating the double logarithmic augmented Cobb-Douglas production function specifically in equation (6). The coefficient of determination (R^2) value is 89.7%. This value implies that the variations in labor, capital, fertilizer, farm size, age, education, extension contact and adaptive capacities explained about 89% of the variations in rice production. The F-statistics indicates that the overall regression is significant at 1% meaning that the independent variables jointly affected rice production. Note that rice is used in this study paddy rice.

From table 7, the amount of labor employed in man days (L), the capital in Tk. (k), fertilizer in kg (fert.), farm size in decimals (FmS.), are consistent with the a priori expectation. The amount of labor employed is significant at 10% level of significance. This implies that labor significantly affected the rice production. Since double logarithmic Cobb-Douglas Production function is used, the coefficients are the elasticity. So at 1% increase in the amount of labor employed will result in an increase in the quantity of rice production by 0.26%. For Ghana Mabe et al. (2012) found that labor have positive and significant impact on rice production. Fertilizer application is significant at 1% level of significance. Therefore, quantity of fertilizer significantly affects the rice production in the study area. As such, 1% increases in the quantity of fertilizer increase the rice production 0.29%. The number of decimals of land cultivated for rice is significant at 1% implies that farm size affect rice production. Hence, an increase in farm size by 1% increases the quantity of rice output by 0.67%. Rice production is more responsive to area expansion than other input variables because farm size has the highest elastic value. These positive impacts of farm size on rice production are consistent with evidence for African studies [51, 77]. As adaptation entails costs, large farms are more likely to adapt earlier than small farmers. Age and Capital (K) are not statistically significant that means they do not bear any meaning.

Education (Edu), extension contact (Ext), high adaptive capacity (HA) and low adaptive capacity (LA) are statistically significant thus affects rice production significantly. Education is significant at 5% level indicate that an increase of 1 year education increase the rice production by 0.51%. Evidence from Africa where farmers with higher educational level were likely to adapt better to climate change thus increase rice production [14] supports this finding. Extension contact (Ext) is statistically significant at 10% level which indicates an increase of 1% extension contact increase rice output by 0.08%. Extension contact acts as a platform for information about new agricultural and adaptive technologies [70, 71]. Derressa et al. [14] also

reported the positive impact of extension contact on the adoption of various adaptation strategies in the face of climate change. Farmers which have high adaptive capacity obtain 0.28% higher rice output than other and similarly farmers which have lower adaptive capacity obtain 0.17% lower rice output than others. This suggests that high adaptive farmers learn and use modern techniques in their farming activities which minimize the detrimental effects of climate change on rice production so; high adaptive capacity positively affects rice production where as low adaptive capacity negatively affects rice production this is similar with the studies of Mabe et al. [57] for Ghana.

5. Conclusion and Policy Implications

5.1. Summary of Conclusion

This study examined farmers' perception about climate change, adaptive capacities to climate change adaptation strategies and their impact on rice production. Farmers' perception appeared consistent with the relevant Ishwardi weather station compared to Bangladesh. The bulk of farmers in the study area adapted to climate change with a range of strategies. The adaptive response typified more a process of autonomous based on their adaptive capacities. The study determines that farmers adapt moderate adaptive capacities to climate change adaptation strategies. But other factors as education level of the household head, farm size, labor, fertilizer, low and high adaptive capacities affect the rice production.

5.2. Policy Implications

The findings of this study have several policy implications for enhancing the adaptive capacities to climate change adaptation strategies. These include scientific breakthroughs, the provision of stronger support services for farmers, training and awareness to the farmers to combat risk.

The need for the development and accessing the high yielding rice varieties, drought tolerance varieties in the study area has prompted scientific breakthroughs in rice production. Crop with short growing season will also be important as season variability is more common. The government should available the information about agriculture to the farmer as soon as possible by enhancing extension contact.

Therefore, rice farmers should be empowered through better extension services in order to attain high adaptive capacity status so as to compensate them in obtaining more rice output. Strengthening agricultural research and support services including information accessibility, education and training for improved crop culture practices, and expanded and efficient surface-water irrigation infrastructure are critically important for increasing the adaptive capacities of the farmers.

