Research Article

Adoption of Resilient Climate Technologies for Crop Production to Mitigate Drought in Northwestern Bangladesh

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Abstract | The current research aims to determine the level of adoption of Resilient Climate Technologies (RCTs) in the drought-prone parts of Bangladesh (northwest part). The study also explores the relationship between farmers' socio-demographic factors and the adoption of RCTs. To accurately reflect the northwest high Barind tract, the Tanore Upazila (sub-district) in Rajshahi District was purposefully chosen as the study's location as the area is highly vulnerable to drought in Bangladesh. Upazilla Agriculture Office (UAO) identified six villages in two Union parishads as highly susceptible to drought area. We have collected 1650 farm families living in the villages; the respective list of farmers was collected from UAO. Among 1650, 10% of the farmers were selected as sample size. From January to October 2022, researchers conducted in-person interviews with participants to gather data for this study. Around 49% of the farmers are in the medium category regarding RCT adoption. A linear regression model was applied to determine the relation between the adoption of RCTs and socio-demographic factors. The more educated and trained, the more exposed to extension services, the media, and organisations were, and the more likely they were to avail of resilient climate adaptation technologies in dealing with recurrent and more severe drought in the Barind region ($p \leq 0.05$). Therefore, it is recommended that the Government of Bangladesh take the necessary steps, including non-formal education campaigns and training, media exposure, and organisational participation.

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Introduction

Bangladesh is the world's most susceptible region to climate change (Hossain *et al*., 2018). According to the Global Climate Risk Index, Bangladesh is one of the nations most impacted by severe weather occurrences, ranking sixth out of 181 countries for climate vulnerability (Jahangir-Alam *et al*., 2022).

Bangladesh's agricultural industry is most at risk from climate change, which suggests a problem with national food security. Additionally, in Bangladesh

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and other disaster-prone countries in the global south, where several diseases are common, climate change adds a new layer of societal risk and vulnerability in these areas (Hoque *et al*., 2019). According to the worldwide circulation model (GCM) projections, Bangladesh's average temperature will rise by 1 degree centigrade by 2030 and 1.40 by 2050. Precipitation during monsoons is predicted to fall by 6.8% By 2050 (Alauddin and Sarker, 2014). In the Barind area of Bangladesh, recent climatic trends reveal that temperatures have risen, the precipitation pattern has altered, and overall precipitation has reduced (Mondol *et al*., 2021). According to climate change scenarios and forecasts, Bangladesh's western region will likely become vulnerable to drought.

Drought in northwest Bangladesh has reduced rice output by 1.33 million tons in recent decades (Mondol *et al*., 2021). The Boro and Aus rice, including traditional and high-yielding varieties, wheat, legumes, sugarcane, potatoes, etc., are among the primary crops that are frequently impacted (Hossain *et al*., 2018).

The Barid area already has higher temperatures and less precipitation than the rest of the country. Extreme drought episodes are becoming more frequent due to climate change, as has already been seen in northwest Bangladesh's Barind region (Ahmed *et al*., 2019). Due to dwindling rainfall, excessive groundwater extraction for agriculture, and excessive groundwater use, there is a growing water deficit in the Barind region. Increased climate variability is also a significant risk factor for agricultural production (Alauddin and Sarker, 2014). Farmers in the upper Barind tract of northwest Bangladesh must adopt specific adaptation strategies to deal with hardship brought on by climate change and projected to arise in the future (Chowdhury, 2019). However, developing new agricultural technologies needs to catch up to the unique problems that climate change brings to local agriculture. Therefore, farmers in the upper Barind cannot successfully adjust to climate change without new agricultural methods.

