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Farmers' Climate Change Adaptation Strategies for Reducing the Risk of Rice Production: Evidence from Rajshahi District in Bangladesh

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Abstract: A lack of adaptive capacities for climate change prevents poor farmers from diversifying agricultural production in Bangladesh's drought-resilient areas. Climate change adaptation strategies can reduce the production risk relating to unforeseen climatic shocks and increase farmers' food, income, and livelihood security. This paper investigates rice farmers' adaptive capacities to adapt climate change strategies to reduce the rice production risk. The study collected 400 farm-level micro-data of rice farmers with the direct cooperation of Rajshahi District. The survey was conducted during periods between June and July of 2020. Rice farmers' adaptive capacities were estimated quantitatively by categorizing the farmers as high, moderate, and low level adapters to climate change adaptation strategies. In this study, a Cobb–Douglas production function was used to measure the effects of farmers' adaptive capacities on rice production. The obtained results show that farmers are moderately adaptive in terms of adaptation strategies on climate change and the degree of adaptation capacities. Agronomic practices such as the quantity of fertilizer used, the amount of labor, the farm's size, and extension contacts have a substantial impact on rice production. This study recommends that a farmer more significantly adjusts to adaptation strategies on climate change to reduce rice production. These strategies will help farmers to reduce the risk and produce higher quality rice. Consequently, rice farmers should facilitate better extension services and change the present agronomic practice to attain a higher adaptation status. It can be very clearly seen that low adaptability results in lower rice yields.

Keywords: climate change; adaption strategies; farmers; rice production; Bangladesh

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1. Introduction

Global scientists have repeatedly shown that climate change is a significant problem for both developed and developing countries, as the pace of climate change is much faster than previously predicted [1]. It has been demonstrated that agricultural productivity worldwide has been dramatically altered by regular climate change [2]. Additionally, it has been estimated that climate change will impact the world food security by the middle of the 21st century [3]. Climate change positively affects agricultural production or the crop yield in higher-income, high-latitude, and mid-latitude countries. However, a negative effect on the agriculture sector's output is faced by lower-income and lower-latitude countries [4]. Because most South Asian countries are low-income, lower-latitude countries, recurrent climate change harms most people's food security in these regions [5]—the production of

South Asian cereal is expected to decrease by up to 30% from 2001 to 2059. Moreover, the gross per capita water loss is expected to reach up to 37% [3].

Bangladesh is an agro-based country where climate change is a crucial factor that has adversely affected its crop production for a long time. The agriculture sector contributes about 16.77% to the GDP, with crops comprising 9.49%, livestock 1.84%, fisheries 3.68%, and forestry 1.76%, considering the catastrophic effects of climate change. Additionally, about 47.5% of Bangladesh's employees are employed in the sector and receive more than 75% of foreign exchange earnings, with export earnings of $899 million [6]. However, Bangladesh's rice and wheat production will have decreased by 8% and 32%, respectively, in the year 2050 versus the base year 1990 [7]. This reduction is unavoidable because of changes in rainfall patterns related to rising temperatures, extended droughts, floods, and increases in sea-level salinity [8]. Furthermore, studies at the national level using crop models, assuming temperature and CO_2 level variables, have exhibited decreased rice production throughout all seasons. One study compared figures for 2050 to the base year 1990 [9]. The production of the two extremely essential rice varieties (Aman and Aus) will be reduced by 1.50–25.8 percent for the variety of Aus and 0.4–5.3 percent for the variety of Aman by 2050, respectively, due to high temperatures [10]. Due to climate change, a 20% and 50% decrease was observed for developing modern varieties of 'Boro rice' for the years 2050 and 2070, since rice is susceptible to climatic conditions. The research predicted that any harmful alterations in climatic influences (relative humidity, temperature, precipitation, and period of bright sunshine) would adversely affect rice yields, so farmers must efficiently adapt to climate change. Bangladesh might establish adaptive responses to climate change to mitigate these impacts, despite significant climate-related difficulties [11].

Empirical studies recognize that adaptation to climate change may minimize its detrimental effects, protect poor farmers' livelihoods, and strengthen all possible advantages a farmer might benefit from [12,13]. Adaptation refers to adaptation to ecological, physical, human, or socio-economic environments in reaction to recognized vulnerability or anticipated and real climate stimuli and their impacts on climate change [14–16]. Considering climate change is necessary because adjustments in agricultural management practices adapt to climate condition changes [17]. It is a policy choice for reducing climate change's detrimental impact on crop production [18]. This policy choice can mitigate the exposure to gradual climate change (salinization and sea-level rise) and severe climatic events, such as floods and droughts [19]. Additionally, by enhancing climate change, adaptive capabilities can reduce the vulnerability of the agricultural system [20,21]. There are two autonomous or expected adaptive reactions. Autonomous adaptation refers to individual farmers' or agricultural organizations' behavior, while regional, national, and international organizations are involved in planned adaptation. Anticipated adaptation is constructing climate-specific infrastructure, regulations, and incentives implemented by farmers and organizations to supplement, improve, and promote responses [22]. The grading of adaptation methods is incremental and transformative [23]. Comprehensive adaptation strategies are short-term reactive interventions that concentrate on preserving the existing system in which deliberate decision-making methods are transformative adaptation strategies.

