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Farmers Adaptation Strategies to Adverse Impacts of Drought on Agriculture of the Central Barind Tract of Bangladesh: An Empirical Study

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Abstract Drought is a reoccurring phenomenon which is considered as one of the topmost slow-onset disasters in the central Barind Tract of northwestern Bangladesh. Due to the consequences of drought, agriculture of this area is highly impacted as well as the farmers fall in multidimensional livelihoods disruption. The objective of the paper is to investigate the existing adaptive measures practicing by farmers to combat adverse impacts of agricultural drought in two representative drought-prone locations of Rajshahi District of Bangladesh. The present study is mainly based on semi-structured household questionnaire survey. Eventually, the survey was conducted in 2019 among 303 households out of 1421 by using Kothari (2004) sampling formula considering 95% significance level and samples are determined through simple random sampling. Both descriptive and inferential statistics are used to analyze the adoption options of the cultivators of the study areas from geographical perspectives. It is found that most of the farmers adopted several measures rely on their traditional knowledge and experiences, participation in community trainings as well as receiving the facilities and support from different GOs and NGOs. Farmers are cultivating drought tolerant crop varieties, adopting rainwater harvesting, intercropping with rice, temporally changing occupation, using fertilizer and composting to accelerate crop production rate, changing irrigation system, participating in agro-training for coping with modern technologies, seeking to draw the compensation from GOs and microcredit of NGOs etc. to minimize drought impacts. However, the findings of present study are expected to provide useful guidelines to policy makers for facilitating farmers in sustaining their livelihoods against adverse impacts of agricultural drought in Barind Tract of Bangladesh.

Keywords: Agricultural drought, Adaptation strategies, Cropping pattern, Central Barind Tract, Bangladesh.

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1. INTRODUCTION

Drought is a repeated extreme weather event in many areas of the world caused by less rainfall and also the area receives bellow mean rainfall resulted the insignificant financial loss as well as agricultural damage (Kamruzzaman *et al.* 2022; Kamruzzaman *et al.* 2019) especially the central Barind Tract of the northwestern part of Bangladesh which, is spectacularly remarkable for agricultural drought (Brammer 1987; Hossain *et al.* 2016). This region is comparatively drier and receives lower rainfall than the other parts of the country (Paul, 1998). Agricultural drought is the ultimate result of meteorological drought which is directly associated with rainfall and water scarcity in soil (Dracup *et al.* 1980; Wilhite and Glantz 1985; Selvaraju *et al.* 2006; Afrin *et al.* 2018). Along with the natural causes, due to the rapid land use changes like other countries of South Asia, many parts of Bangladesh have faced an increased frequency of agricultural droughts in recent years (Shahid and Behrawan 2008). Literature shows that within the last 50 years, Bangladesh has suffered from more than twenty drought conditions, such as, the droughts of 1973, 1978, 1979, 1981, 1982, 1989, 1992, 1994 and 1995 which resulted severe consequences (Paul 1998; Ahmed 2006; Habiba *et al.* 2010). Ahmed (2006) reported that about 47% area of Bangladesh is at risk of drought, and 33% people lives in drought-prone areas of the country. Evidence also denotes that many of the droughts in the history drew greater damage to crops, property, life loss and affected huge population of wider area than a flood or cyclone (Brammer 1987; Paul 1998; Shahid 2008; Shahid and Behrawan 2008; Kamruzzaman *et al.* 2022).

The economy of the country is predominately depended on agriculture due to surface water availability, fertile land and favorable monsoon climate that consists of moderate temperature, seasonal rainfall, high humidity, mild day-length etc. (MoEF 2009). Nevertheless, owing to the impacts of climate change such as uneven rainfall, increased temperature and ground water depletion (Selvaraju *et al.* 2006), the frequency of agricultural drought has increased and significantly impacted farmers' life and livelihood (Ericksen *et al.* 1993; Mahmoud *et al.* 2016). The global circulation model (GCM) has projected that average temperature in Bangladesh will be upraised to 1.0°C by 2030 and 1.4°C in 2050, whereas the mean global temperature of Bangladesh may rise from 1.5 to 1.8° C by 2050 as a result of climate change (Ahmed and Alam 1998; Wheeler and von Braun 2013). Rahman and Lateh (2017) reported that Bangladesh is warming quickly than other parts of the world, thus, water demand has increased and worsening the country's drought (Kamruzzaman *et al.* 2022). In addition, increased climatic variability may create further pressure to drought-prone environment in the northwestern part of Bangladesh and it may turn into a semi-arid regions in near future (Selvaraju *et al.* 2006). The pre-monsoon and post-monsoon periods are most familiar times of droughts in Bangladesh because monsoon rainfall begins earlier than prospected time and in severe conditions drought might be continued throughout the monsoon period (Kamruzzaman *et al.* 2022).

Most of the droughts are typically considered as natural disaster which cannot be stopped but the impacts could be minimized through adaptation measures (Lindoso *et al.* 2014). In this regard, adaptation is considered as the adjustment that reduces vulnerability to shocks. These adjustments may be in response to, or anticipation of real or perceived stressors (UNDP, 2010). Thus, the adaptive measures can differ based on geographical scales, position and people's perception. For example, most of the drought prone areas of Africa, has given emphasis on integrated assessment model for community-based resilience assessment as an adaptation measure (Antwi *et al.* 2014) whereas, in Brazil, government applied different adaptation policies and relief, such as, support to insurance companies, providing emergency loans, water trucks, offering assistance in well drillings, agronomic practices and wide-ranging recovery actions to help communities to bounce back after drought and prepare for further drought events (Martins *et al.* 2017). But the scenario of Bangladesh regarding adaptation measures to combat drought is different. Over population, less man-land ratio, poor education, limited economic resources, unavailability of technological advancement, higher dependency on monsoon climate etc. are the major challenges to implement effective adaptation actions in the drought prone areas. Besides, huge attention has been paid on other rapid on-set natural disasters of Bangladesh, such as, cyclones, storm surges, river bank erosion, flood, landslides etc. (Paul and Routray 2010; Paul and Hossain 2013; Hossain and Paul 2015; Islam and Paul 2018) rather than on this slow on-set disaster. As a result, the priority to combat drought remain less important to the government and policy makers of the country. While most of the countries, focus on the adaptation options from bottom-up approach, Bangladesh is lagging behind. Therefore, to implement a successful adaptation measures it is important to investigate the adaptation options from individual to government level.