However, for eco-sensitive regions like Bangladesh's upper Barind, national research agencies, NGOs, and local farmer groups have produced a lot of innovative, environment-friendly farming equipment (Jabbar *et al*.,2010). Farmers are introduced to these technologies via Department of Agricultural Extension (DAE), NGOs, and certain foreign agencies like FAO. To face the adverse effects of climate change, environment-friendly solutions to strengthen climate resilience are crucial. Additionally, these technologies increase national food security and the local standard of living for farm households. Several technologies to improve climate resilience exist to assist farmers in adapting to climate-induced changes in both the natural and socio-economic systems (Grigorieva *et al*., 2023). These technologies might be "hard" or "soft." Soft technology, commonly called software, is the understanding of processes and procedures for creating goods and services or selecting the best courses of action. Tools, machinery, equipment, and whole production systems are considered part of hard technology, commonly called embodied technology or capital goods hardware. Developing and effectively deploying soft or hard technology requires the proper economic, legal and institutional support. In addition, technologies are generally needed in groups, as no single technology can typically solve all the related problems. At least a soft technology often requires one or more hard technologies to make it operational. Therefore, an effective adaptation strategy will compromise a mix of various climate-resilient technologies for drought adaptation.

Such technologies to adapt to climate change include air conditioning and irrigation technology to deal with reduced precipitation when it causes high temperatures and crop failures. The air conditioning saves the people, and the irrigation saves the crops. Monitoring, forecasting, and early warning systems soft technology can be combined with flood defence infrastructure hard technology to adapt to increasing numbers of natural hazards due to climate change. However, existing technologies need to be improved because climate change will likely require new and higher standards of reliability and performance than the current technology can attain (Tsatsaris *et al*., 2021).

The Barind region and surrounding areas already have severe water scarcity during the Kharif and Rabi seasons. Groundwater scarcity indicates that the water level has been gradually declining for years, which increases the intensity of these periodic droughts because there is less and less water stock to pump out for irrigation, washing, drinking, etc., during times of scarcity. Moreover, over-exploitation of groundwater for irrigation during droughts, as they intensify, accelerates groundwater depletion. This depletion exceeds the increment during the rainy season, causing groundwater stocks to approach zero over time. With groundwater, the survival of farming families and their crops during droughts would become possible.

Consequently, soil erosion and land degradation are taking place in the Barind and affecting the potential of agriculture to succeed there. Furthermore, extreme weather conditions lead to high temperatures, forcing farmers to depend on low-input agriculture and modern technologies (Richard *et al*., 2022). With such technologies, they can maximize production in good weather and recover quickly after disasters.

Increasing risks of climate change affecting the poverty alleviation program in the Barind area. Recent shifts in both coping strategies and livelihood portfolios of rural men and women have occurred due to institutional interference, economic motivation, and employment opportunities in Barind areas (Awal *et al*., 2013).

Climate change adds a new dimension to pre-existing and often endemic community risks and vulnerabilities related to natural disasters. Climate variability and projected global climate change mean their effects need urgent attention.

There needs to be more research in this field. Therefore, we still do not have a complete and accurate scenario of the problems of climate change victims or their ability to adapt agricultural technology to solve these problems in the Barind. So, the present study seeks: (a) to determine the extent of adoption of RCTs for adaptation to drought by the respondents in the high Barind tract and; (b) to explore the relationship between the extent of adoption of RCTs for adaptation to drought by the respondents in the high Barind tract and their socio-economic characteristics.

Materials and Methods

Location, population, and sampling

The Tanore Upazila (sub-district) of Rajshahi District, in the middle of the northwest high Barind tract, was therefore selected purposively as the site for the present study to represent the tract. Kamargaon, Saranjai Union Parishad (Union Parishad is the lowest administrative unit in Bangladesh) of Tanore Upazila was selected purposively as drought highly affects them. The total number of highly drought-affected farmers of the two Union Parishods is 1650. The information was collected from the respective agriculture office. The list is collected from the Upazilla Agricultural Office. 10% of the farmers were selected as samples, as many researchers used and suggested that 10% of the population as sample size is enough (e.g. Lemeshow *et al*., 1990; Haider *et al*., 2017; Bujang *et al*., 2018). Then, the sample size was 165. Farmers were selected using the table of random numbers. Data were collected by the researchers through personal interviews of respondents from January 2022 to October 2022.

