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Factors and practices: farmers' adaptation to climate change in Bangladesh

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ABSTRACT

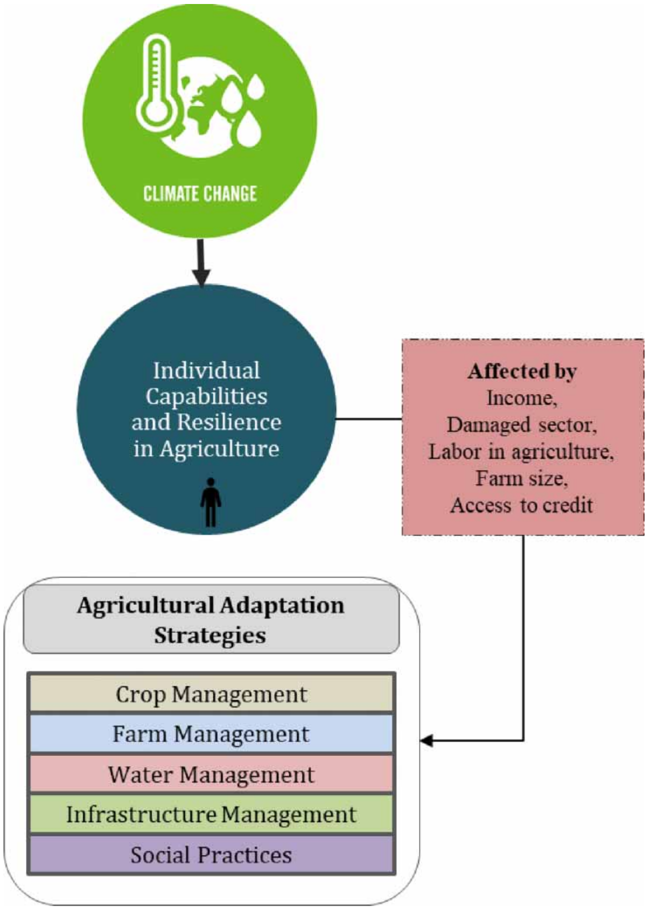
Climate literature is highly pronounced about the impending threat to agriculture taking into account the climate change scenario and suggesting adaptation as a possible option to opt for. Considering this, the study seeks to comprehend the factors influencing farmers' adaptation strategies to cope with climate change in coastal Bangladesh (Koyra Upazila, Khulna). In order to achieve the objectives descriptive, multivariate, and binary logistic regressions were used to analyze the data. Findings demonstrate that the most often used adaptation strategies were crop, water, and infrastructure management. Regression result shows that factors such as gender, labor in the family, farming experience, and the damaged sector are important factors in determining how well adaption methods are implemented. Binary logistic regression analysis explains that age ($p = \leq 0.041$), income ($p = \leq 0.037$), and farm size ($p = \leq 0.005$) are significant factors in deciding on a new adaption option. The outcomes of this research can be used to reevaluate current frameworks and strategies for coping with climate change and to identify the factors that influence policy formulation. In order to improve the water management system for agriculture, policies such as Cash-for-Work (CFW) and Employment Generation Programme for the Poorest (EGPP) may be used to boost local agriculture.

Key words: adaptation factors, adaptation practice, agriculture, climate change, farmer

HIGHLIGHTS

- In Bangladesh, climate change consequences are affecting various sectors and agriculture is one of them.
- We tried to understand the possible factors in climate change adaptation of smallholder farmers.
- In agricultural adaptation strategies, farmers' gender, family labor, farming experience, and damaged sector are significant.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Climate change is a well-acknowledged phenomenon that is linked to frequent extreme weather occurrences and has far-reaching effects on various dimensions of the environment. Among the many far-reaching consequences of climate change, agriculture is suspected to be highly impacted because of its high dependence on the environment (Mendelsohn & Davis 2001; Stern 2006; Howden *et al.* 2007; IPCC 2007; Karl *et al.* 2007). Scientific consent also provides enough clarity on the impending highly negative consequences of climate change on the agricultural sector specifically agriculture in the least developed and developing countries (Howden *et al.* 2007; Parry *et al.* 2004; Schellnhuber *et al.* 2013; Wheeler & Von Braun 2013; Bandara & Cai 2014; Kahsay & Hansen 2016; Myers *et al.* 2017). Additionally, the global trend of climate change impact, particularly in the Asian region, is predicted to be worse more clearly with shooting high temperatures over continental interior Asia. Other robust findings through analyzing data from 1990 to 2005 indicate a significant increase in precipitation in northern and central Asia and a reverse (drought condition) in southern Asia (Mannig *et al.* 2017; Dimri *et al.* 2018). Considering this, agriculture as a climate-sensitive sector, is more likely to experience production losses. Moreover, an estimated, approximately 2.5 billion, number of rural livelihoods directly or indirectly related to agricultural production arrangements are also going to be threatened (Mendelsohn & Davis 2001; Jones & Boer 2003).

Studies also confirm that the absence of adaptation measures, which helps to curb negative effects on a farm level, brings harmful consequences due to climate change. But a great sense of optimism is still left as there are various potential adaptation choices at hand for existing agricultural systems. One thing to remember is that the extents of detrimental effects on the agricultural sector because of climate change are dependent on farming communities' adaptive capacities (Downing 1991; Rosenzweig & Parry 1994; Smith & Lenhart 1996; Mendelsohn & Dinar 1999; Smit & Skinner 2002; Howden *et al.* 2007; Gbetibouo 2009).

A forecast from IPCC proclaims that in facing climate change, developing countries, like Bangladesh, in upcoming decades will continue to face extreme weather events, notably water shortages, temperature rise, and exuberant rainfall causing floods and other climate events (IPCC 2001, 2007). Moreover, in Bangladesh, the agricultural sector is most likely to experience a significant reduction in crop yield on various occasions of climate variability (Islam *et al.* 2011). On top of that, a significant mass of research claims that in Bangladesh, due to climate change, negative environmental impacts are already taking place and temperature is predicted to rise by 1.0, 1.4, and 2.4 °C by 2030, 2050, and 2100, respectively (Agrawala *et al.* 2003; Ahmed 2006; Ruhul Amin *et al.* 2015). Within the same time period, research works also predicted a projected rise in sea-level water by 70 cm (60–80 cm) and 105 cm (85–125 cm). As a consequence, all of these incidents will culminate in tidal surges and extreme tidal events, exacerbating the risk of flooding in coastal regions or near-sea rivers (Brakenridge *et al.* 2013; Schellnhuber *et al.* 2013). Moreover, erratic changes in precipitation have also been predicted such that monsoon seasons will be expected to have more precipitation while other seasons will endure prolonged dry seasons. Due to this event, there will be severe floods during the monsoon and extreme drought throughout the other seasons (Ruhul Amin *et al.* 2015; Islam & Hasan 2020).