A number of studies focused on different aspects of drought risk assessment in Bangladesh (Brammer 1987; Habiba *et al.* 2010; Islam *et al.* 2012; Islam *et al.* 2014), impact of drought on agriculture (Karim *et al.* 2012; Alam *et al.* 2013; Islam *et al.* 2015), food production (Ericksen *et al.* 1993), land degradation (Karim and Iqbal 2001; GOB 2005), economy (World Bank 2000), society (Paul 1998; Coirolo *et al.* 2013;), agricultural drought and induced food shortage due to inadequate food grain production (Karim *et al.* 2012; Hassan and Das 2015) and drought induced crisis of water, it's usage and management (Wilhite 2014; Mahmoud *et al.* 2016). Other researchers have emphasized on response to drought and its management, coping and survival strategies practiced by farmers in drought-prone areas of Bangladesh and elsewhere (Alauddin and Sarker 2014; Lloyd-Hughes 2014; Alam 2015; Alamgir *et al.* 2015; Bird *et al.* 2016). Nonetheless, scants of researches have been carried out so far on the farmer's adaptation strategies to combat agricultural drought in the Barind Tracts of Bangladesh (Alam *et al.* 2014). But it is also highly substantial to integrate the adaptation strategies of the farmer at micro level which can help mitigate the agricultural drought and assist the rising economy of the country; and to implement a successful drought management policy at local level. The main objective of this study is to explore the adaptation strategies of farmers to combat the adverse impacts of agricultural drought and recommend some possible corrective measures to improve the drought situation in the northwestern Bangladesh. The results of the study may help researchers as well as

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government and NGOs to take appropriate drought adaptation policy; thus, facilitating farmers in sustaining their livelihoods against agricultural drought in the near future.

2. MATERIALS AND METHODS

2.1 Study Area

Shahapur and Mohar villages are selected purposively from Godagari and Tanore Upazila respectively of Rajshahi District by using purposive sampling method. The areas are chosen considering the severity of drought impacts (Fig.1). It has been reviewed that Godagari and Tanore Upazilas are severe drought-prone areas which is situated in the central Barind Tract of Bangladesh (Alauddin and Sarker 2014; Islam *et al.* 2014; Alam 2015; Alamgir *et al.* 2015) and most of the households are dependent on agricultural activities to perform their livelihoods. As a result, local farmers of selected areas continue to cope with extreme drought situation. Besides, easy access to transportation and communication facilities also inspired the authors to conduct the survey in these villages.

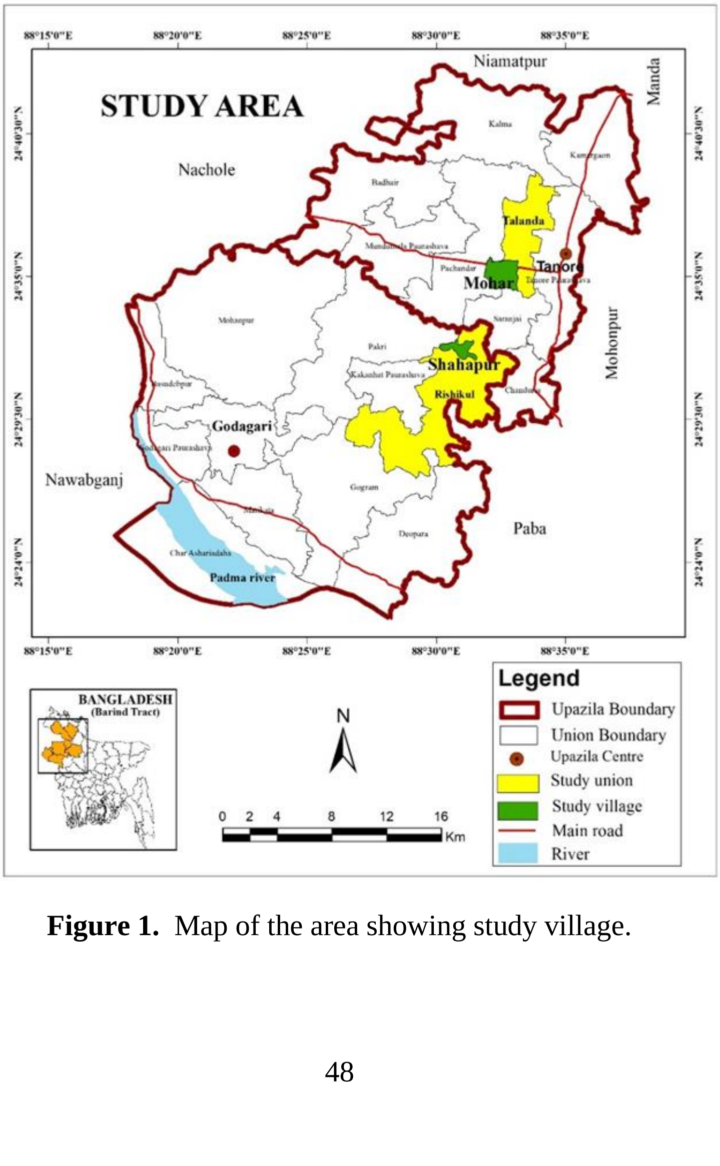

Figure 1. Map of the area showing study village.

2.2 Sampling Procedure and Data Collection Techniques

To meet the needs of the present study, data are mainly collected from primary sources. Standardized household questionnaire survey is conducted to measure the adaptation strategies to combat the drought in the study areas. Both close-ended (with multiple response options) and open-ended (without multiple response options) structured questions are included in the questionnaire, and adaptation measures are classified into three phases such as pre, during and after drought based on time-frame of the agricultural drought. Some relevant variables, for example, adaptation measures by farmers for sustainable agriculture and livelihoods; and mitigation measures, such as, changes in cropping pattern, rainwater harvesting, intercropping with rice, uses of manure and fertilizer, irrigation system, training on using modern technology, compensation to the farmers etc. are also added in the questionnaire to investigate the farmers' adaptation measures to combat drought in the Barind Tract of Bangladesh. By assuming 95% confidence level, total sample size of household survey is 303 out of 1421 (BBS, 2011), and households are selected based on Kothari (2004) sampling formula for known population where all the respondents are farmers. The number of samples are selected from Shahapur (90) and Mohar (213) village which is proportionally distributed according to total household sizes. The farmers are selected by using judgmental and snowballing sampling techniques. Meanwhile, two FGDs are conducted in each study village to validate information collected from household survey data. Each group is consisted of thirteen farmers all of whom are male due to the occupational characteristics of Bangladesh. After completing the household and FGDs survey, some informal interviews with key informants (*e.g.*, agriculture officer, Barind Multipurpose Development Authority (BMDA) officer, local government bodies, and non-governmental organization (NGO worker) are interviewed to collect more in-depth information on drought adaptation measures and to justify the information of the local respondents. Secondary data are also collected from several sources such as, Bangladesh Bureau of Statistics (BBS), Bangladesh Country Report, reports from Upazila Nirbahi Office (UNO), and agriculture office of the study villages to gather information about crop production, crop varieties and quality of the crops in the study area.

