Determinants of Drought Tolerant Rice Variety Adoption: Evidence from Rural Farm Household in Northern Part of Bangladesh

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Abstract. The drought-tolerant rice variety Binadhan-19 study was conducted in five districts: Mymensingh, Ranpur, Pabna, Rajshahi and Chapainwabganj of Bangladesh. A total of 200 farmers were randomly selected (40 from each location) to collect the data with a pre-designed questionnaire. Tabular, descriptive statistics and Probit model were used to fulfil objectives. The estimated log-likelihood value of gender, farm size, yield, agricultural extension services have a statistically and significant positive effect on the adoption of the variety. The household characteristic related variables such as age, experience, annual income, human labour, duration of the variety have no statistically significant effect on the adoption of the variety. Marginal coefficients indicate that if male farmers increased by 100%, the probability of adopting Binadhan-19 variety would increase at 38 times more likely to adopt the variety. If the farm size of Binadhan-19 increased by 100%, the probability of adopting the variety would be increased by 0.07%. A farmer who has access to agricultural extension service is about 39 times more likely to adopt the variety. Again, if the yield increased by 100%, adopting the varieties would increase by 0.08%. The marginal coefficients of locations and soil fertility are negatively significant, indicating that if these two variables increased by 100%, the probability of adopting the varieties would decrease by 0.06% and 30%, respectively.

Keywords: Drought tolerant; Rice; Adoption; Probit model; determinants; Binadhan-19; Bangladesh.

INTRODUCTION

Global food demand and supply is continuously changing due to climate change. Nowadays, floods, drought, heat and cold are seen by many people over the year in the world. Adopting improved agricultural technology and variety in drought-prone areas can be an essential alternative to eliminating food shortages and food insecurity by improving crop productivity and income. Further, promoting the adoption of improved crop varieties sustainably helps improve the welfare of households [9]. The global circulation model (GCM) predicts that the average temperature increases in Bangladesh due to climate change will be 1.0 °C by 2030 and 1.4 °C by 2050, and monsoon precipitation is likely to increase 6.8 % by 2050 [37]. Agricultural production in the face of climate change (CC) requires a change and reorientation of agricultural systems to supply adequate food for the increasing world population [13]. Rice is one of the essential staple's foods in the developing world, accounting for about 19 % of the total crop area harvested, 20 % of the caloric intake from staples and 50% of the food expenses by poor people in low- and middle-income countries [45]. By [14], rice is consumed by more than 4.8 billion people in 176 countries. It is the essential food crop for over 2.89 billion people in Asia, over 40 million people in Africa and over 150.3 million people in America. Demand for rice is expected to grow faster than the production in most countries [42], so much so that by 2025 we will need 800 million tonnes of it annually. At present, many developing countries have become food self-sufficiency because of appropriate policies and strategies taken by their government. But several biotic and abiotic stresses may slow down this progress in future. Understanding these problems, research organisations in different countries such as China, India, Bangladesh, etc., have developed stress-tolerant (submergence, salt, drought, etc.) rice varieties. Rice production would be a significant concern in recent years due to changing climatic conditions. A significant rice yield may hamper only fluctuations of those climatic parameters [12].

The population of Bangladesh will reach about 215 million in 2050. So, food grain must be increased for the upcoming future generation. Drought is one of the vital problems for many countries. The severity of such an issue goes massive when it comes as an obstacle to ensuring optimum agricultural production for a country like Bangladesh. Droughts rank first among all natural hazards when measured in terms of the number of people affected [33, 18, 43]. Although as a natural hazard, droughts differ from other natural hazards in several ways [43]. According to the IPCC special report on the regional impacts of climate change, there would be drastic changes in rainfall patterns in a warmer climate. Bangladesh may experience a 5–6% increase in rainfall by 2030 due to glacier melting and more intense monsoon, which will create frequent, big and prolonged floods and increased droughts outside the monsoon season. As a result of climate change, Bangladesh experiences a dry period for seven months, from November to May, when rainfall is normally low. Drought mostly affects the country in the pre-monsoon (March–May) and post-monsoon periods (October–November) [11]. Droughts are becoming more frequent, intense, spatially extensive, and longer duration [24]. It is one of the major abiotic stresses which adversely affect crop growth and yield and thus a constraint for productivity worldwide [25]. Recent research findings from a field study118 revealed that, on average, a 1% increase in the drought-affected area reduces aman and aus. annual rice production per household by 1,382 and 693 kgs, respectively [29]. This problem occupied an extreme position in the northwest region of Bangladesh. Bangladesh has already shown an increased drought frequency in recent years [44]. The average drought occurrence in Bangladesh is once every 2.5 years [3, 19]. In the last decade, this region has experienced drought once every year [17]. In the northwest region. Drought can have devastating impacts on rice production. Further, every year farmers in these areas incur high costs and huge crop losses due to drought. The impact of drought leads to the shortage of water and food and has a long-term environmental, socio-economic, and health impact on the population [40]. The phenomenon is causing enormous difficulties towards maintaining livelihoods and has become a severe problem in the North Western parts of Bangladesh. Farming of Aus. crop area using unused seasonal rainwater must be increased during the Kharif-1 season as an additional and substitute cereal crop to gradually replace the cultivation of more irrigation water consuming and costly Boro farming [36]. Keeping this in mind, the Bangladesh Institute of Nuclear Agriculture developed an Aus. rice variety, namely Binadhan-19, tolerant of drought. The present attempt has been made to focus on the determinants of the improved variety in the North Western farmers in Bangladesh.