In this context, farm-level adaptation is quite critical to combat climate change. A significant body of research in Bangladesh focuses on their efforts to farm-level adaptation and overcome limitations, particularly the issue of salinity in the south-west coastal region and drought-prone regions in the north-west (FAO 2006; Kainan Ahmed *et al.* 2006; Habiba *et al.* 2012; Alauddin & Sarker 2014; Hassan *et al.* 2014; Vivekananda *et al.* 2014; Alam 2015; Khan *et al.* 2015). Additionally, a considerable portion of research has also identified a number of adaptation strategies including development of adverse environment-resistant crop variations, advanced crop management, enriching human resources with education, diversification of livelihood, easy access to physical resources, and financial resources with market and institutional flexibility. Moreover, research works have also acknowledged the importance of adaptation research to strategize and invocation of fruitful future policy formulation. Incorporation of technology in agriculture is also important to adapt with climate change, particularly through advancement in bioengineering, advanced irrigation systems, and nanotechnology are some of the few aspects of high-tech farming (Deressa *et al.* 2009; Alauddin & Sarker 2014; Alam 2015; Abdul Rajak 2022).

Given the upcoming climate change scenarios, adaptation in agriculture, particularly crop agriculture, is ubiquitous in order to function in a hostile climatic environment. In Bangladesh, several studies have been conducted in drought-prone regions to understand adaptation mechanisms (Alauddin & Sarker 2014; Alam 2015), and one particular study of Saha *et al.* (2016) explored adaptation practices in coastal regions. From this understanding, this research seeks to identify the primary socio-economic factors influencing farmers' crop adaptation decisions. Furthermore, there is no clear evidence on how willing farmers are to accept new agricultural adaptation practices. Taking all of this into account, this study seeks to examine the factors that influence the selection of existing agricultural adaptation practices in facing the climate change crisis.

1.1. Conceptual framework of the study with theoretical insights

The literature identifies that the formulation of climate change policy considers two approaches, *biophysical* and *social* vulnerability approaches. The described relationship in Figure 1 is the reflection of the complementary form of each other rather than the contradictory form. Vulnerability to environmental hazards, explored in the work of Cutter (1996), also considered these two approaches. Scholars in social vulnerability prioritize households, communities (Adger 1999) or small nation (Barnett 2001), or all nations (Brooks & Neil Adger 2003) in the micro-context taking into considering past and present conditions to prescribe a policy. On the other hand, experts on biophysical vulnerability emphasize on physical or natural exposure combined with mid- and long-term future scenarios. The work of Dessai & Hulme (2004) described the adaptation procedure based on the findings of some studies (Tol *et al.* 1998; Reilly & Schimmelpfenning 2000), a top-down approach which works in multiple layers where some studies do not consider adaptation at all (e.g. the 'dumb farmer' hypothesis), some explain arbitrary adaptation process (e.g. 'clairvoyant farmer'), and other studies show observation based adaptation (analogous) or try to model adaptation procedures. Additionally, development status of a country also plays vital role in determining adaptation process too. In this regard, a widespread perceived notion beholds that developed countries are more resilient to climate vulnerability than developing countries. Though, vulnerability-based studies in developed countries were mostly on prediction directed while developing countries, like Bangladesh, research focuses shed lights on the process of vulnerabilities (Dessai & Hulme 2004). In this research, we are primarily focusing on social vulnerability context of climate change, though physical vulnerability is also connected too. Furthermore, agriculture is one of the main focuses in this study

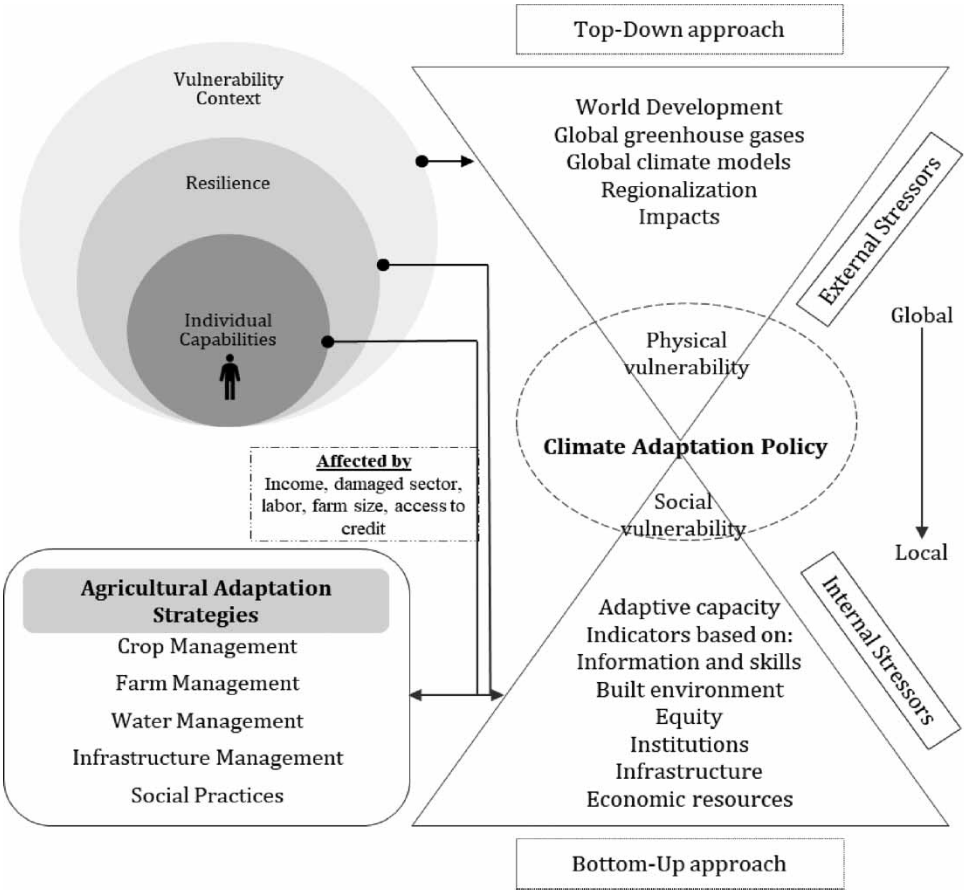


Figure 1 | Conceptual foundation and theoretical connections in understanding the factors influencing climate change adaptation decisions of the farmers. (Extension of the framework of Dessai & Hulme (2004) to link with agricultural adaptation strategies and finding out possible factors responsible for choosing adaptation decisions).

as unveiling the vulnerabilities in agricultural adaptation strategies in small scale or bottom-up perspectives are crucial in understanding of individual capabilities and resilience to provide required policy framework.

In order to outline this research, the following sections provide a detailed explanation and structure of the study. Section 2 describes the rationale behind choosing the study area, sampling procedure, variables selection, and model specification in detail. The subsequent Section 3 elucidates the result based on the field data and the following discussion in Section 4 compares and corroborates similar findings around the study objectives. Sections 5 and 6 describe the policy implications and the limitations of this study respectively. Finally, the last section summarizes the study findings and policy implications while outlining the shortcomings succinctly.