In designing and implementing successful adaptation strategies in reaction to climate change, adaptive capacity is essential. It decreases the risk and severity of adverse climate-related consequences, as it highlights the tools available to mitigate existing vulnerability to climate hazards. A body of literature on rice has shown that a farm's susceptibility to climate change influences exogenous and endogenous climate factors [16]. Human methods, that is, labor-oriented farms, such as ecosystems and biological species, have the intrinsic potential to develop their development strategies so that they become more adapted to local environmental and climatic conditions [15]. Through adaptation in the farming system, farmers may improve their abilities to cope with different degrees of climate shocks. Since adaptive capacity is the human or natural system's ability to effectively respond to climate variability, these adaptation capacities help mitigate the risk of extreme climatic events' possible adverse effects [3]. Several alternatives are available to farmers to help them cope with climate change; several can enhance the soil fertility and humidity, making them ideal for expanding the adaptive capacity, and most can improve crop production sustainably. Changing irrigation, crop varieties, planting trees, soil conservation, the use of clay soil, the diversification of crops and livestock, early and late planting, increasing plant spacing, and adjusting the degree and timing of fertilizer application are the most common adaptation options [17,18,24–27]. Farmers can cope with current and future climate shocks by employing both conventional and newly created adaptation choices that are locally relevant in Bangladesh, such as changing dates of plantations, early rice varieties, mixed cropping, the use of organic/chemical fertilizers, varieties of drought-tolerant rice, farming near water bodies to achieve enhanced irrigation, the establishment of shallow tube wells in a pond, the construction of dams, crop rotation, tree integration on rice farms, and species of a short duration [28–30]. However, there are numerous obstacles, including a lack of knowledge and poor access to credit and perfect information, property, and a shortage of water, to implementing adaptation strategies [25,26,31].

Because of the increase in up to date information, climate-smart agriculture (CSA) approaches are becoming a more relevant strategy for addressing climate change challenges and their effects on food security. A lack of financial and other vital resources prevents a more widespread adoption of CSA activities in low- and middle-income countries. In the face of climate change and severe weather, implementing maximum CSA was shown to increase the food security in Southern Malawi [32]. In developing countries, CSA is becoming increasingly crucial for achieving rural development and environmental sustainability goals. In southern Malawi, program participation in implementing CSA activities is positive and statistically significant [33]. The prospect of financing in organic soil amendments is positively affected by cooperative membership, which is statistically significant. In China, tenure stability, human resources, the farm size, and access to credit all positively and significantly affect the likelihood of joining a cooperative and investing in soil quality initiatives [34].

Farmers in Bangladesh are more sensitive to climate change. Due to this reason, they cannot adapt to climate change with limited information and technology [35]. Despite Bangladeshi farmers' vulnerability to climate change, rigorous studies are limited to farmers' preferences for perceived obstacles, adaptation strategies, and policy consequences [36]. However, whilst many studies have investigated the effect of climate change on adaptation strategies and their determinants in Bangladesh, there have been no quantitative studies on climate change adaptation strategies for reducing the risk of rice production. To calculate the effects of the adaptive ability on rice technology development, this analysis applies quantitative techniques to assess the capacity for adaptation strategies relating to climate change and econometric methods. Additionally, there are several policy options and investment capital for climate hazard adaptation strategies, such as cyclones and floods in Bangladesh [37,38]. However, little has been done to establish drought-resilient adaptation strategies for the Rajshahi District agriculture sector in Bangladesh [39]. Therefore, concerning Rajshahi, which is a relentless drought-vulnerable area of Bangladesh, the current study attempts to develop our perception on the adaptive ability of rice farmers to adopt climate change strategies to reduce rice farmers' risk to adaptation strategies relating to climate change. Do policymakers and technocrats need to know the current level of farmers' adaptive capacity to adapt climate change strategies to reduce the climate change risk relating to rice production? Does more extraordinary agronomic practice influence rice's outstanding production, and does a lower adaptation capacity influence lower rice production? How efficiently do farmers have to adapt to the strategies accessible for adaptation? Therefore, the study intends to measure rice farmers' climate change adaptation strategies for reducing the technology development risk of rice production. The study's findings can be used as an input for prioritizing and designing sector-specific program interventions and contributing to the fragile rice production system in the study area and other areas of Bangladesh with the same characteristics.