2.3 Data Analysis

The surveyed data are entered into SPSS (v 20.0), errors are checked, and necessary corrections are made accordingly. Both descriptive (*e.g.* frequency, percentage, average) and inferential statistics (*e.g.* chi-square, multinomial logistic regression) are used to analyze data. Farmer's perception related to adaptation to drought is almost qualitative data. Multinomial logistic regression model is also used as a vital data analytical procedure to correlate the adaptation measures of drought with different demographic and socio-economic factors. The covariates of different selected adaptive measures are analyzed to identify the significant factors that influence adaptation measures of agricultural drought.

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3. RESULTS

The adaptation strategies are divided into three phases for instance pre, during and post drought according to disaster management cycle.

3.1 Adaptation Strategies in Pre-Drought Phase

Before drought, the respondents of the study villages have taken some adaptive measures such as response to early warning system, indigenous knowledge and practice, and reserving rainwater before drought. Table 1 presents the respondent's opinion on the adaptation strategies in pre-drought phase. The table also shows results of chi-square tests among various adaptation strategies with some important demographic and socio-economic variables.

3.1.1 Response to Early Warning System

Table 1 shows that about 70.45 and 64.45% of the respondents of Mohar and Shahapur village respectively responded to early warning before drought. Both the study villages, the farmers usually understand the early warning by their own perception and observing the weather conditions. No institutional activities regarding the drought warning system are found in those areas. The main findings depict that the respondent who are educated, having high income and associated with agriculture as primary occupation are more adapted to response to the early warning than the uneducated, lower income and non-agriculture based people.

3.1.2 Indigenous Knowledge and Practices

The study finds that about 33.30 (Mohar village) and 36.74% (Shahapur village) respondents have practiced indigenous knowledge regarding drought. Thus, uneducated and lower income level respondents have more association with the use of indigenous knowledge to mitigate adversities of drought than the educated and higher income respondents.

3.1.3 Reserving Rainwater

Table 1 represents that about 44.42% (Shahapur) and 32.46% (Mohar) respondents reserve rainwater in their own ponds, canal and *Khari* (a narrow channel like river) before drought for cultivation. On contrary, a large number of farmers 55.58% (Shahapur) and 67.54% (Mohar) have no access to reserve rainwater facilities and fully dependent on seasonal rainfall for irrigation. As a result, due to irregular rainfall pattern the farmers of the study area suffered a lot and they hardly can cope with adverse drought situation.

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Table 1. Adaptation strategies in pre-drought stages

Adaptation strategies	Shahapur village (%)		Mohar village (%)		Chi-square test (x^2) (Hypothesis and significant)
	Yes	No	Yes	No	Both villages
Response to early warning system	64.45	35.55	70.45	29.59	Age: F= 0.930, df = 4, p =0.920 (NS) Sex: F= 0.823, df = 1, p =0.364 (NS) Education: F= 24.839, df=4, p= 0.000*** Occupation: F=13.479, df =5, p= 0.009** Monthly income: F=12.734, df =5, p= 0.026*
Indigenous knowledge and practices	36.74	63.26	33.30	66.70	Age: F=5.359, df =4, p =0.253 (NS) Sex: F=0.012, df =1, p =0.912 (NS) Education: F= 10.096, df = 4, p =0.039* Occupation: F=7.348, df=5, p=0.196(NS) Monthly income: F=11.492, df=5, p=0.004**
Reserving rainwater	44.42	55.58	32.46	67.54	Age: F= 8.152, df = 4, p =0.227 (NS) Sex: F= 0.367, df = 1, p =0.173 (NS) Education: F= 2.664, df=4, p= 0.615(NS) Occupation: F=11.537, df =5, p= 0.173(NS) Monthly income: F=12.734, df=5, p= 0.076(NS)

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$, *df = degree of freedom, NS = Not significant*

3.1.4 Regression Analysis to Identify Factors Influencing Adaptation in Pre-Drought

Multinomial logistic regression model in Table 2 presents that different demographic and socioeconomic factors have influenced on various adaptive measures to mitigate drought impacts. The results find that the education level of the respondents has a significant influence on adopting the measures of early warning. The respondents who are educated can understand the early warning messages better than the uneducated ones. While the income of the household has also significant influences on adopting the measure of indigenous knowledge and practice as an adaptation strategy. Poor income level of the respondents has more association with the use of indigenous knowledge to reduce the adverse situation of drought than the higher income. On the other hand, age, sex and occupation are not significant for adopting adaptation measures to combat agricultural drought. The result of logistic regression also reveals that there is no significant influences on reserving rainwater in the study villages.

Table 2. Multinomial logistic regression analysis for different adaptive measures in pre-drought period

Independent variables	B	Std. Error	Wald	Sig.	Exp (B)	Model fitting information
Response to early warning system						
Age	.085	.113	.560	.454	1.088	-2 Log Likelihood:
Sex	.156	.430	.131	.717	1.169	Intercept only = 118.952;
Education	.558	.438	1.627	.002	.572	Final= 92.985
Occupation	.039	.009	.152	.696	1.039	Chi-square= 25.9167;
Income	-.032	.119	.072	.788	.969	df= 5, Sig.= 0.011
						Pseudo R-square
						(Cox and Snell) = 0.082
Indigenous knowledge and practices						
Age	-.111	.109	1.033	.309	.895	-2 Log Likelihood:
Sex	.192	.421	.207	.649	1.211	Intercept only = 273.094;
Education	.157	.117	1.801	.180	1.170	Final= 252.362
Occupation	.034	.093	.138	.710	1.035	Chi-square= 20.733; df=5;
Income	1.370	.457	8.989	.003	.254	Sig. = 0.054
						Pseudo R-square
						(Cox and Snell) = .066
Reserving rainwater						
Age	-.015	.109	.019	.890	.985	-2 Log Likelihood
Sex	.583	.459	1.613	.204	1.791	Intercept only= 299.846;
Education	-.045	.111	.169	.681	.956	Final = 293.762
Occupation	.045	.092	.228	.633	1.045	Chi-square= 6.085; df= 5,
Income	-.087	.109	.638	.424	.917	Sig.= .298
						Pseudo R-square
						(Cox and Snell) = .020
The reference category is 'yes' and df =1						