2. MATERIALS AND METHODS

2.1. Study area

This study was conducted (Figure 2) in the UC (lower unit of local government) of Koyra Upazila (subdistrict), Khulna district in Bangladesh, very adjacent region to the Bay of Bengal and a highly vulnerable region to various natural calamities, including tropical cyclones (Tasnuva *et al.* 2020). The study area is adjoined by the mangrove forest, and has a total of 1,775.40 km^2 land area with seven unions (smaller administrative units), 71 mauzas, and 133 villages (BBS 2014). Considering the geographical placement of the study area, Koyra Upazila, a set of different climate-induced disasters such as tropical cyclones, storm surges, floods, tidal surges, tidal floods, riverbank erosion, salinity intrusion, and sea-level rise are quite frequent in this area (Alam *et al.* 2018). Because of the geographical settings of this area, tropical cyclones are a common disaster. Furthermore, the area was severely impacted by Cyclones Sidr and Aila in 2007 and 2009, respectively (UN 2010).

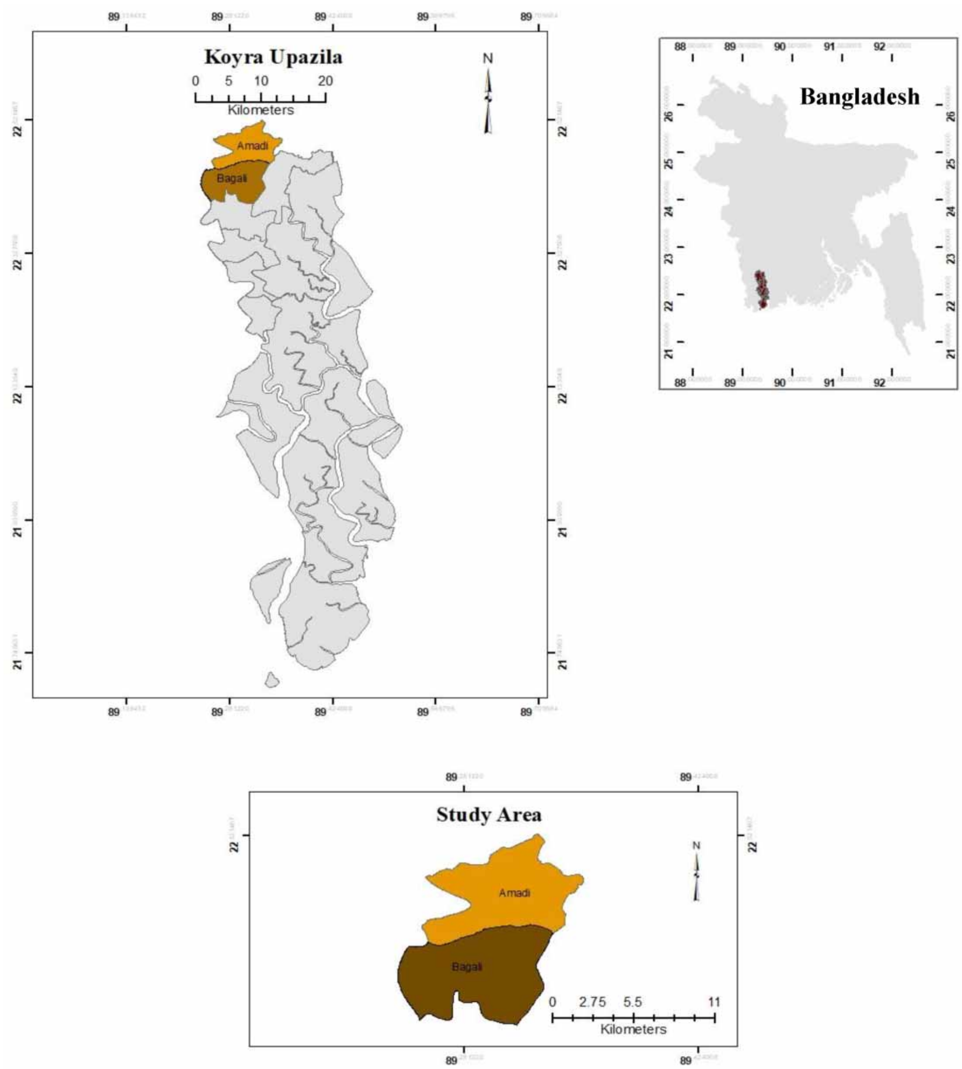


Figure 2 | Location of the study sites.

2.2. Sampling procedure, sample size determination, and data collection

Considering the vast region of the study area first, a purposive sampling technique was used to select the study area. In order to draw a rational outline behind the purposive selection of the study area, agricultural activities were observed in the seven unions of Koyra Upazila. After a careful investigation and individual opinions of the inhabitants, a cross check procedure was followed with the local 'Member' (administrative power holder at the local level) to identify the study area based on agricultural practices. In such case, areas and unions close to the coast and mangrove forests were observed with less or even no agricultural practices due to the high concentration of salinity in the root zone of soil and frequent inundation of salt water (Haque 2006). Moving toward inland agricultural practices were observed in various forms of crop cultivation including paddy and watermelon. Bearing this in mind, two unions were selected purposively, where agricultural activities were noticeable, and samples were drawn using a simple random sampling procedure. In such case, the sample size from each union was calculated using the formula of Cochran (1942), where the precision level is 10% and the confidence level is 95%, as noted in the following equation,

$$n = \frac{z^2 pq}{e^2} \tag{1}$$

$$n = \frac{1.96^2}{.01}$$

$$n = 96.04$$

$$n \cong 96$$

where n is the number of samples, z is the critical value and a standard value for the corresponding level of confidence, which is 1.96 at 95% confidence level. p is the estimator of a proportion, $p = 0.5$, $q = 1–p$, and e is the margin of error or precision in this case which is 0.01.

From Equation (1) sample size *(n)* was calculated at 96 from each union culminating in the final sample size at 192 from two unions (study area). After determining the sample size, data have been gathered using a structured questionnaire. Each participant in this study was exposed to a set of structured questionnaires regarding their demographic information and information related to adaptation practices and procedures in facing climate change. The questionnaire was split up into two sections. The first section had a total of 15 questions concerning respondent's demographics, farming income, experience, land size, number of cultivated plots, family labor in agriculture, credit access, damaged sector and damaged amount due to climate change, and training on climate change adaptation, membership in a local organization, and finally, received assistance from the local NGO/government. The second section had 12 questions on five different adaptation options, namely crop management, water management, farm management, physical infrastructure management, and social practices. Various subcategories of these five broad adaption measures were disclosed to understand the most practiced adaptation options. In terms of assessing the validity of the initially prepared questionnaire first, independent consultation with an expert was arranged. Secondly, from the initial consultation, various important points emerged and a second review of the questionnaire was evaluated with a group of three experts in connection with the first expert. Finally, the questionnaire was adjusted a little bit from the field experience.