2. Materials and Methods

2.1. Study Area and Collection of Samples

This study uses primary data collected through a cross-sectional survey of households engaged in farming in the Rajshahi District. For the analysis, the authors selected this region because of its extensive reliance on crop agriculture. The district is the 'granary house' of the country. It is characterized by deficient rainfall and a high temperature, rendering it severely susceptible to drought, and rice farming is the main livelihood-supporting operation [30]. The survey was performed from June to July 2020 in the district. We used a multistage random sampling method to pick the respondents. Random sampling was used at the first level to select two Upazillas (Godagari and Tanore). Then, two villages were chosen for each of the Upazillas, resulting in four villages (Deopara, Matikata, Saranjai, and Badhair). Therefore, the survey included data from 400 farming households randomly selected from four villages (100 from each village). It provides a sample size of a predetermined number of households of 10% from each village as the number of households engaged in farming varies significantly within each village. As 5% of total households was considered to be appropriate for cross-sectional household surveys, this is sufficient [40]. Additionally, rural farming communities in the study region constitute a mostly homogeneous community, which also validates the use of a limited sample [41]. The rice farming households were the unit of study and were selected using the list of farming households obtained from the Sub-Assistant Agricultural Officers by simple random sampling (SAAOs). The study collected data through a systematic interview schedule to address the research question, including questions relating to the various dimensions of adaptive potential for climate change adaptation strategies and the socio-economic characteristics of farming households.

2.2. Data Analysis

Descriptive figures, percentiles, and 5-point ordinal scales were used for statistical analysis to assess farmers' opinions on the adaptive potential for climate change adaptation strategies. The study used the production function by Cobb–Douglas to measure the impact of the adaptive potential on the production of rice in the region under investigation [42].

2.3. Measurement of Adaptive Capacities of Farmers to Strategies of Adaptation

The adaptive potential is a farmer's willingness to implement climate change adaptation methods to reduce climate change's negative effects on agricultural development. Some empirical studies have used five characteristics, such as expertise, usage, availability, accessibility, and consultation, to assess the adaptive capacities of farmers [30,43–45]. A useful adaptation requires an understanding of the need to adapt and the options available, as well as access to and the use of the most relevant ones [46]. The extent of the use of new agronomic practices for climate resilience depends on the awareness of those strategies and government institutions' role related to agriculture [30]. In developing countries, most farmers are not well-educated. It is challenging for them to use climate change mitigation strategies individually. Institutions play an essential role in encouraging farmers to use new climate change mitigation techniques to reduce their production losses [47]. The technologies include crop (genetic engineering) breeding, early warning systems, water management practices, irrigation, and protective structures. Therefore, the adaptive ability needs to improve the sustainability by creating new options using new technologies [48]. Furthermore, the adaptive potential varies with agricultural institutions and is a function of the availability and accessibility of innovations [49,50]. Institutional facilities play a vital role in bringing society together, providing meaning and intention, and adapting [51].

In this study, the adaptation strategies are the practice of organic/chemical fertilizer, farming near water facilities, improved irrigation, varieties of rice in the early maturing stage, mixed cropping, drought-tolerant rice varieties, changing plantation dates, the incorporation of trees on rice farms, crop rotation construction of dams, and setting up shallow tube wells in ponds. This research follows the methodology developed to assess farmers' adaptive capacities for adaptation strategies [30,43–45]. The expectations of farmers about strategies for adaptation to climate change were used to measure the adaptive ability. The study asked the farmers to show how each factor influences the adaptive ability in this method, where the lowest value of the degree is 0.25. For each of the attributes, the highest degree of score attainment is 1.

The score level with a greater degree of attaining each attribute in this analysis was 0.75. Finally, in terms of knowledge, it was considered that the higher the degree of knowledge of each farmer about each adaptation strategy, the better the farmer's knowledge of a specific adaptation strategy. Table 1 shows the summary measurement of each attribute. Equation (1) presents the adaptive capacity (AdapCap) of an i-th farmer to adaptation's j-th strategy:

$$AdapCap_{ij} = \frac{k_{ij} + U_{ij} + V_{ij} + A_{ij} + C_{ij}}{N_A}, \quad (1)$$

where K_{ij} is the knowledge of the ith farmer on the jth strategy of adaptation, V_{ij} is the accessibility of inventions on j-th strategy adaptation to the ith farmer, U_{ij} is the level of usage of the jth adaptation strategy by the i-th farmer, A_{ij} is the accessibility of innovations on the jth adaptation strategy to the ith farmer, C_{ij} is the level of consultation with agriculture extension officers by an ith farmer on jth adaptation strategies, and N_A is the sum of applicable attributes. Equation (2) shows farmers' average adaptation capacity for the jth adaptation strategy, where N is the sample size.

$$AveAdapCap_j = \frac{\sum AdapCap_{ij}}{N} \quad (2)$$

Table 1. Scores of farmers' 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. (2012), Mabe et al. (2012), and Bikash et al. (2015).