Adoption of RCTs

The diffusion of innovation refers to the process through which a new activity, concept, or technology becomes widely adopted within a population. This process is influenced by several key properties, including relative advantage, complexity, divisibility, observability, and compatibility (Kumar *et al*., 2018). Adoption occurs through various stages, encompassing individual, cultural, societal, and institutional variables, such as awareness, information gathering, knowledge acquisition, assessment, trial, and eventual adoption.

The acceptance of technology is facilitated by its simplicity, observable results, utility in addressing a need, and affordable capital costs. The adoption of new and accessible technologies at the farm level is influenced by a combination of scientific, economic, and human behavioural factors (Tey and Brindal, 2012). While technology development often originates from physical science or biology, economic considerations primarily drive its acceptance. However, the behavioural and psychological aspects of technology adoption, though less conspicuous, play a significant role in determining whether a technology is embraced or not.

Managing climate risks requires a strong focus on climatic resilience, particularly in agricultural systems. It includes these systems' ability to foresee, prepare for, adapt to, absorb, and recover from the effects of severe weather events and climate change (Thonicke *et al*., 2020). Improving resilience entails putting into practice both immediate and long-term plans for mitigating and adapting to climate change, as well as making sure that a wide range of stakeholders are included in decision-making processes.

Achieving Sustainable Development Goals like No Poverty (Goal 1), Zero Hunger (Goal 2), and Climate Action (Goal 13) depends on improving food security and climate resilience in agriculture while also lowering carbon emissions or reaching carbon neutrality. But this is a big obstacle for the agricultural industry.

In the face of climatic unpredictability, Resilient Climate Technologies (RCTs) provide a paradigm for using natural resources in crop and animal production systems in a sustainable manner to increase productivity and farm incomes (Mukherjee, 2022). With many nations implementing RCTs to increase productivity, sustainability, and climate resilience, it is becoming clear that RCTs are a superior option to traditional agricultural methods.

There are three main ideas behind RCTs: Using crop residues and cover crops to add more organic matter to the soil; reducing mechanical soil disturbance and directly seeding into tilled soil to improve soil health and organic matter; and using a wider range of crops in different ways, such as in rotations, associations, and sequences, to make the system more resilient. To support ecological sustainability, these ideas may be incorporated into a variety of production systems, including horticulture, agroforestry, rainfed and irrigated agriculture, organic farming, rotational farming, and integrated crop-livestock systems.

Measurement of variables

Independent variables of the study are shown in Table 1 with the measurement techniques. The dependent variable was the adoption of RCTs to mitigate drought. It was measured by adopting fifteen drought adaptation technologies like irrigation in drought, drought-resistant rice varieties, etc. The researchers asked the farmers to indicate the extent of adoption by checking any responses from not at all too frequently (0-3), a four-point Likert scale. Thus, a respondent's score could range from 0 to 45, where 0 indicates no adoption and 45 means the maximum adoption.

Econometric method

A multivariate linear regression analysis was performed in order to determine the components that affect the adoption of RCTs. We investigated the relationship between farmers' sociodemographic characteristics and the adoption of RCTs. Likert scale data were quantified in order to do parametric analysis (Liu and Chalmers, 2018). The equation for this research is as follows.

Adoption of RCTs= β0 + β1.Age + β2.Education + β3.Family size + β4.Farm size + β5.Farming experience + β6.Training received + β7.Annual family income + β8.Extension media exposure + β9.Organizational participation+ϵ ….(i)

Here; Adoption of RCTs represents the predicted adoption of climate technologies. β0 is the intercept term. β1, β2, β3, β4, β5, β6, β7, β8, and β9 are the coefficients representing the effect of each independent variable. Age, education, family size, farm size, farming experience, training received, annual family income, extension media exposure, and organizational participation is the independent variable. ϵ is the error term, representing the unexplained variability in adoption not accounted for by the independent variables.