2.3. Data analysis and layout of the models

2.3.1. Multivariate model

2.3.1.1. Dependent variable. In coastal regions, adaptation measures are important in the perspective of how they are carried out. In this research, farmers in the study areas were observed practicing adaptation measures according to their needs and capabilities; as a result, the adapted strategies vary from household to household. Understanding different adaptation strategies for better grasping the farmers' socio-economic and socioenvironmental characteristics, the methodology of Yila & Resurreccion (2013) has been followed. In this regard, 17 common strategies under four broad adaptation measures were disclosed to the study participants to determine the overall degree of climate change adaptation strategies (Table 1). In order to make the analysis convenient, two categories were formulated from the broad 17 adaptation strategies and thus one category, adapted strategies by farmers was assigned a numeric value of 1.0, and the other category, strategies not adapted by farmers, was scored as 0.0. Afterwards, all scores were aggregated and divided by 19 to obtain a composite index of adaptation. For calculating the adaptation index, the following simple formula was used

$$\text{Adpatation index} = \frac{\text{Number of households}' \text{ adapting particular measure}}{\text{Total sample size}}$$

The result from this index was considered as the dependent variable which reflects the range of strategies adapted. Some strategies, such as soil conservation and use of farm related infrastructure (like, temperature and moisture sensors, aerial images, and GPS technology) were observed missing in adaptation practices. Nevertheless, the composite index aids understanding of the variation in strategy adaptation and its causes, contributing to the formulation of policies for effective implementation of climate change adaptation options (Hassan & Nhemachena 2008; Deressa *et al.* 2009).

2.3.1.2. Independent variable. In order to establish a logical relationship with the various adaptation measures, disclosed in this study, initially 14 variables were considered as independent variables for stepwise regression analysis. Moreover, to maintain the explanatory power and sensitivity of the constructed model only the significantly correlated variables with the dependent variable were included in the final model. All 14 independent variables were entered step by step into the

Table 1 | Household-level climate change adaptation strategies considered in the construction of the index of adaptation

Five adaptation measures	Number of household adapting	Percent adopter	Percent non-adopter	Index
Crop management measures				
Change crop calendar	27	14.06	85.94	0.14
Crop diversification	83	43.23	56.77	0.43
Change farm location	43	22.40	77.60	0.22
Use improved seeds or crops	159	82.81	17.19	0.83
Apply fertilizer	185	96.35	3.65	0.96
Water management measures				
Irrigation	169	88.02	11.98	0.88
Water resource conservation	72	37.50	62.50	0.38
Rainwater harvesting	23	11.98	88.02	0.12
Farm management measures				
Soil conservation	42	21.88	78.13	0.22
Tree plantation	22	11.46	88.54	0.11
Agroforestry	52	27.08	72.92	0.27
None of these	106	55.21	44.79	0.55
Infrastructure management measures				
Farming infrastructure	190	98.96	1.04	0.99
Farming technology	11	5.73	94.27	0.06
Social practices				
Use local traditional knowledge	129	67.19	32.81	0.67
Community organization help	48	25.00	75.00	0.25
Migration	5	2.60	97.40	0.03
Raising awareness	96	50.00	50.00	0.50
None of these	19	9.90	90.10	0.10
Composite index				**.41**

Source: Field survey, 2021.

model. Finally ten variables were dropped because they had non-explanatory power, and four variables, with significant explanatory power were retained.

2.3.1.3. Collinearity check. In order to fit a linear model to the test, it is necessary to check the predictors for collinearity, which determines whether or not the predictors estimated in the model are dependent on each other. In this regard, the variance inflation factors (VIFs) for the coefficients are a better diagnostic for determining whether coefficients are poorly estimated due to collinearity (Tomaschek *et al.* 2018). In the case for our selected independent variables, the VIF value was <1.05 confirming the non-existence of multicollinearity. According to Sheather (2009) and Chatterjee & Hadi (2006), the boundary value for the collinearity problem ranges between 5 and 10. Additionally, we have also tested the condition index representing value <8, where multicollinearity exists when condition indices are higher than 10 to 30.

2.3.1.4. Model formation (factors affecting adaptation practices). The main objective of this research is to explore the factors which are determining farmers' adaptation practices amid climate change scenarios in agriculture. In order to leverage the study objective multivariate linear regression was applied, which is a suitable analytical tool for this conjecture. This analytical tool is quite simple but the findings produced from this methodological procedure have good policy relevance for the promotion of climate change adaptation measures. With this understanding, stepwise multiple linear regressions were utilized to understand the possible influencing factors in adaptation practices against climate change in crop agriculture. Moreover, the literature also supports that this method is useful for the construction of an adaptation model when both independent and dependent variables are numerical (Raquel 1985; Paudel & Thapa 2004; Yila & Thapa 2008; Hair 2009). The dependent variable in this analysis is a numerical index which was assumed to vary from one household to another. On the contrary, most of the independent variables are in numerical form (e.g. age, income) except gender, education, damaged sector, credit accessibility, climate adaptation training, membership in a local organization, and received help an NGO/government. These non-numerical variables were coded from 0 to 1 based on the available categories in each variable. These qualitative variables were converted into dummy variables following the method mentioned above, so as to make these variables compatible with the linear regression model. Furthermore, this particular methodological procedure is quite appropriate to determine the power of independent variables on the dependent variable. Particularly, this approach explains the impact of each independent variables on the regression model (Mardia *et al.* 1982; Mehta & Kellert 1998; Hair 2009). Eventually, using a straightforward statistical test, this analysis has a high ability to incorporate the effects of each independent variable on the dependent variable. To pursue the stepwise multiple regression analysis, the dependent variable, adaptation of climate change strategies is hypothesized as being influenced by a set of independent variables: X_1, X_n (Table 4). From the above discussion, the final looks like as follows:

$$\gamma = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n$$

where γ is the dependent variable (adoption of climate change adaptation practices), β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients of the predictor variables X_1, X_2, X_n.

The model was constructed using the stepwise probability criteria of F to enter $p \leq 0.050$, and probability of F to remove is ≥ 0.100.

2.3.2. Binary model

This study has used a binary logit model to analyze the various factors affecting farmers' decision in accepting new adaptation strategies in facing severe weather episodes in agricultural production. Farmers' decision in accepting new adaptation strategies was explored in a discrete choice form (where 1 = yes, 0 = no). More lucidly, one (1) denotes farmers who want to adapt new strategies to climate change in their agricultural production. By contrast, zero (0) denotes farmers who do not want to adapt new strategies to climate change. This research anticipated that a variety of factors influence farmers' decisions to adapt a new strategy to climate change in agricultural production.