Three categories were used, based on the adaptive capacities of each attribute. The adaptive capacities to which each farmer was attributed are low, moderate, and high adaptive capacities (Table 2). In Table 2, the classifications of average capacities of adaptation (high, moderate, and low) of each adaptation technology are also described. The table demonstrates that the ith farmer would be poorly adaptive to the jth strategy of adaptation if the adaptation capacity was calculated as in the scale of $0 < \mathrm{AdapCap_{ij}} < 0.33$. The mild and high capacity range of adaptation of the ith farmer to the jth strategy of adaptation was estimated as $0.33 \leq \mathrm{AdapCap_{ij}} < 0.66$ and $0.66 \leq \mathrm{AdapCap_{ij}} \leq 1.00$.

Table 2. Degree of farmers' capacities of adaptation.

Degree of Adaptive Capacities	Ranges of Indices for $AdapCap_{ij}$	Ranges of Indices for $AveAdapCap_j$
LAC	$0 < AdapCap_{ij} < 0.33$	$0 < AveAdapCap_j < 0.33$
MAC	$0.33 \leq AdapCap_{ij} < 0.66$	$0.33 \leq AveAdapCap_j < 0.66$
HAC	$0.66 \leq AdapCap_{ij} \leq 1.00$	$0.66 \leq AveAdapCap_j \leq 1.00$

HAC = high adaptive capacity; MAC = moderate adaptive capacity; LAC = low adaptative capacity. Source: Modified from Nakuja et al. (2012), Mabe et al. (2012), and Bikash et al. (2015).

2.4. Econometric Model

This research uses the Cobb–Douglas production function to assess the impacts of the adaptive ability on rice production. A technical relationship between inputs and the output is shown in Equation (3):

$$Q_i = \gamma_0 K_i^{\gamma_1} L_i^{\gamma_2} e^{\mu_i}, \quad (3)$$

where Q_i is the total rice production of the ith farmer, K_i is the input of capital used by the ith farmer, L_i is the number of inputs of labor needed by the ith farmer for production, μ is the error term, and γ_1 and γ_2 are the slope coefficients respectively for capital and labor. The study calculated rice production in kilograms (kg). Simultaneously, it calculated the capital and labor inputs by the sum of Bangladeshi Taka (Tk.) and working days, respectively. Then, as shown in Equation (4), an increased Cobb–Douglass output was generated by adding both dummy and continuous explanatory variables. The total rice production (Q_i) was the dependent variable in this defined model. At the same time, the dummy independent variables were extension communication (*Ext*), adaptive ability indicators (HA_i and LA_i), and access to education (*Edu*). The continuous explanatory variables were the fertilizer quantity (*Fert*), farm size (*FmS*), and farmer age (*Fert*) (*Age*). For farmers who have access to extension, the vector 'Extension contact' is dummy 1 and otherwise, 0. Otherwise, a farmer with at least primary education is dummy 1 and 0. Hai and Lai are adaptive capability measures that reflect high and low capacities of adaptation. Otherwise, a farmer with low capacities of adaptation is dummy 1 and 0. Furthermore, high adapters are given a score of 1; otherwise, the score is 0. The fertilizer amount unit is KG. The unit of the size of the farm is decimal. The unit of age is years. The expected sign of the independent variables are given in Table 3.

Table 3. Expected sign of the independent variables.

Variables	Parameters	Expected Sing
Capital	γ_1	+
Labor	γ_2	+
Fertilizer	γ_3	+
Farm Size	γ_4	+
Age	γ_5	+
Extension Contact	γ_6	+
Education Access	γ_7	+
Low Adaptive Capacity	γ_8	−
High Adaptive Capacity	γ_9	+

Constant returns to scale accompany the Cobb–Douglas output feature [52]. The production function of Cobb–Douglas measures the effects of inputs on performance for simplicity, considering the drawback of constant returns to scale [53]. Therefore, the study used Cobb–Douglas production as an augmented form, which is defined as follows:

$$Q_i = \gamma_0 K_i^{\gamma_1} L_i^{\gamma_2} Fert_i^{\gamma_3} FmS_i^{\gamma_4} Age_i^{\gamma_5} e^{\gamma_{6Exti_i}} e^{\gamma_{7Edu_i}} e^{\gamma_{8LA_i}} e^{\gamma_{9HA_i}} e^{\mu_i}. \quad (4)$$

Equation (4) can be transformed as a double log Equation (5) by taking the natural log to both sides, as shown below:

$$In(Q_i) = \gamma_0 + \gamma_1 In(K_i) + \gamma_2 In(L_i) + \gamma_3 In(Fert_i) + \gamma_4 In(FmS_i) + \gamma_5 In(Age_i) + \gamma_6 In(Ext_i) + \gamma_7 In(Edu_i) + \gamma 8LA_i + \gamma_9 HA_i + \mu_i \quad (5)$$