3.2 Adaptation Strategies During Drought

During drought the respondents of the study villages also undertake different adaptive measures to combat drought. Some of the important adaptation strategies of the farmers are changing in occupation, adapting with potable and safe drinking water, cultivating drought tolerant crops, and harvesting rainwater. Different strategies adopted by the farmers during drought are given in Table 3.

3.2.1 Adaptation with Safe and Potable Drinking Water

Most of the respondents (about 88.10%) relies on deep tube well as the main source and hand pump tube well as a secondary source of safe drinking water during the period of agricultural drought due to the cause of ground water layer depletion. It is found that majority of the people are adopting modern strategies (deep tube well, hand pump) to access drinking water instead of dependent on natural reservoirs.

3.2.2 Change in Occupation

Table 3. Adaptation strategies during drought in the study villages

Adaptation strategies	Shahapur village (%)		Mohar village (%)		Chi-square test (x^2) (Hypothesis and significant)
	Yes	No	Yes	No	Both villages
Adaptation with safe and potable drinking water	87.90	12.10	88.31	11.69	Age: F=1.421, df =4, p =0.841(NS) Sex: F=12.066, df =1, p =0.001** Education: F=19.228, df=4, p = 0.001** Occupation: F=52.487, df=5, p= 0.000*** Monthly income: F=21.793, df=5, p= 0.001**
Change in occupation	27.86	72.14	19.23	80.77	Age: F=8.958, df =4, p= 0.062 (NS) Sex: F=2.806, df =1, p = 0.094 (NS) Education: F=21.223, df=4, p=0.000*** Occupation: F=26.043, df=5, p= 0.000*** Monthly income: F=14.335, df=5, p= 0.014*
Cultivate drought tolerant crops	85.69	14.31	85.00	15.00	Age: F=2.447, df =4, p= 0.654(NS) Sex: F=2.991, df =1, p =0.084(NS) Education: F=5.528, df =1, p=0.019* Occupation: F=16.550, df=5, p= 0.005** Monthly income: F=10.735, df =5, p=0.057(NS)
Rainwater harvesting	38.93	61.07	23.90	76.10	Age: F=15.046, df =4, p=0.068(NS) Sex: F=2.066, df =1, p=0.173(NS) Education: F=11.067, df=4, p= 0.839(NS) Occupation: F=12.411, df=5, p= 0.494(NS) Monthly income: F=7.793, df=5, p= 0.074 (NS)

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$, *df = degree of freedom, NS = Not significant.*

Table 3 finds that only 23.54% farmers temporarily change their occupation to cope with severe drought condition and rest of them remain jobless or continue to work on a farm work. It is found that uneducated farmers who switch their occupation is mainly shifted to non-agricultural laboring, petty business or informal jobs, such as, rickshaw pulling in the nearest urban areas, mason, carpenter, and brickfield laboring, *etc*. Besides, it is also investigated that most of measures regarding change of occupation are autonomous and instant of nature rather than a planned adaptation strategy.

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3.2.3 Cultivate Drought Tolerant Crops

Table 3 presents that farmers grow different types of drought tolerant rice such as, Parija, Swarna, Bina-7, BRRI (Bangladesh Rice Research Institute)-32, and IR (International Rice)-50, etc. which require less irrigation for production. At present, large number of farmers about 85.69 and 85.0% respondents from Shahapur and Mohar village respectively cultivate drought tolerant crops to adopt with severe droughts. It is also found that people of both villages produce various kinds of fruits, such as, mango, banana, jujube, mulberry, lemon, jackfruits, etc. which grow well in drought situation. Therefore, the study suggests that the adaptation regarding drought tolerant crops are very successful to combat the drought situation in the study area in Barind Tract of Bangladesh.

3.2.4 Rainwater Harvesting

Rainwater harvesting is also an alternative option to reduce stress on surface and ground water and to combat drought. Farmers reserve the rainwater in own ponds, water control storage, and Khari for irrigation to cultivate crops during the drought situation. Table 3 shows that the respondents (in Shahapur 38.93% and Mohar 23.90%) who have own pond, reserved rainwater and used it during drought season. It is also observed that some water reservoirs are constructed by local people, government and BMDA to store sufficient rainwater in case of water scarcity. Therefore, the main findings of the study regarding rainwater harvesting denotes that although one third farmers are harvesting rainwater as an alternative source but two third farmers are still not aware about the use of rainwater. It could be a long-term successful adaptation strategy if the awareness could be increased in the study area to minimize the adverse impact of drought.

3.2.5 Regression Analysis to Identify Factors Influencing Adaptation During Drought

From the result of logistic regression, the covariates of different adaptive measures to agricultural drought reveals that there is an influence of the selected demographic and socioeconomic factors on various adaptive measures to mitigate the impacts of drought on agriculture. Table 4 presents that the educational status of the respondents have statistically significant influence on safe drinking water during drought. On the other hand, education and the occupation of the households have also statistically significant influence on changing the occupation and cultivating drought tolerant crops during adverse impacts of drought. The uneducated respondent having agriculture as primary occupation mainly shifted to non-agricultural activities than the educated. The present study also finds that, highly educated and agro-based respondents are relatively more interested to cultivate the drought resistant crops compared to others.

