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EFFECT OF CLIMATE CHANGE ADAPTATION STRATEGIES ON PRODUCTION EFFICIENCY OF CHICKPEA AND LENTIL IN RAJSHAHI DISTRICT

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ABSTRACT

Adaptation assists farmers to cope with climate change by reducing adverse effect and increasing productivity of agricultural production. The study was undertaken to evaluate the effect of climate change adaptation strategies on production efficiency of selected pulse crops in Bangladesh. A total of 100(50 chickpea and 50 lentil farmers) pulse growers were selected. A multistage random sampling technique was followed to select the sample farmers. Descriptive statistics and statistical analytical tools such as multinomial logit model and stochastic frontier production function were used. The most common strategy followed in the study areas was increased insecticides or pesticides application (90%) due to climate change. Farmers also followed more doses of fertilizer application (85%), crop diversification (60%), change in land under pulse cultivation (25%), land fragmentation (3%), relay cropping (6%) and seed treatment (11%) as main adaptation strategies to climate change. Climate change awareness had positive, farm size had negative but connection to extension services had both positive and negative significant relationship with choosing and using different climate change adaptation strategies in chickpea cultivation. Education, climate change awareness and extension contact had significant positive relationship and farm size had both positive and negative significant relationship with choosing and using different climate change adaptation strategies in lentil cultivation. Seed had negative and other agrochemicals had positive and significant effect on the yield of both pulses. Average technical efficiency of the farmers was 0.83 and 0.82 for chickpea and lentil respectively implies that there is a scope of increasing productivity of chickpea and lentil by 17% and 18% respectively using current level of inputs only by increasing the farmers' efficiency. Adaptation strategy multiple planting dates had positive and significant effect on technical inefficiency of chickpea growers. Adaptation strategy relay cropping had negative and significant effect on technical inefficiency of lentil growers. Pulse production efficiency can be increased by eliminating the constraints to adopt climate change adaptation strategies.

Key words: Climate change, adaptation strategy, production efficiency, chickpea, lentil.

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I. INTRODUCTION

Climate change is an emerging issue which negatively contributing many sectors in the world is considered to be one of the most serious threat to sustainable development. Bangladesh is highly susceptible to agricultural damage because it is one of the most climate-vulnerable countries in the world (Gain *et al.*, 2012; Hossain and Huq, 2013; Huq *et al.*, 2012; Auerbach *et al.*, 2015). Small-scale farmers in the developing countries like Bangladesh highly depend on agriculture for sustaining their livelihoods damage. For this reason, they are most likely to be affected by climate change impacts (Gain *et al.*, 2012; Huq *et al.*, 2012; Huq and Huge, 2012; Karim *et al.*, 2012). Adaptation reduces the negative effect of climate change (Adger *et al.*, 2003; Kurukulasuriya & Meldelson, 2006). Modification of agronomic techniques and farm strategies in order to cope with climate change is necessary to meet growing demand of agricultural produces. It has been considered as the main coping strategies which are supposed to help the farmers to improve their productivity and efficiency in crop production and also increase their returns to farming.

Pulse being a climate sensitive crop, is badly affected by the climate change. Pulses are vital legume crops in Bangladesh because of their significance in food, feed, and cropping systems. It is considered as the protein of the poor as they have lesser access to animal proteins. It contains about twice as much protein as cereals. It also contains amino acid lysine which is generally deficient in food grains (Elias *et al.*, 1986; Rahman *et al.*, 2012). Thus, the pulses are essential components of the daily diets of the people of Bangladesh. Among them lentil and chickpea are most preferable for consumption to the Bangladeshi people, but domestic production is not sufficient to meet the demand. Bangladesh has deficit in producing of them and the shortage are met by importing. In 2017-18, Bangladesh produced only 4964 MT chickpea and 1,76,633 MT lentil which were so tiny to meet consumption requirement and to satisfy domestic needs it imported 2,04,197 MT and 2,69,148 MT chickpea and lentil respectively (BBS 2019). Production of particular pulses would be raised up by implementing adaptation strategies to climate change as well as increasing the efficiency of the farmers.