3. Results and Discussions

3.1. Degree of Capacities of Adaptation of Farmers to Strategies of Adaptation

Table 4 presents the degree of adaptation of farmers engaged in rice production for different adaptation strategies. The study investigated how the respondents interviewed have adapted to changing planting dates, rice varieties that mature early, and rice varieties that withstand drought because these attributes' capacities of adaptation lie in the range of 0.66 to 1.00. Changing planting dates and drought-tolerant rice varieties exhibit the highest and lowest adaptive capacities of 0.81 and 0.74, respectively, among these highly adaptive attributes. The adaptive ability level for the 'drought-tolerant rice varieties' attribute is 0.76.

Table 4. Degree of capacities of adaptation of farmers.

Agronomic Practices	Adaptive Capacities ($AdapCap_j$)	Rank	Degree of Adaptive Capacities
Changing planting dates	0.81	1	HAC
Early maturing rice varieties	0.76	2	HAC
Drought-tolerant rice varieties	0.74	3	HAC
Use of chemical/organic fertilizers	0.65	4	MAC
Farming near water bodies	0.64	5	MAC
Mixed cropping	0.58	6	MAC
Improved irrigation	0.36	7	MAC
Set up shallow tube well in the pond	0.33	8	MAC
Building of dams	0.31	9	LAC
Integration of trees on rice farms	0.28	10	MAC
Crop rotation	0.28	10	MAC
Average	**0.52**	**-**	**MAC**

HAC = high adaptive capacity; MAC = moderate adaptive capacity; LAC = low adaptative capacity. Source: Author's calculation from a field survey (2020).

The usage of farming near water bodies, chemical/organic fertilizers, mixed cropping, enhanced irrigation, and a shallow tube setup in the pond are the adaptation strategies with modest adaptive capacities. The study found that out of the eleven adaptation strategies, farmers in the study region are moderately adaptive to the five adaptation strategies. Farmers somewhat adaptive to chemical/organic fertilizer usage have the highest adaptation value of 0.65, whereas the lowest value of the shallow setup tube well in the pond is 0.33. The estimated adaptive ability levels are 0.64, 0.58, and 0.36, respectively, for strategies such as farming near water sources, mixed cropping, and enhanced irrigation. It should be noted that farmers adapted poorly to adaptation strategies in the study area, such as creating dams, incorporating trees into rice farms, and crop varieties. To hold water on the field of rice, the capacity of adaptation value of building dams is 0.31. Again, the adaptive ability value is equal to 0.28 for incorporating trees into rice farms and crop rotation. Additionally, in the study area, the average adaptive ability value of farming households is 0.52. It asserts that rice farming households are somewhat adaptive to adaptation strategies of climate change in the study region.

Table 5 shows attributes that determine the high or low adaptive capacities of the farmers. Table 5 demonstrates that farmers have high adaptive capacities for three adaptation strategies out of eleven adaptation techniques (e.g., modifying date of the plantation, varieties of early maturing rice, and varieties of drought-tolerant rice). These three factors (information, use, and consultation) play an essential role in a high farmer adapter among five characteristics. These characteristics are (e.g., knowledge, use, availability, accessibility, and consultation) because of the mean values of changing plantation dates, varieties rice of early maturing, and varieties drought-tolerant rice, which are the highest among the eleven adaptation strategies. They are 0.57, 0.78, and 0.72 for knowledge; 0.68, 0.80, and 0.67 for use; and 0.78, 0.81, and 0.69 for consultation.

Table 5. Attributes that differentiate between low and high adaptive capacities.