Table 4. Multinomial logistic regression analysis of covariates for different adaptive measures during drought

Independent variables	B	Std. Error	Wald	Sig.	Exp (B)	Model fitting information
Adaptation with safe drinking water						
Age	-.030	.157	.036	.850	.971	-2 Log Likelihood:
Sex	.794	.501	2.508	.113	2.212	Intercept only = 267.785; Final= 235.695
Education	.329	.346	1.627	.002	.572	Chi-square= 32.09; df= 5, Sig.= 0.000
Occupation	.093	.132	.492	.483	1.097	Pseudo R-square
Income	-.285	.196	2.101	.147	.752	(Cox and Snell) = 0.100
Change in occupation						
Age	.188	.130	2.098	.147	1.207	-2 Log Likelihood:
Sex	.064	.458	.019	.889	1.066	Intercept Only = 302.630
Education	.670	.165	1.433	.000	1.954	Final= 275.711
Occupation	.535	.134	4.295	.002	.586	Chi-Square= 26.919; df= 5; Sig= 0.000
Income	.005	.142	.001	.972	1.005	Pseudo R-Square
						(Cox and Snell) = .085
Cultivate drought tolerant crops						
Age	.011	.143	.006	.939	1.011	-2 Log Likelihood:
Sex	.199	.493	.163	.687	1.220	Intercept only= 293.016;
Education	.497	.152	1.655	.002	.609	Final = 279.459
Occupation	.337	.110	9.426	.001	1.400	Chi-square= 13.557; df=5; Sig.= 0.019
Income	.023	.157	.022	.882	1.024	Pseudo R-rquare
						(Cox and Snell) = .044
Rainwater harvesting						
Age	.019	.114	.029	.865	1.020	-2 Log Likelihood
Sex	.018	.442	.002	.968	1.018	Intercept Only= 279.071
Education	.094	.119	.629	.428	1.099	Final= 278.215
Occupation	.000	.096	.000	.994	.999	Chi-Square= 856; df= 5, Sig.= 0.973
Income	-.075	.116	.418	.518	.928	Pseudo R-Square
						(Cox and Snell)= .003
The reference category is 'yes' and df = 1						

3.3 Adaptation Strategies in Post-Drought

The study finds that, in the study villages farmers developed various adaptive measures, such as, changes in cropping pattern, cultivation of high yielding rice varieties, intercropping with rice, use of fertilizer and composting, changes in irrigation facilities, etc. to mitigate the negative impact of agricultural drought.

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3.3.1 Changes in Cropping Pattern

Table 5. Before and after cropping pattern and crop production in the study villages

Season	Previous adaptation practices (Before BMDA 1990)		Present adaptation practices (2019)		Changes in amount of production (MT/ha) and crop varieties	Reason of changes (Informal interview)
	(Crop varieties)	Production (MT/ha)	(Crop varieties)	Production (MT/ha)		
Rabi	Potato	8.9-11.9	Potato	27.3 - 29.0	Potato (+17.75)	Increased due to deep tube well irrigation facilities
	Mustard	0.6-0.9	Mustard	2.4 – 3.0	Mustard (+1.2)	Increased due to use of organic fertilizer,
	Sugarcane	4.5 – 5.0	Rice (*Suman swarna*)	9.5 – 12.1	Replaced by Sumon Swarna	drought resistant and high yielding rice variety
	Pulses	1.2-2.7	Rice (*Chini atap*)	4.9 – 5.7	Replaced by Chini atap	High yielding variety, good in quality
	Wheat	3.3 - 4.0	Rice (BRRI-76)	5.1 – 5.8	Replaced by BRRI-76	Required short growth duration, limited irrigation
Pre-kharif (Rice varieties)	Bashfali	2.0	*T. Aman*	7.0 – 8.9	Replaced by *T. Aman*	Performs well under drought condition, high yielding
	Raghusail	3.9	*T. Aush*	4.6 – 5.8	Replaced by *T. Aush*	Required less irrigation facilities, early harvesting
	Indrosail	3.2	*Zira*	10.5 – 12.6	Replaced by *Zira*	High yielding variety, Good in quality
	Tanguir	1.8	Mango	11.2 – 12.0	Replaced by Mango	Suitable weather conditions, facility of intercropping with rice varieties
	Local varieties	4.0	IRRI-28	6.5 – 7.0	Replaced by IRRI-28	Performs well under drought condition
Kharif (Rice varieties)	Bahurupi	2.9	*Swarna*	7.5 – 8.8	Replaced by *Swarna*	Good in quality, require short time for production
	Latisail	2.7	Bina-7	5.0 – 5.9	Replaced by Bina-7	High yielding and relatively drought-tolerant
	Billmota	3.7	BRRI-28	4.3 – 5.8	Replaced by BRRI-28	Growth duration is very short (105 days)
	Local Varieties	1.3	BRRI-39	3.8 – 4.5	Replaced by BRRI-39	High yielding and require short growth duration

(MT =metric ton, ha. = hectare) Source: Agriculture office of Gadagari and Tanore upazila; Household survey, 2019.

The crop calendar of Bangladesh is divided into three main seasons such as Rabi (November–March), *Pre-kharif* (April–June) and *Kharif* (July–October). The change in cropping pattern and the crop production after taking adaptation strategies are presented in Table 5. In 1990s, farmers produced some traditional commonly practiced crops, such as potato, wheat, mustard, sugarcane, pulses etc. during Rabi cropping season but at present they cultivate new drought tolerant rice varieties, such as, Sumon, Swarna, Chini atap, BRRI- 76 as adoption of new adaptive measures. On the other hand, the production of potato (17.75MT/h) and mustard (1.2MT/h) is increased than the earlier period. At *pre-kharif*, farmers cultivated several local rice varieties but in 2019 those varieties are replaced by new verities such as *T. Aman* (*Transplaned Aman*), *T. Aush* (*Transplaned Aush*), Zira, IRRI (International Rice Research Institute)-28, etc. Similarly, some local rice varieties (Bahurupi, Latisail, Billmota) are also replaced by Swarna, Bina-7, BRRI-28, BRRI-39 during kharif cropping season. It can be mentioned that without the support of different GOs and NGOs, it is hardly possible for the farmers to adopt new high yielding crop varieties. However, the present study finds that majority of the farmers adopt drought resistant crop varieties which are mostly high-yielding, good in quality, early harvesting, require short growth duration and require limited irrigation facilities for production.

3.3.2 Adaptation with High Yielding Rice Varieties

Table 6. Cultivation of high yielding rice varieties

	Shahapur		Mohar		Both villages		Yield (MT/ha)	Growthduration (Days)
	(f)	(%)	(f)	(%)	(f)	(%)		
Swarna	17	18.9	40	18.8	57	18.8	8.15	145
BRRI-39	4	4.4	17	8.0	21	6.9	4.5	130
BRRI-76	3	3.3	18	8.5	21	6.9	4.9	125
BRRI-28	2	2.2	11	5.2	13	4.3	5.50	105
IR-28	4	4.4	17	8.0	21	6.9	3.6	100
Bina-7	18	20.0	69	32.4	87	28.7	5.45	115
Zira	42	46.7	41	19.2	83	27.4	7.20	150
Chi-square test (x^2) = F: 26.696, df= 6, sig. = 0.000.								