Results and Discussion

Socio-demographic characteristics (SDC)

The farmers' SDCs are presented in Table 1. In-depth information on the socioeconomic traits of respondents is described in the table, which also measures the distribution of each category's members. Age is used to classify respondents into three categories: young (under 29 years old), middle-aged (30–48 years old), and elderly (above 48 years old). The majority (61.8%) are in the medium age bracket, meaning that a significant fraction of people are in the prime working age range. Second, education levels are classified as illiterate to graduate, with 38.78% of the population having finished secondary school. Some other research (Asadullah and Rahman, 2009; Hasan *et al*., 2018) also found that most of the farmers were up to secondary school. This indicates that the respondents have a modest degree of education. The majority of families are medium-sized (5-6 persons) (45.5%), with small families (2-4) coming in second (43.6%). In 2022, an average of 4.4 people were reported to live in a family in rural areas (HIES, 2022). The farm size was classified according to guidelines from the Bangladesh Bureau of Statistics (BBS, 2011). The results reveal that most respondents (58.2%) had small farms, showing a preponderance of small-scale agricultural enterprises in the population polled.

Table 1: *Socio-economic characteristics of the respondents.*

Variables and measuring technique	Categories	Respondents		M	SD
		F	%		
Age (in actual age)	Young age (Up to 29 years)	37	22.4	39.49	10.22
	Middle age (30-48 years)	102	61.8		
	Old age (above 48 years)	26	15.8		
	Total	165	100.0		
Education level (year of schooling)	Illiterate (0)	3	1.8	9.33	3.59
	Primary level (1-5)	39	23.63		
	Secondary level (6-10)	64	38.78		
	Higher secondary level(11-12)	30	18.18		
	Graduate level (15)	29	17.57		
	Total	165	100.0		
Family size (actual number of family members)	Small family (2-4)	72	43.6	4.85	1.21
	Medium family (5-6)	75	45.5		
	Large family (>6)	18	10.9		
	Total	165	100.0		
Farm size (in hectare)	Landless (up to 0.002)	2	1.2	0.88	0.72
	Marginal (0.02-.2)	16	9.7		
	Small(between 0.2-1.0ha)	96	58.2		
	Medium(between 1.01-3.0 ha)	47	28.5		
	Large(above 3.0 ha)	4	2.4		
	Total	165	100.0		
Farming experience (actual year)	Low (Up to 5 years)	8	4.8	21.0	10.35
	Medium (6-20years)	85	51.5		
	High (>20years)	72	43.7		
	Total	165	100.0		
Training experience (days)	No training experience (0)	50	30.3	4.50	4.47
	Low training experience (1-3)	23	13.9		
	Moderate training experience(4-9)	49	29.7		
	High training experience (>9)	43	26.1		
	Total	165	100.0		
Annual family income (000 Bangladeshi taka)	Low income (up to 115)	36	21.8	219.00	113.20
	Medium income (116-300)	91	55.2		
	High income (>300)	38	23		
	Total	165	100.0		
Extension media contact (scale score)	Low extension contacts (up to 15)	50	30.3	21.60	10.21
	Medium extension contacts (16-26)	68	41.2		
	High extension contacts (>26)	47	28.5		
	Total	165	100.0		
Organisational participation	No participation (0 days)	29	17.6	3.38	2.62
	Low participation (1-3 days)	53	21.1		
	Medium participation (4-6 days)	65	39.4		
	High participation (>6 days)	18	10.9		
	Total	102	100		

There are three categories for farming experience: low, medium, and high. A considerable fraction (51.5%) of the respondents fell into the medium experience group, indicating a reasonable degree of experience. The distribution of training experience is similar, with intermediate training experience comprising the