Attributes	Descriptive Statistics	Adaptation Strategies										
		CPD	EMRV	DTRV	UCF	FNWB	MC	II	SSTP	BE	ITRF	CR
Knowledge	Mean	0.57	0.78	0.72	0.65	0.47	0.56	0.37	0.60	0.25	0.31	0.17
	Std. Devi.	0.24	0.26	0.28	0.26	0.36	0.48	0.29	0.30	0.19	0.59	0.35
	Skewness	0.07	0.02	0.09	0.10	0.15	0.20	0.07	0.18	0.11	0.01	0.09
	Kurtosis	−0.87	−1.24	−1.37	−1.08	−1.87	1.38	0.78	1.21	1.87	0.76	0.67
Use	Mean	0.68	0.80	0.67	0.78	0.56	0.41	0.38	0.51	0.19	0.27	0.22
	Std. Devi.	0.34	0.79	0.32	0.80	0.88	0.47	0.59	0.35	0.34	0.16	0.19
	Skewness	0.03	0.08	0.07	0.13	0.02	0.16	0.09	0.01	0.10	0.17	0.04
	Kurtosis	−0.78	−1.37	1.56	1.02	1.67	−0.9	−0.2	1.37	1.75	3.01	−1.7
Availability	Mean	0.25	0.51	0.33	0.77	0.28	0.46	0.87	0.38	0.25	0.29	0.14
	Std. Devi.	0.33	0.21	0.11	0.23	0.18	0.01	0.16	0.25	0.18	0.22	0.15
	Skewness	0.06	0.13	0.02	0.18	0.23	0.18	0.04	0.09	0.12	0.10	0.08
	Kurtosis	0.17	−0.37	0.35	−0.32	2.56	1.45	−0.3	−0.8	1.43	1.32	0.87
Accessibility	Mean	0.33	0.52	0.32	0.76	0.56	0.47	0.41	0.37	0.25	0.22	0.17
	Std. Devi.	0.18	0.22	0.15	0.23	0.19	0.01	0.18	0.27	0.25	0.19	0.16
	Skewness	0.07	0.49	0.25	0.60	0.24	0.14	0.05	0.11	0.17	0.19	0.05
	Kurtosis	1.34	−0.52	0.75	−0.47	1.18	0.45	−0.8	0.67	1.34	1.67	−0.7
Consultation	Mean	0.78	0.81	0.69	0.44	0.54	0.56	0.42	0.43	0.30	0.29	0.12
	Std. Devi.	0.16	0.24	0.14	0.31	0.33	0.27	0.28	0.16	0.18	0.21	0.11
	Skewness	0.04	0.07	0.11	0.19	0.06	0.03	0.07	0.16	0.21	0.08	0.07
	Kurtosis	1.75	−0.52	1.13	−0.45	1.18	−0.8	1.17	−0.7	−1.4	1.34	0.18

Note: CPD = changing dates of plantations; EMRV = early maturing rice varieties; DTRV = drought-tolerant rice varieties; UCF = use of chemical/organic fertilizer; FNWB = farming near water bodies; MC = mixed cropping; II = improved irrigation; SSTP = set up shallow tube well in pond; BE = building of embankments; ITRF = integration of trees into rice farms; CR = crop rotation; number of observations (N) = 400.

For five adaptation strategies (water bodies, chemical/organic fertilizers, mixed cropping, enhanced irrigation, and shallow tube setup), farmers who are intermediate adapters have a lower mean value for knowledge, use, and consultation. For the remainder of the three adaptation methods, farmers who are lower adapters have the lowest mean value of information, usage, and consultation (e.g., vessel construction, tree incorporation into rice farms, and crop rotation), and the values are 0.25, 0.31, and 0.17 for knowledge; 0.19, 0.27, and 0.22 for use; and 0.30, 0.29, and 0.12 for consultation. The result shows variations in adaptive capacities by differences in knowledge, use, and consultation with government agriculture-related institutions for any adaptation strategy. Lower adaptive capacities can be observed for farming households that scored low for these three attributes. Most farmers in Bangladesh do not have an adequate awareness of climate change and associated strategies for adaptation. Agriculture-based government institutions play an essential role in increasing awareness of climate change and related adaptation strategies among farmers and using different adaptation strategies to minimize climate change's adverse effects. In general, if they have developed agricultural institutions, societies are superior in terms of adaptive capacities in comparison to those with less developed agricultural institutions [54]. This implies that the possibility of a higher adaptive potential requires an equal distribution of society's resources following the proper arrangements of agricultural institutions regulating the allocation of and access to resources [14,55–57]. The adaptive capacity to cope with climate change is also impacted by how communities can use resources [50]. The percentage distribution of respondents according to the degree of adaptive ability for climate change adaptation strategies is shown in Table 6. Table 6 reveals that 45.0% of the 400 farmers surveyed have a low degree of adaptation to climate change adaptation strategies, whilst 38.5% of the participants are also mild adapters. Moreover, just 16.5% of the respondents interviewed are strongly accustomed to responding to climate change. While the majority (45.0%) of farmers engaged in rice production are low adapters to adaptation strategies of climate change, the farmers surveyed are moderate adapters, on average. This is because 0.51, which belongs to a range of moderate adapters (0.33 per AveAdapCapj < 0.66), is the average mean adaptive potential in the study area. It shows that farmers in the research region are moderately adapted to climate change adaptation strategies since they do not have all the tools they need to respond to climate change successfully.

Table 6. Percentage of the degree of adaptive capacities of respondents.

Adaptive Capacity	Mean	Frequency	Percentage
High Adapters	0.69	66	16.5
Moderate Adapters	0.53	154	38.5
Low Adapters	0.32	180	45.0
Average	0.51	400	100.0

Source: Author's calculation from a field survey (2020).