The binary logit model as a widely practiced, since the adoption of 1960s, model has analytical advantage in manipulating discrete binary outcomes (Cramer 2003). In this study, general form of binary logit model has been constructed following Cramer (2003) and Greene (2003).

$$P_i\,(Y_i = 1)\frac{e^{X\beta}}{1 + e^{X\beta}}$$

where P_i is the probability of the occurrence of one event ($Y_i = 1$: event occurs; $Y_i = 0$: event does not occur), β is the vector of parameters, and X is the vector of the factors affecting.

$$\text{Accepting new adaptation measure } (P_i) = \beta_0 + \beta_{1\,age\,i} + \beta_{2\,income\,i} + \beta_{3\,labor\,i} + \beta_{4\,farm\,size\,i} + \beta_{5\,access\,to\,credit\,i\,(dummy)} + \beta_{6\,recieved\,help\,i\,(dummy)} + \varepsilon_i$$

Most of the data analysis has been performed utilizing R version 4.1.0 and the graphical presentation of maps was done using ArcGIS, version 10.3.

3. RESULTS

3.1. Historical weather pattern in the study region

We started the Results section with an explanation of historical context of the weather pattern in the study areas. Analyzing the secondary data, we observe the average rainfall and temperature pattern in Khulna from 1981 to 2020. Figures 3 and 4 show the changing weather patterns in the study area. In Figure 3 after 2013, increased trends in the average precipitation

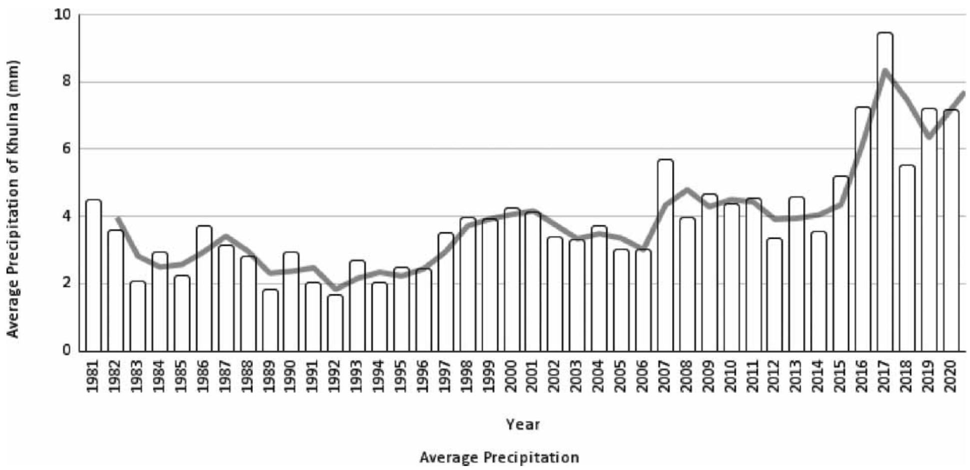


Figure 3 | Annual rainfall at Khulna district, 1981–2020. (*Source*: Prediction of Worldwide Energy Resources, NASA.)

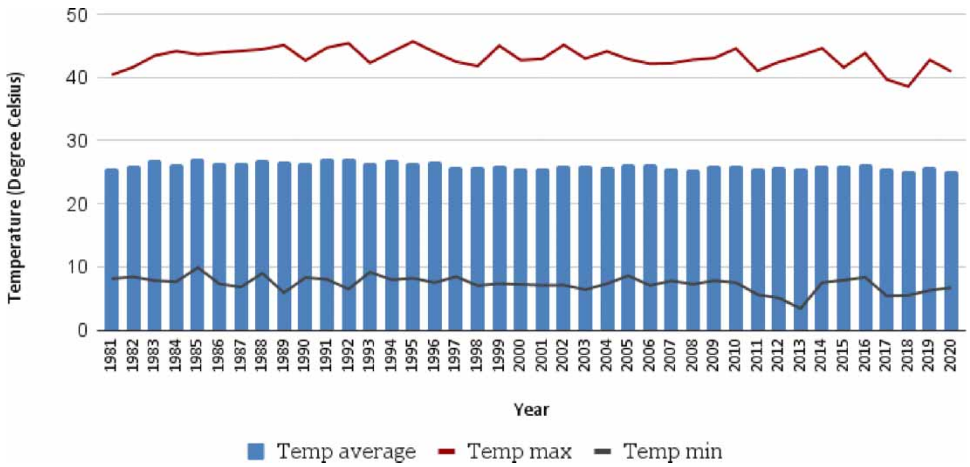


Figure 4 | Average annual temperature distribution in Khulna 1981–2020. (*Source*: Prediction of Worldwide Energy Resources, NASA).

amount are considerably the more obvious pattern. Beginning in 2013, and continuing until 2020, temperature has followed the same trends, with some peaks and troughs in Figure 4. Several different cyclonic storms have also been observed during this time period. The effect of Cyclone Sidr contributed a significant increase in average precipitation in 2007. Cyclone Mahasen (May 16, 2013), Cyclone Roanu (May 21, 2016), Cyclone Mora (May 28, 2017), and Cyclone Amphan (May 28, 2017) were among the other cyclonic events that occurred between 2013 and 2020. (May 16, 2020). Moreover, cyclone Yaas (May 23, 2021) was recently added to the list. In a broader sense, Bangladesh has been hit by 154 cyclones, 43 of which have been classified as severe (Dasgupta *et al.* 2014). The worst tropical cyclone, Sidr, hit Bangladesh's coastline in November 2007 and was by far the most destructive in 10 years (GoB 2008). After that, cyclone Nargis struck coastal Bangladesh in May 2008, followed by Cyclone Bijli in April 2009 and Cyclone Aila in May 2009 (Dasgupta *et al.* 2014).

3.2. Existing adaptation strategies

In order to understand the existing adaptation practices of farmers in facing climate change conditions, farmers were exposed to five different adaptation strategies in this study, and each adaptation strategy had multiple options for sub-adaptation strategies. From Figure 5, among the exposed adaptation measures, application of fertilizer (12.5%), use of improved seeds (10.7%), and crop diversification (5.6%) were all highly observed adaptation techniques under the umbrella term of crop management adaptation strategies. While irrigation with the use of pumping machines (11.4%) was a widely used measure for