The agricultural research literature contains numerous studies on adopting improved (high yielding) crop varieties [15, 16, 22, 27]. The majority of the previous studies focused on identifying the factors affecting technology adoption [1, 2, 21, 41] while others examined the effect of adoption on efficiency and productivity [4, 7, 20, 30] or household welfare [5, 7, 8, 10]. In addition, authors [28, 16] investigated the impact of NERICA adoption on income and poverty in Uganda and Nigeria, respectively. However, empirical study on the determinant of drought rice is hard to find. Most studies on farmers' joint adoption decisions have focused on adopting improved crop varieties and inorganic fertiliser [26, 34, 35, 39]. Therefore, determinants of drought-tolerant rice varieties adoption are needed for future policy as well as sustainability. Finally, the study's objective was to determine factors affecting the adoption of drought-tolerant variety cultivation in the study areas.

METHODOLOGY

Study areas, Sampling Procedure and Sample Size. The study was conducted in five districts of Bangladesh. Purposive sampling and multistage stratified random sampling techniques were followed to collect sample farmers for this study. Five districts under each environment were selected in this study. According to the literature review, Chapainawabganj, Rajshahi and Pabna were selected as high to moderate drought-prone areas, whereas Rangpur and Mymensingh were selected as slight and no drought areas. Then one Upazila from every five districts and two blocks from each Upazila were purposively selected in consultation with DAE personnel and rice scientists. Finally, a total of 200 farmers, taking 40 from each district, were randomly selected for the study, where 20 were adopters, and 20 were non-adopters of drought-tolerant variety. In the sampled areas, data were collected through a pre-designed interview schedule. Tabular, descriptive statistics and probit models were used to analyse the collected data. Collected data were edited, summarised, tabulated and analysed to fulfil the objectives of the study.

Table1 – Study areas and characteristics of Aus. rice locations in Bangladesh

No	Areas	Upazilla	Characteristics
1	Mymensingh	Gouripur	Very Suitable
2	Ranpur	Kaunia	Suitable
3	Pabna	Iswardi	Moderate suitable
4	Rajshahi	Tanore	Marginally suitable
5	Chapainawabganj	Nachol	Not suitable

Descriptive statistics used different statistical tools like averages, percentages, and ratios to present the study results. Probit and Logit models have been used extensively by economists of agricultural production and farming systems to study and analyse farmers' adoption and diffusion of agricultural interventions.

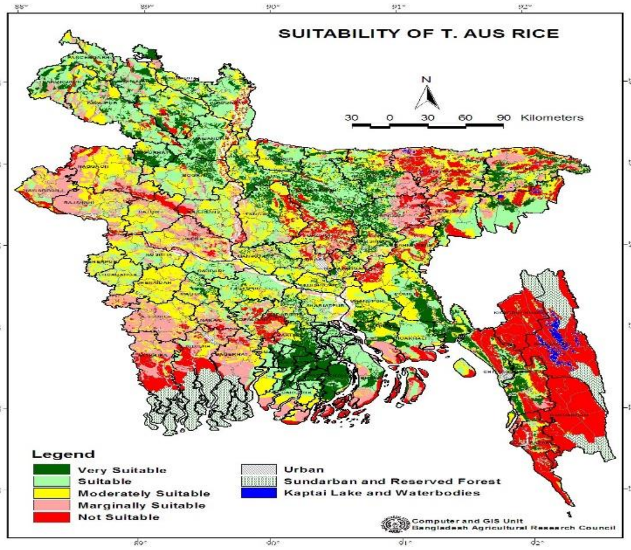
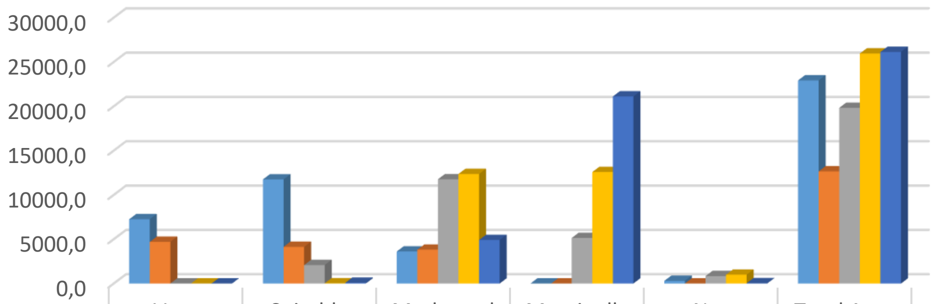