3.2. Effects of Adaptive Capacities of Farmers on Rice Output

Table 7 presents the results of the model considering the impacts of adaptive capacities on rice production. The double logarithmic augmented production function (Cobb–Douglas) defined in the equation is expected to produce these effects (5) as the approximate model has an F-value of 52.0065. This overall model is statistically significant at a 1% level of significance. The R2 value is 0.78, which shows that the independent variable describes 78% of the variance of the dependent variable. The statistical value of 2.03 from Durbin–Watson indicates that the model does not suffer from the serial autocorrelation problem. As the variance of the error term is constant, the White test guarantees the absence of heteroscedasticity. This is because 27.5678 is the measured chi-square value, which is essential at 5%. It can be said from Table 7 that the quantity of labor input (L), fertilizer quantity (Fert), and farm sizes (FmS) are the explanatory variables that are compatible with the earlier predicted signs. At a level of 10%, the amount of labor employed in rice production is significant, implying that the labor input significantly affects rice production. When the double Cobb–Douglas logarithmic output function is used, elasticity coefficients are used. Therefore, the results obtained indicate that if the farmers used 1% of the extra amount of labor input, the rice production would be increased by 0.26%. Labor has a beneficial and significant effect on rice production in Nigeria and Ghana [44,58]. This may be because labor-intensive farming practices have led to increases in rice production [59]. The coefficient of the amount of fertilizer used in rice production is positive and essential at a level of 1%, meaning that rice production will increase by 0.29% as the amount of fertilizer added increases by 1%. This result is in line with findings from Nigeria and Ghana [60,61]. Rice production is also greatly influenced by the number of decimal places of land cultivated for rice production.

Table 7. Results of OLS regression.

[1] Dependent Variable: Rice Output				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	***p*-Value**
In(K)	0.126	0.082	1.545	0.124
In(L)	0.260	0.145	1.793	0.075 *
In(Fert)	0.290	0.079	3.664	0.000 ***
In(FmS)	0.673	0.101	6.649	0.000 ***
In(Age)	−0.088	0.166	−0.530	0.597
Ext	0.087	0.487	1.798	0.073 *
Edu	0.0292	0.532	0.5515	0.582
LA	−0.1756	0.071	−2.449	0.015 ***
HA	0.2336	0.568	4.288	0.000 ***
C	5.692	1.002	5.682	0.000 ***
R-square		0.781343	Mean dependent var	6.784210
Durbin–Watson Test		2.0312	Prob(F-statistic)	0.000 ***
Log likelihood		−4.2135	F-statistic	52.0065
White Heteroskedasticity Test				
Chi-square		27.5678	Prob. chi-Square (15)	0.1763 **

Note: [1] Dependent Variable: Natural logarithm of rice output; dependent variable: In(Q); method: Least Squares. ***, **, and * indicate a 1%, 5%, and 10% significance level, respectively.

Therefore, as the farm's size increases by 1%, the quantity of rice production will increase by 0.67%. As the farm size has the highest elasticity value, rice production is more sensitive to expanding the farm size (area under cultivation) than other inputs. The positive effects of farm size on rice production are consistent with evidence from a study on Africa [25,62]. Since adaptation requires large farms and costs, large farmers are more likely than small farmers to adopt such practice earlier. Even though age is not consistent with the expected signs, farmers' age, capital (K), and education (Edu) are not relevant. Extension contacts (Ext), a low adaptive capacity (LA), and a high adaptive capacity (HA) have a statistically significant impact on the production of rice. Extension contact (Ext) is statistically significant at a 10% level of significance, suggesting an improvement in rice production by 0.08% from a 1% extension contact. Extension contact (Ext) is a program that offers information on emerging agricultural technologies and adaptive technologies [26,63,64]. The interaction with extension positively affects the adaptive potential of adaptation strategies for climate change [26]. Farmers with a high adaptive ability have a 0.23% higher value than others in rice production, and, similarly, farmers with a lower adaptive capacity have a 0.17% lower value than others in rice production. In their farming operations, a highly resilient farmer learns and uses modern techniques, and therefore, rice production rises by reducing the adverse effects of climate change. The households with a more extraordinary adaptive ability used more adaptation strategies to positively stimulate rice production. It can therefore be assumed that a high adaptive capacity has a positive impact on rice production. In contrast, a low capacity of adaptation harms rice production, which is close to the results of the Philippines, Uganda, and Ghana [44,65–67].

4. Discussion

This study describes the adaptive capacities of farmers engaged in rice production in relation to adaptation strategies addressing climate change and the degree of adaptive capacities to reduce the rice production development risk. The review uses rice farmer opinions about climate change adaptation strategies, and for this reason, presents the following attributes: Awareness; usage; accessibility; availability; and consultation. As there was variability in farmer decision-making actions, there was a key obstacle to understanding possible adaptive responses of farmers. Although external factors do not influence individual behavior, an individual's perception of climate change is affected by agriculture's internal characteristics. Considering the understanding of climate change, the behavior found in this study is highly complex and frequently influenced by very personal factors, such as debt, family breakups, or the availability of off-farm income.