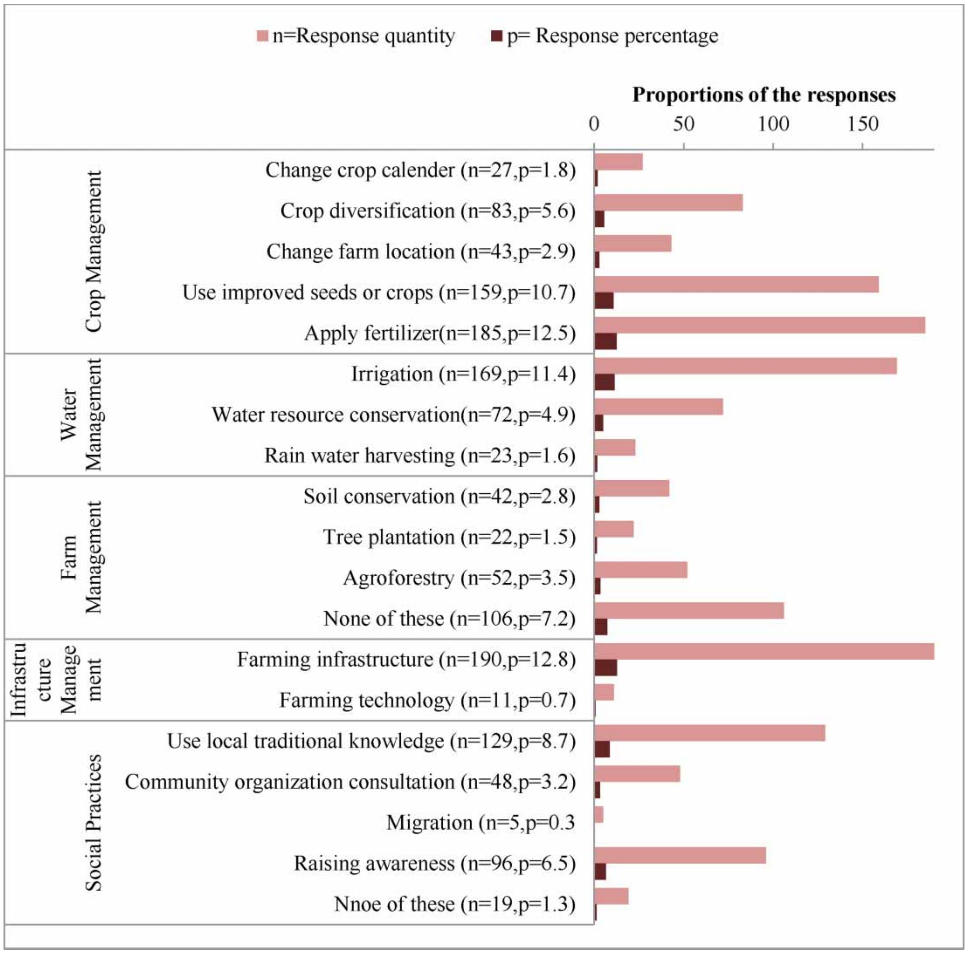


Figure 5 | Existing adaptation strategies and practiced proportions based on the broad five spectrums of the adaptation strategies. (*Source:* Field Survey 2021).

maintaining agricultural irrigation under water management strategies. Farm management was less common, but some farmers practiced agroforestry in their backwards. The utilization of agricultural infrastructure, particularly tractors and shallow pump machines (12.8%), were widely noted.

3.3. Predictions of the models

3.3.1. Factors determining adaptation strategies

One of the goals of this research was to better comprehend the factors that influence farmers' climate change adaptation strategies, as reflected in the climate change adaptation index (Table 1). Results from correlation (Table 2) show that few factors are responsible for farmers' adaptation practices. Positive significant factors like income ($p = 0.034$), damaged sector due to climate change impacts ($p = 0.015$), family labor involved in agriculture ($p = 0.000$), credit access ($p = 0.002$), and assistance from an NGO/government ($p = 0.047$) influence farmers' adaptation choices. But gender (-0.243, $p = 0.000$) and farm size (-0.138, $p = 0.028$) have significantly negatively correlated and had no impact in choosing adaptation strategies.

As explained previously in methodology, among 14 independent variables only 4 variables (gender, family labor in agriculture, farming experience, and damaged sector of agriculture) significantly explained the variation in deciding multiple climate change adaptation strategies (Table 3). Analysis unfolds that both multiple R and R^2 values have increased with the addition of each independent variables from X_1 to X_4, and have reasonable explanatory power on the models. The final model, with four independent variables, has a significantly high level of explanatory power, compared to the other three variables, as reflected in the adjusted $R^2 = 15\%$. The model has a high statistical significance with a minimum error of the estimate,

Table 2 | Detailed description and measurement outcomes of the independent variables initially considered for the regression analysis)

Variables	Description and unit of measurement	Mean	Correlation	*P*
Age (X_1)	Average age of the HH in years	42.07	0.077	0.143
Gender (X_2)	Dummy take the value of 1 if male and 0 if female	–	−0.243***	0.000
Education (X_3)	Education level of the respondents. (i) no education, (ii) primary, (iii)secondary, (iv) tertiary	–	0.111	0.062
Income (X_4)	Average income of HH	59,718.75	0.132*	0.034
Damage (X_5)	Average damage amount incurred upon HH	13,109.38	0.082	0.130
Damaged sector (X_6)	Categorical variable	–	0.157*	0.015
Family men involved in farming (X_7)	Household labor force involved in agriculture (number/household)	1.65	0.24***	0.000
Farm size (X_8)	Average size of farm owned by a farm household (in Bigha)	2.15	−0.138*	0.028
Farming experience (X_9)	Average years HH has been farming	12.38	−0.047	0.257
Number of Plots (X_{10})	Average number of farming plots owned by a farm household (in Bigha)	1.63	0.046	0.262
Access to credit (X_{11})	Dummy take the value of 1 if Yes and 0 if No	–	0.202**	0.002
Attended climate adaptation training (X_{12})	Dummy take the value of 1 if Yes and 0 if No	–	0.069	0.171
Membership in local organization (X_{13})	Dummy take the value of 1 if Yes and 0 if No	–	0.02	0.391
Received help from NGOs/ governments (X_{14})	Dummy take the value of 1 if Yes and 0 if No	–	0.121*	0.047

Statistically significant at ***0.001; **0.01; *0.05.

Table 3 | Inclusion of the significant variables in the model and the summary of the stepwise regression models

Model	*R*	R^2	Adjusted R^2	Std. error of the estimate
1	0.243[a]	0.059	0.054	0.339
2	0.328[b]	0.107	0.098	0.331
3	0.378[c]	0.143	0.129	0.325
4	0.410[d]	0.168	0.15	0.321

Source: Field survey, 2021.
[a]Predictors: Gender.
[b]Predictors: Gender, family men involved in farming.
[c]Predictors: Gender, family men involved in farming, farming experience.
[d]Predictors: Gender, family men involved in farming, farming experience, damaged sector.

and it can partly explain the study area's environment in terms of the application of adaptation of climate change strategies in a complex socio-economic and socio-cultural perspectives.

From Table 4, the *F* ratio of explanatory variables in the final model is statistically significant at 0.001. The significant value of the *F* ratio explains that the variables included in the model are appropriate. Table 5 describes that the four variables significantly explaining the variations and among all the variables only gender, family labor in agriculture, farming experience, and damaged sector of agriculture appear to be the most influential factors, explaining nearly 60% of total variation. The result further demonstrates that the included factors in the model play influential roles in deciding adaptation strategies to climate change in a smallholder agricultural system. Regression analysis showed that all variables, except gender and farming experience, have positive effects on adaptation choices. An increase of agricultural labor and increase of damage lead to a positive move toward implementing climate change adaptation strategies by (0.343) and (0.16) times, respectively. But changes in gender and farming experience negatively influence adaptation of various climate change strategies (−0.203) and (−0.227).