Figure 1 – Showing the suitable areas of Aus. rice cultivation in Bangladesh



	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable	Not Suitable	Total Area
Mymensingh	7253,8	11745,1	3617,5	0,0	300,7	22917
Ranpur	4699,3	4137,0	3815,7	0,0	0,0	12652
Pabna	0,0	2082,8	11758,1	5143,7	837,4	19822
Rajshahi	0,0	23,5	12359,5	12578,6	993,5	25955
Chapainawabganj	0,0	82,3	4910,4	21105,5	32,9	26131

Figure 2 – Bar diagram showing total Aus. rice area in selected areas of Bangladesh

In Pakistan, [19] used the Probit model to examine the role of credit in agricultural development and identify the determinants of adoption of wheat varieties. Authors [3] also used this analysis to identify the characteristics of insecticide farmers. In the present study, the Probit regression model was used to determine the adoption and non-adoption of the variety. The probit model is a statistical probability model with two categories in the dependent variable (Liao). Probit analysis is based on the cumulative normal probability distribution. The binary dependent variable, y, takes on the values of zero and one. The outcomes of y are mutually exclusive and exhaustive. The dependent variable, y, depends on k observable variables x_k, where $k=1...K$. While the values of zero and one were observed for the dependent variable in the probit model, there was a latent, unobserved continuous variable, y^*.

$y^{*}=\sum_{k=1}^{k}\beta_{k}x_{k}+\varepsilon$ (1)

where ε is IN (0, σ^2)

The dummy variable, *y* was observed and was determined by *y** as follows.

$y=\{1, \text{ if } y^{*}>0\}, 0 \text{ otherwise}$ (2)

The point of interest relates to the probability that y equals one. From the above equations,

$Prob(y=1)=Prob\sum_{k=1}^{k}\beta_{k}x_{k}+\varepsilon>=$

$=Prob(\varepsilon>-\sum_{k=1}^{k}\beta_{k}x_{k})=$

$=1-\Phi(-\sum_{k=1}^{k}\beta_{k}x_{k})$ (3)

where Φ was the cumulative distribution function of ε (Liao).

The Maximum Likelihood Estimation (MLE) technique was used to estimate probit model parameters. MLE focused on choosing parameter estimates that gave the highest probability or likelihood of obtaining the observed sample *y*. Thus, the main principle of MLE was to choose as an estimate of β the set of *K* numbers that would maximise the likelihood of having observed this particular *y*.

The specification of the Probit model was as follows.

$y_i=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6++\beta_7X_7+$

$+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+\beta_{11}X_{11}+\beta_{12}X_{12}+ +\beta_{13}X_{13}+U_i$

where Y_i=Farmers adopting Binadhan-19 variety (if adopted=1; Otherwise=0); α=Intercept, X_i=Explanatory variables, β_i=Coefficients of respective variables, and U_i=Error term.

The independent variables were captured as:
X1=Age of the respondent (Year)
X2=Gender
X3= Education (Year of Schooling)
X4= Farmer's experience in farming (years)
X5= Family size
X6=Annual income
X7= Farm size (hectare)
X8= Yield
X9=Duration (days)
X10=Ext. contact
X11=Soil fertility
X12=Human labour
X13= Locations

Measurement of dependent and explanatory variables were given in Table 2.