This research classifies rice farmers' adaptive capacities for adaptation strategies relating to climate change as low, moderate, and high adaptation degrees. The double logarithmic Cobb–Douglas production function was employed to evaluate the impacts of rice farmers' adaptive capacities for adaptation strategies of climate change on rice production in Rajshahi, Bangladesh. Using a dummy variable, this model only considered a high and low adaptive ability and excluded a moderate adaptive capacity. The study found that the farmer's capacity is more homogeneous and very similar to a low adaptive capacity. The range of farmers' moderate adaptive capacities is 0.33 per AveAdapCapj < 0.66, but we noticed from the data analysis that more than 40 out of 77 farmers with moderate adapters have a value of 0.34 to 0.40 adaptive capacities. The outcome of this study shows that farmers in Rajshahi, Bangladesh are highly adaptive to changing the date of the plantation, varieties of rice that mature early, and types of drought-tolerant rice.

In contrast, farmers are somewhat adaptive to agronomic practices such as organic/chemical fertilizer, mixed cropping, farming near water facilities, increased irrigation, and well-built shallow tubes in ponds. They are inadequately adaptive to embankments, the integration of trees on rice farms, and crop rotation. Therefore, it seems clear that farmers are highly adaptive to agronomic practices that are easy to adopt (changing the date of the plantation, varieties of early maturing rice, and varieties of drought-tolerant rice). Simultaneously, they are inadequately adaptive to more costly practices (e.g., crop rotation, dam building, and the integration of trees on rice farms), where up-front investment costs can be a significant barrier to adaptation. The result shows that variations in adaptive capacities are caused by differences in knowledge, use, and consultation. The high score of these three attributes determines the farming households' high adaptive capacities and vice versa. Generally, the study area farmers are somewhat adaptive to adaptation strategies of climate change, as this is justified by the average capacity of adaptation value of 0.52. Still, only 16.5% of farmers have high adaptation capacities, whereas 45.0% of farmers have low adaptation capacities, for the study area. We can conclude that rice production in the study area is significantly affected by the degree of adaptation to climate change, the amount of labor employed, the quantity of fertilizer used, the farm size, and the extension contact. It verifies that farmers in the study area with high adaptation capacities achieve a greater rice output, whereas farmers with low adaptive capacities produce less rice output. This means that high degrees of adaptation reduce the risk of rice production.

5. Conclusions

This study's motive was to assess farmers' adaptation strategies of climate change to reduce the rice production risk in Rajshahi, Bangladesh. Rajshahi was chosen as a study area because it is characterized by deficient rainfall, a high temperature, and drought. Rice farming is the main livelihood-supporting occupation in this area. The study used 400 randomly selected data from rice farming households. The findings and field-level experiences found that the rice farmers who have less education are poorly adaptive to climate change adaptation strategies. The farmers who are poorly adaptive to climate change adaptation strategies achieve a lower rice output. The study found that the proper adaptation of a particular method indirectly depends on consultation with agriculture extension officers to provide information about climate change and adequate adaptation strategies for agronomic practices to reduce the climate change risk in the rice production process. The study demonstrates that rice farmers should be empowered with high adaptive capacities by effective agronomic practices at the local level in Bangladesh. This is essential because the most dominant factor determining the variability between low and high adaptive farmers is consultation with agriculture extension officers. It also demands more detailed information on the weather forecast and extreme climatic events.

Based on the results of the study, it can be concluded that rice-producing farmers can adapt well in areas that fit into the well-known and applied technological systems. Knowledge related to the new sowing time, water supply, or fertilization is not a very expensive answer, but it is still part of adaptation. Adaptation areas, which no longer apply at the farm level and to several units of an affected ecological area, are no longer part of the adaptation reactions in the study area. The design of water protection dams, the introduction of the tree installation program, the establishment of protective tree plantations, and the use of crop rotation to support biodiversity and thus adaptation are not part of the overall adaptation strategy. Complex knowledge of ecosystems was not required in previous production practices. The effects of climate change require extra knowledge and cooperation with competitors and market participants, which was unprecedented in the previous period. Therefore, adaptation to climate change justifies increased external support for farmers, which is accompanied by more serious climate protection investments. The most important of these is the launch of state programs related to the construction of (non-farm level) water protection dams and the launch of a tree installation program supporting the protection of rice-growing areas for the necessary microclimatic environment.

The farmers may quickly understand the climatic change and take the necessary steps to adapt to the changing climate. Farm-level adaptation should be encouraged through policies that emphasize the vital position of providing knowledge on improved production techniques and raising farmers' awareness of climate change. Community education represents the most successful way to accelerate adaptation and improve household decision-making about adaptation strategies. Government agencies should encourage a growing scientific awareness and the introduction of modern climate-adapted rice cultivation technologies and biotopes.

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