Table 4 | ANOVA of regression models

Model		Sum of squares	Degrees of freedom	Mean square	*F*	Sig.
1	Regression	1.371	1	1.371	11.933	0.001***[a]
	Residual	21.832	190			
	Total	23.203	191			
2	Regression	2.491	2	1.246	11.367	0.000***[b]
	Residual	20.712	189			
	Total	23.203	191			
3	Regression	3.315	3	1.105	10.444	0.000***[c]
	Residual	19.889	188			
	Total	23.203	191			
4	Regression	3.897	4	0.974	9.436	0.000***[d]
	Residual	19.306	187			
	Total	23.203	191			

Source: Field survey, 2021.
Statistically significant at ***0.001; **0.01; *0.05.
[a]Predictors: Gender.
[b]Predictors: Gender, family men involved in farming.
[c]Predictors: Gender, family men involved in farming, farming experience.
[d]Predictors: Gender, family men involved in farming, farming experience, damaged sector.

Table 5 | Coefficients of independent variables included in the regression model *no. 4*

	Unstandardized coefficients		Standardized coefficients		
	β	SE	*B*	*t*	Sig.
Constant	0.684	0.074		9.209	0.000***
Gender	−0.249	0.083	−0.203	−3.012	0.003**
Family men involved in farming	0.141	0.032	0.343	4.461	0.000***
Farming experience	−0.011	0.004	−0.227	−2.969	0.003**
Damaged sector	0.085	0.036	0.16	2.375	0.019*

Source: Field survey, 2021.
Statistically significant ***0.001; **0.01; *0.05.

3.3.2. Factors determining accepting new adaptation strategies

Table 6 reports and explains farmers' intention to accommodate new adaptation practices and whether or not adaptation decisions are influenced by socio-economic and demographic characteristics. If new adaptation measures were introduced to them to combat the climate crisis, their inclination to adapt those measures are also critical to assess. In this regard, respondents were asked the opinions of whether they would implement new adaptation practices or not. All the significant variables previously explored in the multivariate linear regression has also been used in this stage too. Results from the binary logistic regression shows that every increase in the unit of age ($p = \leq 0.01$), income ($p = \leq 0.01$), and farm size ($p = \leq 0.005$) influence to accept new adaptation practices. Every unit of income increased shows that farmers are 2.65 times more likely to go for new adaptation options. Similarly, an increased unit of age of the farmers also showed that they are 2.2 times more likely to adapt new adaptation measures. Accesses to credit and received assistance from an NGO/government do not have any significant contribution in choosing new adaptation measures.

4. DISCUSSION

In this study, farmers' agricultural adaptation measures, as well as related factors in determining adaptation measures were examined. According to the study findings, farmers use a wide range of adaptation mechanisms, both knowingly and

Table 6 | Adoption of farmers' adaptation practices

Factors/Covariates	Odds ratio	Sig.	95% CI Lower	95% CI Upper
Age	2.204	0.041*	1.033	4.703
Income	2.653	0.037*	1.059	6.647
Family labor	2.094	0.138	0.789	5.56
Farm size	0.314	0.005**	0.14	0.702
Access to credit				
No	(ref.)			
Yes	0.421	0.086	0.157	1.128
Received help/assistance				
No	(ref.)			
Yes	0.362	0.062	0.124	1.054

Source: Field survey, 2021.
Stastically significant ***0.001; **0.01; *0.05.

unknowingly. Findings suggest that various demographic and socio-economic characteristics contribute significantly to the various adaptation measures of the farmers. In the face of climate change, gender, household income, and damaged sectors all have significant associations with adaptation practices in order to maintain some adaptation measures such as water, crop, farm, and infrastructure management. Literature also confirms the significance of demographic and socio-economic characteristics in the adaptation decisions (Deressa *et al.* 2009; Apata 2011; Ndambiri *et al.* 2012). Moreover, studies by Hassan & Nhemachena (2008) and Ishaya & Abaje (2008) also showed a significant relationship with adaptation practices with gender, credit access, farming experience, farm size, and other socio-economic characteristics. According to the findings, family labor is significantly correlated with adaptation decisions. Because labor is an essential component of any practical endeavor, household labor availability appears to be an important variable. Moreover, linking this to agriculture the scenario is that households with more labor are better prepared to take on various adaptation strategies when compared to those with limited labor (Ishaya & Abaje 2008; Yila & Resurreccion 2013). A study by Deressa *et al.* (2009) also finds the importance of family labor in agricultural adaptation practices. Adaptation to climate change largely relies on the availability of the labor force. Other variables, such as membership in local organizations, credit accessibility, adaptation training, and damage amounts, were not significantly associated with climate change adaptation practices. Similar findings were also discovered in Nepal and Myanmar (Piya *et al.* 2013; Ahmad & SeinnSeinn 2015; Thoai *et al.* 2018).

The regression analysis results show that a household head would be able to manage all adaptation measures more effectively if she had more family labor, more farming experience, and full consideration of climate change impacts on specific sectors. Additionally, adequate household labor is effective for farm management because necessary adaptation strategies, despite their willingness, are hard to implement and beyond capability when households do not have necessary labor. In some cases, inadequate family labor forces farmers to opt for employing wage laborers. However, smallholders are beyond the affordability to manage extra hands with little surplus which does not allow them to practice climate change adaptation strategies (Yila & Resurreccion 2013). Additionally, higher age of the household head alternatively more experienced in agricultural activities increases the probability of accepting adaptation options (Deressa *et al.* 2009). Another study by Jin *et al.* (2016) showed that farmers' farm size, farming experience, education level play significant role in choosing adaptation measures mostly in crop diversification.

In this study, income and farm size were important factors in defining the important elements for choosing new climate change adaptation strategies in agriculture. Confirming this consistent finding, the study of Thoai *et al.* (2018) also showed that households with large farm size were more likely to accept climate change adaptation strategies than smallholders. Moreover, farm size determines the farmers' adaptation decisions in maintaining climate change adaptation measures (Nhemachena & Hassan 2007; Piya *et al.* 2013; Ashraf *et al.* 2014; Ahmad & SeinnSeinn 2015; Asfaw *et al.* 2016; Jin *et al.* 2016). One of the possible reason behind this causation was explained in the study of Thoai *et al.* (2018), where author described that higher economic loss caused by climate change are significant in the large-scale farm size than small scale farms which works as a possible factor for adopting climate change adaptation strategies. Furthermore, in our study credit accessibility and assistance from an NGO/government organizations were not significant for considering adaption options. Similar findings also reflected in the study of Piya *et al.* (2013) describing access to credit as a negative impact on adaptation measures. Additionally, in accepting new adaptation measure smallholder farmers often hesitate because they are partly suspicious about the benefits and socio-economic constraints, which also works as a contributing factor. Similarly, practicing only indigenous strategies also becomes impossible for various reasons (Yila & Resurreccion 2013). Descriptive findings, from our study, regarding existing adaptation practices show that crop management is the highly practiced adaptation measures corroborating the findings of Hassan & Nhemachena (2008). In view of the fact that, high reliance on crop diversification and crop management help farmers' to diffuse risks in agriculture (Adger *et al.* 2003; Ashraf *et al.* 2014). In addition to this, infrastructure and water management were two other popular adaptation measures identified in this study.