Table 2 – Measurement of dependent and explanatory variables

Variable	Type	Measurement
Dependent variable	Dummy	1 if farmer has adopted, otherwise 0
Explanatory Variable		
X1=Age	Continuous	Age of the Household head (years)
X2=Gender	Dummy	1 if the household respondent was male, otherwise 0
X3= Education	Continuous	Formal education of the respondent (years of schooling)
X4= experience in farming	Continuous	Farming experiences of the respondents (years)
X5= Family size	Continuous	Number of active (aged 15–60 yrs.) members in the family (persons)
X6=Annual income	Continuous	Amount of money earned by the family members in a year ('000 BDT)
X7= Farm size	Continuous	Amount of land under Binadhan-19 cultivation (ha)
X8=Yield	Continuous	Yield obtained by farmers in kg
X9=Duration (Days)	Continuous	No of days required for harvest
X10=Ext. Contact	Dummy	If favourable=1; otherwise=0
X11=Soil fertility	Continuous	High=1, Medium=2
X12=Human labour	Continuous	No. of labour/ha
X13=Location	Continuous	Score

RESULTS AND DISCUSSION

Demographic characteristics of the Binadhan-19 cultivated farmers. The demographic characteristics of the rice farmers were presented and discussed according to their age, education, family size, income and years of farming experience. The distribution of the farmers by age showed that the mean age for Binadhan-19 cultivated farmers was 38 years. This implies that the rice farming populations were still within their productive age and could still engage efficiently in rice production. Rice farming is a labour-intensive occupation and exerts energy for land preparation, nursery, planting, weeding and harvesting. The findings are similar to those of [5], who found out that the mean age of upland rice farmers and swamp rice farmers in Ebonyi State was 37.3 years and 39.2 years, respectively.

This is encouraging as an active age implies increased productivity and enables farmers to engage in other value-added activities like rice processing. Among the farmers, 86% was educated, categorised as illiterate, Primary, Secondary, Higher secondary, and above. In the study areas, farmers' average experience was 20 years, and income was tk. 235066 per year for adopters, and non-adopters, it was 17 years, and income was tk. 215587, respectively. The average family size was six, where 50 % was male, and 50% was female (Table 3).

Pattern of input use for rice cultivation. Farmers in the study areas used various inputs for rice cultivation. Farmers used on an average 126 person-days per hectare of total human labour for modern high yielding variety adopter where family labour was 57 person-days and hired labour was 69 person-days. On the other hand, in the case of non-adopter variety, on average 132 person-days per hectare of total human labour for modern high yielding variety adopter where family labour was 60 person-days and hired labour was 72 person-days.

Table 3 – Socio-demographic profile of the selected rice farmer's during 2019

Variables	Adopter (Average)	Non-adopter (Average)
Age (years)	38	41
Educational Status (%)	86	78
Family size (no.)	6	6
Male	3	3
Female	3	3
Income (Tk/year)	235066	215587
Farming experience (years)	20	17
Farming as a single occupation	99	80
Farming+ business	27	30
Farming+ job	11	05
Farming+others	24	12
Training or extension services (%)	20	10

For rice, the cultivation adopter used 37 kg seed per hectare of land and applied urea at the rate of 111 kg/ha, TSP 119 kg/ha, and MoP 86 kg/ha in where non-adopter used 42 kg seed per hectare of land and applied urea at the rate of 115 kg/ha, TSP 110 kg/ha, and MoP 107 kg/ha for Aus. rice Cultivation. It was observed that among the chemical fertiliser, farmers used the highest amount of TSP for the studied districts (Figure 2).

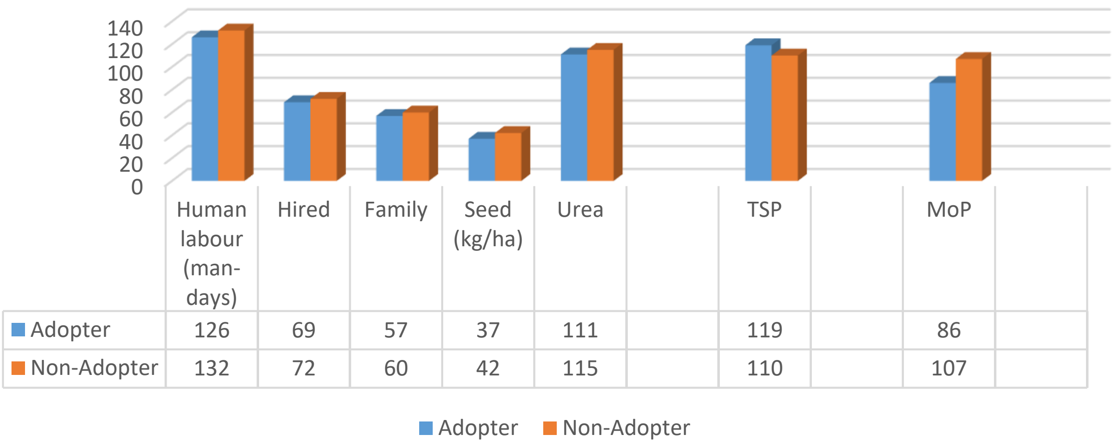


Figure 2 – Bar diagram showing input use pattern of adopter and non-adopter of improved rice cultivation in Bangladesh