Bangladesh Rice Research Institute (BRRI) has invented various high yielding rice varieties which perform well in drought condition for drought prone areas (Hossain et al. 2016). The study finds that farmers cultivate *Zira*, *Swarna*, BRRI-28, IR-28, Bina7, BRRI-76 and BRRI-39 varieties of rice. Among them Swarna (8.15 MT/ha), *Zira* (7.20 MT/ha), BRRI-28 (5.50 MT/ha) and Bina-7 (5.45MT/ha) are widely grown rice varieties in both villages (Table 6). Most of the respondents have mentioned that very good quality, relatively drought-tolerant, high yielding and short duration for production are the main reasons of growing new

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rice varieties. The number of farmers involved in cultivation of *Swarna* is almost the same in both the study villages. Farmers also argue that these high yielding rice varieties are also grown within short duration than other varieties which help them to combat drought.

3.3.3 Intercropping with Rice

The present study finds that mango, jujube, mulberry and other varieties of fruits are intercropped with dominating crop to minimize drought impacts in the study villages. Farmers from both areas take this initiative as an adaptive measure because these fruits species are less vulnerable to drought or water shortage, and it provides an opportunity to harvest more than one food items in the same field at one time. Figure 2 represents that about 53.7% of respondents are involved in cultivating various types of mango such as *Gopalbogh*, *Khisanbogh*, *Langra*, *Fazlee* and Ashhwina in the study villages. Usually, the mango saplings are intercropped with *T. aman* and *Boro* rice varieties. Besides, Jujube (*Zizyphus mauritiana*) is a tropical fruit capable of striving against ample temperature range and is also drought tolerant (Selvaraju *et al.* 2006). In the study villages, jujube is intercropped during *kharif* season with *T. Aman* rice varieties, and it requires limited irrigation facility. About 29.7 and 21.4 % of respondents in Shahapur and Mohar villages are planting jujube and intercropped with rice respectively.

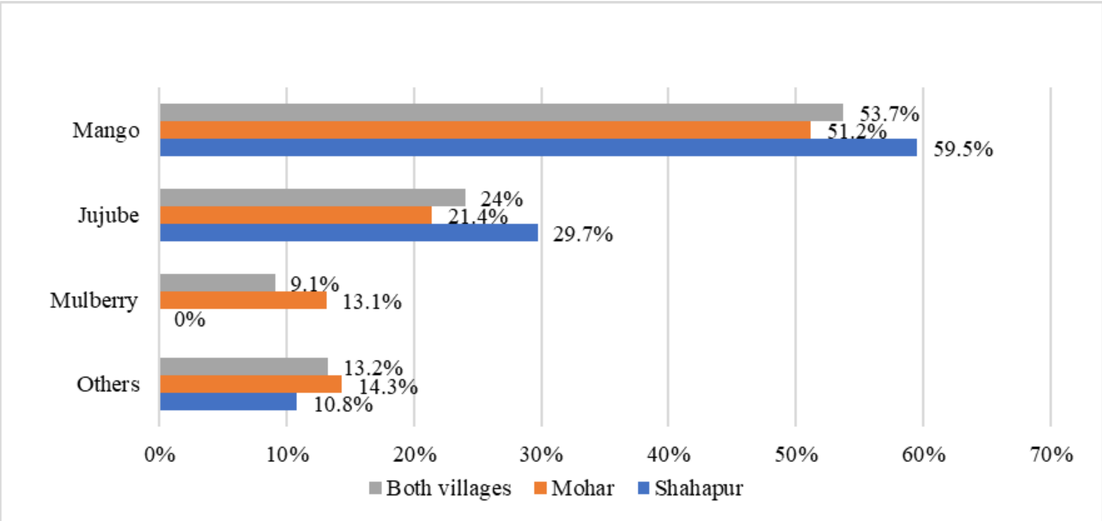

Figure 2. Sources of irrigation facilities in the study villages.

3.3.4 Fertilizers and Composting

The soil of the study area contains relatively low organic matter and has lack of capacity to absorb moisture content resulting in low agricultural production (Paul *et al.* 2014). In most cases, the majority of farmers (almost 97%) adopt different types of agronomic managements, especially agronomic practices help to improve soil quality and increase agricultural productivity to cope with recurrent drought. Figure 3 reveals that the farmers use chemical (65%), compost (16.5%), bio-fertilizes (11.6%) and others (6.9%) in the study villages to cultivate more crops. It has been found that use of chemical fertilizers is higher than bio fertilizers. Nonetheless, few traditional methods such as use of cow dung, decomposition of domestic waste, mulching (soil covering) and growing green herbs are also alternatively used as organic manure to increase the production in spite of having drought prone situation.

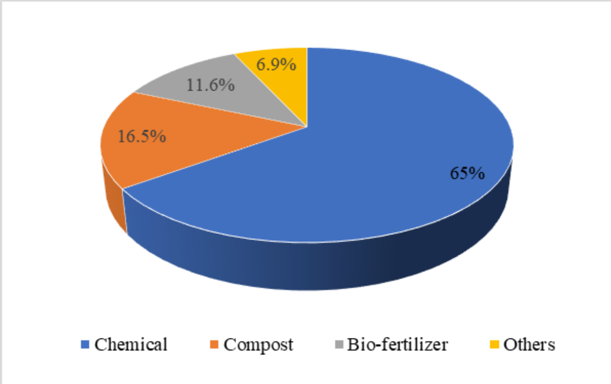

Figure 3. Use of fertilizer and composting in the study villages.