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majority (29.7%). The distribution of annual family income is well balanced, with a sizable percentage (55.2%) earning a middle income. The average annual family income of the farmers was 219,000 Bangladeshi Taka (BDT). This amount is lower than the national average of 2457.92 USD (1 USD= 109.86 BDT) (Mapper, 2024). Farmers have less income than the national average in Bangladesh (Alamgir, 2018). There are many degrees of extension media interaction; medium contacts account for 41.2% of all connections. The respondents' highest ratio (43.7 per cent) had medium farming experience. However, most respondents (30.3%) had no training, whereas 29.7% and 26.1% of respondents showed moderate training experience (4-9 days) and high training experience (>9 days), respectively. Most respondents have low to medium contact with the Agriculture Ministry, extension service media, and organisational participation. Other research in Bangladesh (e.g., Karmruzzaman *et al*., 2018; Rahman *et al*., 2020) also accords with this finding.

Adoption of resilient climate technologies by the farmers for adaptation to drought

The dependent variable in this research was the rate at which farmers in Bangladesh's northwest high Barind Tract adopted RCTs for drought adaptation. This rate was determined by calculating an adoption score. The actual score, however, was between 6 and 41, with an average of 22.28 and a standard deviation of 9.13. The farmers were divided into three groups based on their potential adoption scores: Low adoption (up to 13), Medium adoption (14–23), and High adoption (above 23). The categories and distribution of the respondents are shown in Table 3. The analysed data indicate that more than half of the respondent farmers (61.8 per cent) had medium adoption. In a research, Roy *et al.* (2021) found medium-level adoption of climate-resilient technologies. In contrast, one-fifth of the respondent farmers (20.6 percent) had low adoption of resilient climate technologies.

The status of adopting resilient climate technologies for drought adaptation was explored with some identified technologies. The adoption quotient of all the selected drought adaptation technologies is ranked based on the adoption presented in Table 2. The use of irrigation during drought is used to the greatest extent. Kuwayama *et al.* (2019); Ray *et al.* (2018); Dey *et al.* (2011) also found a similar result in their findings. The use of organic manure and homestead vegetable cultivation is ranked second. The Alternate Wet and Drying (AWD) method is ranked third among 15 technologies. Research also recommended AWD for cultivating drought-prone areas of Bangladesh (Alauddin and Sarker, 2014).

Relationship between the SDCs and the adoption of RCTs

Among nine variables, four independent variables are positive and significantly related to the dependent variable. These significant independent variables are

Table 2: *Technology-wise adoption status of the farmers for drought adaptation.*

Technology	Extent of adoption and their score				Total	Rank
	Frequently (3)	Sometimes (2)	Seldom (1)	Not at all (0)		
Use of irrigation in drought	106	38	16	5	410	1
Use of organic manure	90	51	7	17	379	2
Use of crop mulching	24	27	19	95	145	13
Use of early cropping	40	62	17	46	261	6
Use of late cropping	34	43	23	65	211	8
Use of dry seedbed method for raising seedlings for T. *Aman* rice cultivation	27	37	15	86	170	12
Homestead vegetable cultivation	90	41	27	7	379	2
Use of less water-loving crop	42	33	22	68	214	7
Establishment of mango orchard	58	36	17	54	263	5
AWD	47	64	18	36	287	3
Use of mini ponds for supplemental irrigation	49	24	28	64	174	10
Use of mulching	28	36	17	84	173	11
Use of farm yard manure	28	25	10	102	144	14
Use of short duration variety	53	54	19	39	286	4
Papaya cultivation	25	39	29	72	182	9

Table 3: *Distribution of the farmers according to their adoption of climate resilient technologies for drought adaptation.*

Categories of adoption	Scoring method	Respondent farmers (N=102)		Mean	SD
		No.	Per cent		
Low adoption (up to 13)	Score	25	15.2	22.28	9.13
Medium adoption (14-23)		81	49.0		
High adoption (above 23)		59	35.8		
Total		165	100.0		

Table 4: *Multiple linear regression model between technology adoption and the socio-demographic factors of the respondent.*