Determination of factors affecting the adoption of the variety. The estimated log-likelihood value is highly significant, indicating that the model with predictors is to be preferred over a model without predictors. Gender, farm size, yield, and agricultural extension services have a statistically positive effect on adopting the variety. The household characteristic related variables such as age, experience, annual income, human labour, duration of the variety have no statistically significant effect on the adoption of the variety. The study areas and soil fertility are negatively significant for adopting the variety (Table 4).

Table 4 – Maximum likelihood estimates of variable determining adoption of the variety among respondent farmers

Variable	Co-efficient	Std. Err	Z statistic	Probability
X1=Age	-.0000819	.0101874	0.01	0.994
X2=Gender	1.17387*	.7144071	1.64	0.100
X3= Education	.0944802	.0621191	1.52	0.128
X4= Experience in farming	.0028103	.0103253	0.27	. 0.785
X5= Family size	-.0719539	.0603571	1.19	0.233
X6=Annual income	2.58e-07	5.06e-07	0.51	0.610
X7= Farm size	.0022593**	.00078	2.90	0.004
X8=Yield	.003857 **	.001837	2.10	0.036
X9=Duration (Days)	.0001081	.0153831	0.01	0.994
X10=Ext. contact	.3857288 **	.1960491	1.97	0.049
X11=Soil fertility	-.9313744***	.2483106	3.75	0.000
X12=Human labour	-.0015828	.0054463	-0.29	0.771
X13=District	-.0018017**	.0009324	1.93	0.053
Number of observations	199			
LR chi^2 (12)	45.52			
Prob > chi^2	0.000***			
Pseudo R^2	0.1650			
Log-likelihood	-121.51639			

Notes: *, **, *** represent statistically significance at 10 %, 5 % and 1 % respectively.

Marginal coefficients indicate that if male farmers increased by 100 %, adopting the Binadhan-19 variety would increase at 38 times more likely to adopt the variety. If the farm size of the variety Binadhan-19 increased by 100 %, the probability of adopting the variety would increase by .07%. A farmer who has access to agricultural extension service is about 39 times more likely to adopt the variety. Again, if the yield increased by 100%, adopting the varieties would increase by .08%. The marginal coefficients of the district and soil fertility are negatively significant. If these variables increase by 100%, the probability of adopting the varieties will decrease by .06% and 30%, respectively (Table 5).

Table 5 – Marginal Effect Estimates of the Probit Model

Variable	dy/dx	Std. Err	Z	Probability
X1=Age	-.000027	.0033589	0.01	0.994
X2=Gender	.3870364 *	.2306375	1.68	0.093
X3= Education	.0311511	.0201507	1.55	. 0.122
X4= Experience in farming	.0009266	.0034029	0.27	0.785
X5= Family size	.0719539	.0603571	1.19	0.233
X6=Annual income	8.51e-08	1.66e-07	0.51	0.609
X7= Farm size	.0007449 **	.0002441	3.05	0.002
X8=Yield	.000855**	.000631	1.36	0.032
X9=Duration (Days)	0000356	.0050719	0.01	0.994
X10=Ext. Contact	.0850021**	0.067438	1.26	0.028
X11=Soil fertility	-.3070833 ***	.0728358	4.22	0.000
X12=Human labour	0005219	. .0017946	0.29	0.771
X13=Location**	.0005941	.0002999	1.98	0.048

Notes: *, **, *** represent statistically significance at 10 %, 5 % and 1 % respectively.

CONCLUSIONS

Improving rice variety allows farmers to earn more money because of less input requirement like human, irrigation and fertiliser and shorter growth duration (100-105 days) than local rice variety. Econometrics analysis showed that gender, farm size, yield, extension contact is statistically significant in adopting the variety. In addition, farmers of the study areas mention positive traits of the variety like palatability, refined rice, ease to harvest, less water and urea requirement etc.

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