3.3.5 Changes Irrigation System and Facilities

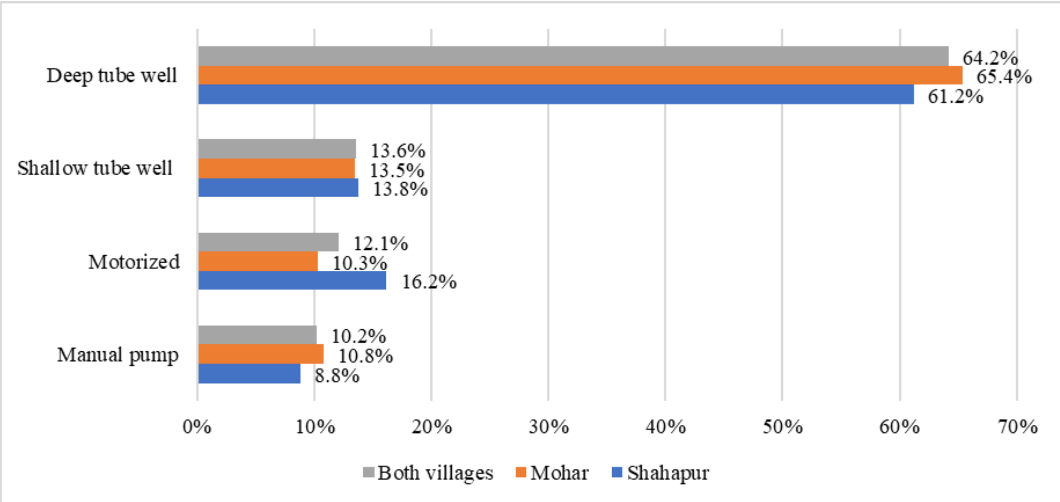

Figure 4. Sources of irrigation facilities in the study villages.

In the study villages, almost 100% agricultural land is irrigated and ground water is one of the main sources of irrigation. This study finds that, farmers use ground water (99.9% of the respondents) for irrigation and make choice of crops according to the availability of irrigation facilities. In the Barind Tract, BMDA has taken various adaptive measures to improve irrigation system in order to promote agricultural activities. Most of the farmers get irrigation facilities and are satisfied with these for cultivation. The deep tube well is widely used in the large part of the study areas for irrigation. It is found that, about 64.2% respondents use deep tube well, 12.1% use motorized pump, 13.6% use shallow tube well, and 10.2% use manual pump as irrigation (Fig. 4). The present study also finds that average irrigation cost using deep tube well is Tk. 5500 per hector at the rate of Tk. 125 per hour and the farmers pay the bill with prepaid card. Therefore, such findings reveal that poor farmers are incapable in most cases to adopt expensive irrigation strategies to combat drought for continuing agriculture. Besides, the farmers depend on rainfall as the major source of irrigation while reducing ground water level. As some areas have already under the threat of over extraction of ground water (Rahman and Mahbub 2012), so changing the irrigation system might be an efficient strategy to combat drought impact in the Barind Tract.

3.3.6 Adaptation to Recover from Food Scarcity

Among the drought affected inhabitants, recovery from food scarcity is one of the most challenging adaptive measures after severe drought. Table 7 expresses that about 72.20 and 79.81% farmers in Shahapur and Mohar village respectively recovered from food scarcity after drought and rest could not recover due to poor economic condition and lack of food production. In the study villages, most of the farmers mentioned that they recovered from food scarcity by own food production and agriculture sharecropping. They also opined that government relief and the assistances from various organizations played a vital role in this regard.

3.3.7 Farmers' Participation in Training about Modern Technology

Table 7 reveals that only 34.83% farmers of Shahapur and 24.90% of Mohar village have participated in training programs about the use of modern technologies in agriculture to reproduce crops as well as to bounce back to normal life. Various organizations such as BMDA, allied NGOs, private sector etc. organized those training programs to train the farmers in the study villages. On the other hand, majority of the farmers (70.13%) remain out of training about agriculture. However, the number of participations in different training programs are still low which often hinders the way to adopt new technological adaptation measures.

3.3.8 Compensation to the Farmers

Table 7 shows that in the study villages, after drought the affected people (about 43.33% in Shahapur and 42.64% in Mohar) have received financial assistance to recover from the adverse impacts of drought. The present study also finds that they received this financial assistance from various organizations such as micro-credit NGOs, insurance and others organizations in the study villages. Whereas, rest have not received any assistance due to high interest rate. Therefore, many respondents have urged for credit supports from GOs and NGOs with easy terms and conditions especially after drought.

Table 7. Adaptation strategies during post drought in the study villages

Adaptation strategies	Shahapur village (%)		Mohar village (%)		Chi-square test (x^2) (Hypothesis and significant) Both villages
	Yes	No	Yes	No	
Adaptation to recover from food scarcity	72.20	27.80	79.81	20.19	Age: F=10.989, df = 4, p = 0.027* Sex: F= 5.739, df = 1, p = 0.017* Education: F=14.758, df =4, p= 0.005** Occupation: F=31.808, df=5, p = 0.000*** Monthly income: F=18.509, df=5, p=0.002**
Farmers' participation in training about modern technology.	34.83	65.17	24.90	75.10	Age: F =13.196, df = 4, p =0.010* Sex: F= 0.013, df =1, p=0.909 (NS) Education: F=5.311, df =4, p= 0.257 (NS) Occupation: F=1.517, df = 5, p= 0.911 (NS) Monthly income: F=4.252, df =5, p=0.514 (NS)
Compensation to the farmers	43.33	56.67	42.64	57.36	Age: F =13.431, df =4, p=0.009* Sex: F =0.568, df = 1, p= 0.451 (NS) Education: F= 7.865, df =4, p= 0.097 (NS) Occupation: F=12.859, df=5, p=0.025* Monthly income: F=9.876, df=5, p= 0.079(NS)

*** $p < 0.001$; ** $p < 0.01$; * $p< 0.05$, *df = degree of freedom, NS = Not significant.*

3.3.9 Regression Analysis to Identify Factor Influencing Adaptation in Post Drought Period

Table 8 presents the logistic regression analysis to identify factors that influence the adaptation strategies after drought. The educational status and occupation of the households have statistically significant influence on recovery from food scarcity after drought. The educated respondent having agriculture as primary occupation are more capable of recovering from the food scarcity after drought than the uneducated. On the other hand, age of the respondents has statistically significant influence on farmer's participation in training about modern technology as a measure for adaptation strategies. The result of logistic regression also reveals that there are no significant influences of compensation to the farmers on adaptation in the study villages. In addition, the model fitness information also proves that there is a significant relationship between the dependent and independent variables in the final model.