Appendix

Normality Test: Normality is used to inference for the

hypothesis testing and thus estimates for the true coefficients. The error term is assumed to follow the normal distribution with zero mean and constant variance, so it can be a best linear unbiased estimator. The hypothesis for normality test is as follow:

- H₀: The residuals are normally distributed.
- H₁: The residuals are not normally distributed

Series: Residuals
 Sample 1 200
 Observations 200

Mean	-1.23e-15
Median	0.041963
Maximum	0.666685
Minimum	-0.636578
Std. dev.	0.247370
Skewness	-0.053146
Kurtosis	3.472148
Jarque-Bera	0.419648
Probability	0.810727

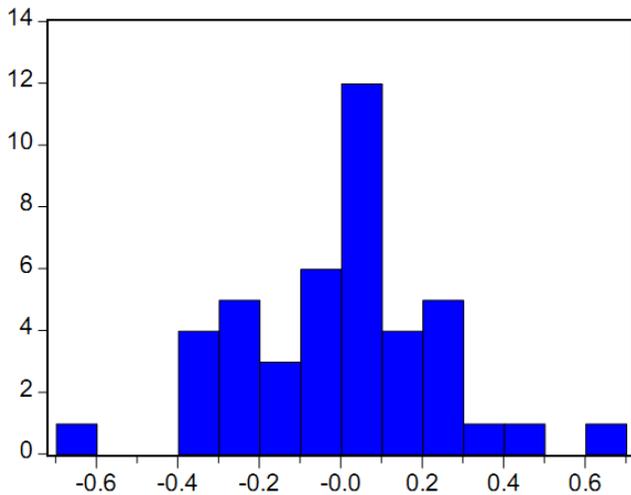


Figure A1. The Result from the Histogram Normality Test.

From the histogram, it seems that the residuals are normally distributed. Since the probability is 0.810727 and it is larger than the critical value which is 5% significant level.

Multicollinearity Test: Multicollinearity is the existence of strong correlation among the explanatory variables. If correlation coefficient thus computed is equal to or greater than 0.80 there exists Multicollinearity (Looms and Walsh, 1997).

Table A1. Correlation Matrix of Coefficient.

	Age	Farm size	Fertilizer	Labor	Capital	Education
Age	1					
Farm size	0.46	1				
Fertilizer	0.32	0.74	1			
Labor	0.43	0.63	0.57	1		
Capital	0.50	0.60	0.45	0.42	1	
Education	0.71	0.30	0.49	0.31	0.65	1

The test result show that the values of the correlation

coefficient of all explanatory variables are the benchmark value i.e. 0.80 on the basis of the above results we reject the hypothesis of multicollinearity among the explanatory variables.

Autocorrelation Test: Since our model does not include any lag variable thus the existence of Autocorrelation can be tested with Geary Test. This is a non-parametric test, and suggests that expected number of runs be in between $\{E(k) \pm 1.96 \sigma_k\}$ with 95% confidence interval. The values of mean $[E(k)]$ and variance (σ_k) are calculated as follows (Gujarati, 1995):

$$E(k) = \frac{2n_1n_2}{n} + 1 \text{ and } \sigma_k^2 = \frac{2n_1n_2(2n_1n_2 - n)}{(n)^2(n-1)}$$

- Where,
- n = Sample size
- n₁ = Number of positive residuals
- n₂ = Number of Negative residuals
- k = Number of runs

The decision rule is that we don't accept the null hypothesis of randomness with 95% confidence if

$$[E(k) - 1.96 \sigma_k \leq k \leq E(k) + 1.96 \sigma_k]$$

If the number of estimated runs (k) falls in between the two values, then we accept the randomness of residuals, and thus reject the existence of autocorrelation.

In this case, there are,

- k = 90
- n₁ = 112
- n₂ = 88
- So,
- E(k) = 99.56
- $\sigma_k^2 = 43.86$
- $\sigma_k = 43.86$
- $\{E(k) \pm 1.96 \sigma_k\} = 99.56 \pm (1.96 \times 6.62)$
- $= 99.56 \pm (12.9752)$
- $= [112.53, 86.58]$

The total number of runs in these calculations is 90, which lie in between the two values so we accept the hypothesis of randomness of residuals and thus reject the existence of autocorrelation.

Heteroscedasticity Test: Homoscedasticity is another important assumption of the OLS, which means constant variance of the error term. In the present study, White test have been applied for detecting the problem of heteroscedasticity in the data.

The hypothesis made for the heteroscedasticity problem is:

- H₀: There is no heteroscedasticity problem.
- H₁: There is heteroscedasticity problem.

Table A2. The Result of White Heteroscedasticity Test.

F-statistic	11.18080	Probability	0.000270
Obs*R-squared	13.76465	Probability Chi-Square	0.071026

The output results showed that Probability 0.071026 > 5%, So we should accept the null hypothesis, indicating the absence of heteroscedasticity in the model.

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