Model	Unstandardised coefficients		Standardised coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.792	3.013		-0.263	0.793
Age	0.120	0.107	0.135	1.126	0.262
Education	1.141	0.142	0.450	8.014	0.000
Family size	-0.036	0.288	-0.005	-0.124	0.902
Farm size	-0.159	0.574	-0.013	-.277	0.782
Farming experience	-0.095	0.103	-0.108	-0.919	0.359
Training received	0.337	0.122	0.165	2.766	0.006
Annual family income	0.010	0.004	0.121	2.361	0.019
Extension media exposure	0.297	0.051	0.332	5.879	0.000
Organisational participations	-0.059	0.173	-0.017	-0.344	0.732

education level, training experience, extension media contact, and organisational participation (Table 4). Education enables individuals to attain knowledge and thus increase their power of understanding. Also, the findings indicate that the more education the respondents have, the more likely they are to adopt climate-resilient technology for adaptation to drought. Similarly, training can have the same effect. Therefore, a well-trained and well-educated person can cope with the adverse climatic situation (Ado *et al*., 2020). Another research found similar relations between education and willingness to adopt new technology (Majumder *et al*., 2014; Nagar *et al*., 2021). Balogun (Balogun *et al*., 2022) established a connection between training and technology adoption.

Farmers with no or low extension media contact are expected to be less willing to adopt new technology because they need more awareness of the new methods. One with extensive extension contact has likely received more information on farm technology, increasing their knowledge of their options. Such knowledge is probably conducive to motivating respondents to adopt drought adaptation climate resilient technologies. Media exposure enables an individual to gain understanding and broaden his outlook. Another research also found such a relation with technology adoption (Partey *et al*., 2020). In addition, the organisational participation of the respondent farmers in organisations was an essential factor in farmers adoption of drought adaptation climate resilient technologies. That relationship was positive, meaning the more farmers participated in organisations, the more they adopted drought adaptation climate resilient technologies.

Conclusions and Recommendations

Environment-friendly climate and climate-resilient drought adaptation technologies are some of the most important ways to combat the climate change effect in Bangladesh, particularly in agriculture. In our study, the majority of farmers were found to have a moderate level of adoption of resilient climate technologies for drought adaptation. Relevant training programs should be undertaken for the respondents who live in hazardous climate conditions, especially in the drought-prone Barind area, to upgrade their awareness, motivation, and understanding of eco-friendly climate-resilient drought adaptation technologies. The various GOs, NGOs, and international organisations should conduct training programs.

Adopting resilient climate technology for drought adaptation depends on the nature of the technology, availability of inputs, technical knowledge, and other characteristics of the farmers.

Considering the findings, a suitable combination of climate-resilient technologies is necessary to ensure high-quality food production during drought. Therefore, extension service providers (DAE, BADC, BMDA), research institutes, agricultural universities, and NGOs should bear this in mind and work harder to persuade farmers about the benefits of climate-resilient technology for drought adaptation.

To overcome the effect of seasonal drought, GOs, NGOs, and donor organisations should conserve rainwater by developing reservoirs like Khari canals, rubber dams, and concrete-made containers for water harvest.

Media contact increases farmers knowledge about different aspects of agriculture. Therefore, policies like parallel exposure to additional and various information sources should be provided for the farmers to increase their adoption of climate-resilient technology for drought adaptation. GOs and concerned NGOs can play a vital role in this regard. Finally, necessary steps are taken to ensure more frequent adoption of resilient climate technologies for drought adaptation.

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Novelty Statement

The more educated and trained, the more exposed to extension services, the media, and organisations were, and the more likely they were to avail of new climate adaptation technologies in dealing with recurrent and more severe drought in the Barind region in Bangladesh.

Authors' Contribution

Rejvi Ahmed Bhuiya: Initial manuscript preparation and data collection

Md. Ruhul Amin: Instruments for conducting the study, data analysing, and supervising.

A.K.M. Kanak Pervez: data analysis, developed the key concept, and prepared the final draft.

Conflict of interest

The authors have declared no conflict of interest.

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