Table 8. Multinomial logistic regression analysis of covariates for different adaptive measures in post drought

Independent variables	B	Std. Error	Wald	Sig.	Exp (B)	Model Fitting Information
Adaptation to recover from food scarcity						
Age	-.057	.128	.197	.657	.945	-2 Log Likelihood:
Sex	.065	.444	.022	.885	1.067	Intercept only = 106.950;
Education	.787	.400	7.595	.006	.332	Final= 84.015
Occupation	.337	.110	9.426	.002	1.400	Chi-square= 12.935; df= 5, Sig.= 0.028
Income	-.034	.140	.059	.808	.967	Pseudo R-square (Cox and Snell) = .073
Farmers' participation in training about modern technology						
Age	.588	.577	7.081	.008	.215	-2 Log Likelihood:
Sex	.105	.449	.055	.815	1.111	Intercept only = 271.873;
Education	.156	.123	1.600	.206	1.169	Final= 251.074 Chi-square= 20.799;
Occupation	-.064	.097	.438	.508	.938	df= 5; Sig. = .053
Income	0.16	.118	.019	.889	1.017	Pseudo R-square (Cox and Snell) = .066
Compensation to the farmers						
Age	.077	.105	.534	.465	1.080	-2 Log Likelihood
Sex	-.139	.401	.121	.728	.870	Intercept only= 314.414
Education	.166	.110	2.267	.132	1.181	Final= 302.925
Occupation	.079	.089	.786	.375	1.082	Chi-square= 11.489;
Income	.166	.109	2.321	.128	1.180	df= 5, Sig.= .042 Pseudo R-square (Cox and Snell) = .037
The reference category is 'yes' and df= 1						

4. DISCUSSION

The study finds that farmers have adopted different types of adaptation measures, such as, response to early warning, changes in cropping pattern, cultivating drought tolerant crops, irrigation from reserved water, rainwater harvesting, changing the occupation etc. using their traditional knowledge and skills. Based on the findings of the study it is revealed that pre-drought stage, most of the farmers of both villages rely on self-observation to detect the possibilities of drought rather than depending on the early warning disseminated by Bangladesh Meteorological Department. Farmers also use their indigenous knowledge and experiences about understanding the upcoming drought situation and take precautions based on the observatory perception. About one third of the farmers reserve rainwater for irrigation to mitigate the potential consequences of drought, whereas, most of them still depend on

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seasonal rainfall due to poor economic and educational condition. From the previous literature, it is found that drought as a naturally occurring climatic phenomenon has impacted on human and environmental activity (Sheffield *et al.* 2009). The inhabitants of both study locations collect drinking water from deep tube well as the main source of drinking potable and safe water during drought. Quite a good number of farmers changed their occupation for sustaining their livelihoods. As agricultural activities become limited in farm lands, they were forced to alternate their profession to others. In the study villages, deep tube well is the main sources of cultivation and most of the farmers cultivate various drought-tolerant crops which require limited irrigation facilities to cope with drought situation. After drought, the main findings of the study also show that the inhabitants of the study villages have changed the cropping pattern as well as crop varieties and cultivated drought resistant crops in *Rabi, Pre-kharif* and *Kharif* drought to get more production to combat drought. Due to the scarcity of rainfall during Rabi season, agricultural lands were kept fallow in previous days (Hossain *et al.* 2016). However, at present the farmers cultivate various high yielding drought tolerant crops and their production has also increased than that in the earlier period. The Barind Tracts are famous for high-yielding mango production which is also relatively profitable than the cultivation of rice (Selvaraju *et al.* 2006). Mango, jujube, mulberry etc. are intercropped with rice varieties in the study villages and these fruits are less vulnerable to drought or water shortage. It is noteworthy that such intercropping was completely absent before the operation of BMDA in the Barind Tract. Besides, water scarcity due to climate change (such as drought and lack of sufficient surface water for agricultural production) led farmers to become more vulnerable to drought in contrast to other parts of the country (Hossain *et al.* 2016). It also reveals that majority of the farmers are illiterate; therefore, in most cases they are unable or reluctant to apply modern technologies in agricultural field. To recover from the adverse impacts of drought the farmers have participated in different training programs about modern technology and also have received financial assistances from various GOs and NGOs. In terms of impact and adaptation measures towards drought, the results show that there is not much difference between the farmers of two different villages. Therefore, from the above discussion and based on the findings, the present study advocates for cultivating high yielding rice varieties, intercropping with rice, rainwater harvesting, improving existing irrigation facilities, participation of farmers in modern training, credit support for poor farmers, awareness raising and assisting farmers to diversify livelihood activities to minimize the adverse impacts of drought in near future in the Barind Tract of Bangladesh.

5. CONCLUSION

The main focus of the study is to explore farmers' adaptation strategies to drought in northwestern Bangladesh which finds that most of the farmers adopted several measures accumulating their experiences and practices such as understanding the early warning by individual observation, reserving rainwater by the use of pond, water reservoir during pre-

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drought period. As well as they successfully used to adopt drought tolerant crops, high yielding crop varieties, intercropping farming and use of modern fertilizers to handle the drought condition with the enormous assistance of GOs and NGOs. However, they also used to minimize food crisis and participate in microcredits to minimize the impacts after drought. On the contrary, it is also found that the institutional early warning system, use of safe drinking water, temporal occupation change, harvesting rainwater, large participation in training, easy loan policies are lagging behind due to poor education, income and ineffective policies of GOs and NGOs. The current level of adaptation by the farmers is mostly autonomous and still inadequate to cope with the challenges of drought. Moreover, planned adaptation is required for the effectiveness of drought adaptation actions. Respondents have opined to give emphasis on the participation of experts for this purpose; and they expect governmental assistance. It is mentionable that the planners and policymakers, agriculture extension officers, NGOs workers and other government organizations can play a vital role in the central Barind Tract of Bangladesh to lead successful drought mitigation. Therefore, participation and awareness building programs should be mandatory for understanding different adaptive measures about drought. Advertising and mock drill programs of electronic media, including drought education in school can help people to understand drought and also to teach people to cope with drought. This should be helpful for planners, agriculture extension officials and NGOs to improve responses for further incidences of drought and thus, lessen the resulting difficulties. Besides, governmental assistance regarding the incorporation of traditional adaptive measures with modern adaptive strategies needs to be ensured for the sustainable agricultural development of our study area of the country.

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AUTHORS CONTRIBUTION

Mousumi Akando Mou prepared the first draft and reviewed literature. Second author, the supervisor of the whole paper, checked the draft and prepared for the final. Third author helped to input and analyze data and write the draft paper.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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