Another important finding also shows that male-led farms are more likely to adapt water management practices. Findings from Tenge *et al.* (2004) also showed that female-headed households were less likely to implement soil and water conservation measures. One of the possible reasons, we observed during the study, explains the fact that water management in this study was observed in carrying water through a small water canal or carrying water with a water pot to water the plant which is troublesome. Also, this practice is more convenient for a male farmer than female. Another possible reason explained in the study of Yila & Resurreccion (2013) that, female-headed households are less likely to adapt climate change strategies due to cultural and social barriers that limit women's access to land and information. Furthermore, different geographical and cultural contexts might influence female-headed households to adopt climate change adaptation measures too. To point this out the study of Hassan & Nhemachena (2008) in South Africa showed that female-headed households are less likely to take up adaptation than male-headed households.

The final result from multinomial logistic regression, to understand the most demanded adaptation practices, water management practices stood out compared to farm management across the age and income level of the farmers. A greater emphasis on water management practices was observed by farmers to differentiate themselves from different climate change adaptation scenarios. One important thing to consider is that water management in coastal areas is important because, due to the proximity to the sea, salinity problems are highly reported in these areas. Crucial sectors like agro-economy, economy, and human health in coastal areas are in great jeopardy due to the high salinity conditions and the situation only aggravates during the cyclonic storm surge (Rakib *et al.* 2019a, 2019b; Uddin *et al.* 2019). In the study by Rahim *et al.* (2018) found that the maximum salinity problem occurs during the month of March to June. Due to this high salinity agricultural activities are significantly negatively impacted and cultivatable lands are left to fallow. Livelihoods related to agriculture are halted to put a stop. A study of Jin *et al.* (2016) outlined the fact that gender differences in agriculture showed a significant preference for technological practices in water management measures. They also found better educational qualifications of farmers' increases investments in irrigation infrastructure in adapting climate change conditions in agriculture. It is undoubtedly true that the education level of the household head and his adaptation to climate change in water management are highly associated (Maddison 2007; Deressa *et al.* 2009). Moreover, water management procedure in this study was highly demanded because of the unavailability of irrigation water due to drying up the water resources and a scarce number of groundwater irrigation facilities. Farmers highlighted they require proper irrigation facilities with the re-dredging of existing water canals. A study by Ashraf *et al.* (2014) found that due to lack of water management measures farmers' were unable to practice some of the crop management adaptation measures which ultimately resulted in low agricultural production.

5. POLICY IMPLICATIONS

The findings of this study have some important policy implications for the promotion of climate change adaptation strategies at the farm level regionally and locally. First, government should focus and extend services in improving the capability and effectiveness of different programs as a catalyst for appropriate climate change strategies. Speaking of the agricultural policy of Bangladesh, the Department of Agricultural Extension (DAE) pronounces some of the initiatives including supply and availability of quality seeds, fertilizers, irrigation, pesticides, etc. Though it is mentioned that agriculture extension service will be strengthened to encourage a self-motivated cooperative system of production, but the implementation of these services is required to be ensured (MoA 1999). Secondly, strengthening both formal and informal institutions is a vital prerequisite to effective adaptive capacity at the local and regional level. These institutions would expand knowledge and capacity about climate change in all levels of the formal governance structures and possibly promote more anticipatory capacity building. In this regard, the National Agricultural Research System (NARS) aims to strengthen and coordinate different programs through periodic evaluation (MoA 1999). Thirdly, for better water management in agriculture, excavation of the water canals is highly prioritized by the farmers. In order to make this challenge turn into a fruitful adaptation strategy Cash-For-Work (CFW) program within the Employment Generation Programme for the Poorest (EGPP) would be a great approach both for the enhanced adaption strategy as well as for the program itself too. Finally, civil societies and environmental NGOs should actively participate in crafting and advocating for robust and efficient strategies and agricultural management and adaptation. Different NGOs and banks are providing credits. Moreover, government has assigned different bodies of authorities with merging both government and private bodies to facilitate agricultural development (MoA 1999).

With the changing conditions of climate change and its negative consequences on coastal areas requires more attention into policy framework. In view of the findings of this study, government and relevant stakeholders should focus on improving the capability and effectiveness of the extension service, which is a catalyst for the promotion of appropriate climate change strategies.

6. FUTURE DIRECTION

In this research, we have tried to explain the possible factors responsible for choosing different adaptation decisions. Based on our field visit and pertinent literature search, we chose the factors and tested them against the existing adaptation strategies. This is sufficed, based on literature, to explain the existing process but elaborated and comprehensive planning of research works are required to understand more clearly the adaptation strategies and introducing the new adaptation options both locally and regionally. Moreover, the dominant adaptation strategies, according to this study, water management and fertilizer use were explored which also might pose some environmental impacts. Though water management in our study was explored in terms of using water from nearby existing water bodies like canals and ponds rather than exploiting ground water. Nonetheless, future researchers are also encouraged to understand the causal pathways in terms of adaptation practices against climate change are imposing further environmental threats or not. One important aspect which is also encouraged to debunk in the future study is the implication of socio-cultural factors and the mind set of farmers, if any, to understand climate change adaptation perspectives. Additionally, institutional and political factors coupled with cognitive and psychological factors also merit further deep understanding of adaptation decisions and inclinations.

7. CONCLUSIONS

The purpose of this paper was to investigate farmers' adaptation practices and to identify the factors that influence various adaptation measures. Results show that farmers' gender, income, damaged sector, family labor, farm size, access to credit, and help from NGOs/governments are significantly correlated factors in adaptation decisions. But the overall analysis shows that only gender, family labor, farming experience, and damaged sector are significant determinants in practicing adaptation measures. Furthermore, crop and infrastructure management measures were the most important of the five adaptation measures while farm management was the least practiced option observed in this study. Under the five broad adaptation measures, fertilizer and improved seed use were highly observed in crop management. The primary water management adaptation measure was irrigation from ponds and canals. Infrastructure management only was observed through the application of tractors in ploughing and processing crops. Also, finally, the social practice was maintained through the adaptation of traditional methods of agricultural process.

The findings of this study have practical implications in initiation of geography-based government interventions in boosting regional agricultural adaptation mechanisms, particularly water management, which will support poor people, farmers, and community at the same time. Additionally, agricultural policy extension to strengthen and encourage self-motivated cooperative system of production at the local level is also needs to be considered alongside.

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CONFLICT OF INTEREST

The authors declare there is no conflict.

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