A number of studies have been conducted on the adoption and profitability of lentil and chickpea in Bangladesh (Siddique *et al.*, 2020; Sharna *et al.*, 2020; Hajong *et al.*, 2020; Islam *et al.*, 2020; Matin *et al.*, 2018; Rahman *et al.*, 2012). Studies on adaptation strategies followed in crop farming in Bangladesh, however, are limited. Islam *et al.* (2019) conducted a research on farmers' adaptation strategies to drought conditions and found that the association between the implemented adaptation measures and selected variables suggests that the farm size, irrigation accessibility, monthly household income, land ownership status, literacy level, and poverty status played significant role in the implementation of adaptation measures. Huda (2015) assess different adaptation options for two rice growing seasons, namely Boro and Aman in coastal areas of Bangladesh. The study reveals that marginal impacts of temperature on farm net income are negative for all seasons. The marginal impacts of rainfall were found to be positive and significant for all models in the study. It is also evident from the analysis that successive adaptation significantly increases farm productivity and contributes to the revival of farm revenue up to a threshold level. Kabir *et al.* (2017) evaluated farmers, perceptions of and responses to environmental change in southwest coastal Bangladesh and identified on-farm adaptation strategies included adjusting planting dates, excavating trenches in rice-fields, adopting new crops, salinity-reducing technologies, livestock-rearing and home-yard cropping. Non-farm adaptation strategies included wage employment, short-term migration and self-employment. Adaptation was facilitated by income-earning opportunities, training and credit, and impeded by lack of access to water, markets, capital and extension services. Kabir *et al.* (2016) conducted a research on farming adaptation to environmental change and results showed that with current management practices, the rice/shrimp system is economically more viable (higher returns to land and labour and less risky) than the rice/non-rice system. The existing literature, however, has not adequately covered the impact of climate change adaptation strategies on production efficiency of lentil and chickpea. This study was designed to address the issue.

By reducing the negative effect of climate change on specific pulse production, total production in Bangladesh can be increased which will contribute to cut off the import. For this reason, it is required to evaluate the production efficiency under different climate variability. The study had identified climate change adaptation strategies used by pulse growers and factors that influence the choice of climate change adaptation strategies, estimated technical efficiencies in pulse production and also determined the impact of climate change adaptation strategies used by the farmers on pulse production efficiency. Findings of this study will be supportive to formulate policy in this regard.

II. METHODOLOGY

The study was conducted in Rajshahi, the major pulse growing district of Bangladesh (BBS 2019). According to the amount of consumption two major pulses namely, lentil and chickpea were selected for this study. Selection of sample size is an important question among the researchers. When the population size is known and the researchers are careful of the heterogeneity problem, any number (equal to or) greater than the statistically large sample (of 30 sample units) may be appropriate (Freund and Williams, 1983). However, a total of 100 farmers (50 lentil farmers and 50 chickpea farmers) were selected for the study. A multistage random sampling technique was followed to select the sample farmers. At first, Rajshahi district was selected as a climate vulnerable and pulse growing area. In the second stage, Godagari upazila was selected on the basis of area and production of chickpea and lentil. Thirdly, 2 (two) agricultural blocks namely, Mohanpur and

Dewpara were selected in consultation with DAE personnel for selecting sample farmers. Finally, a required number of samples were randomly selected from the complete list of chickpea and lentil farmers for interview. Primary data were collected in March 2020 through interviewing the farmers using a structured pre-tested interview schedule. The data for this study was analysed using both descriptive and inferential statistics. Descriptive statistics, namely percentages and frequencies were used to identify climate change adaptation strategies used by pulse growers. Multivariate discreet choice model (i.e., multinomial logit model) was estimated to identify factors that influence the choice of climate change adaptation strategies. Cobb-Douglas stochastic frontier production function was applied to estimate technical efficiency. Finally, influence of climate change adaptation strategies on pulse production efficiency was analysed by using technical inefficiency model.

Analytical technique

Multivariate discreet choice model

The Multinomial logit (MNL) model for climate change adaptation choice specifies the following relationship between the probability of choosing option Y_i and the set of predictors X_i as (Greene, 2003):

$$\Pr(Y_i = j) \frac{e^{\beta_i X_{ij}}}{1+\sum_{m=1}^{5} e^{\beta_m X_{ij}}}, j = 1,2,3 \ldots, 5= \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where β_j is a vector parameter that relates the socio-economic, farm and institutional characteristics X_i to the probability that $Y_i= j$. Because the probabilities of the five (5) main climate change adaptation strategies must sum to one, a convenient normalization rule is to set one of the parameter vectors, say β_0, equal to zero (β_0=0). The probabilities for the five (5) alternatives then become (Greene, 2000):

$$P_j = \Pr(Y_i = j) = \frac{e^{\beta_j X_{ij}}}{1+\sum_{m=1}^{5} e^{\beta_m X_{ij}}}, j = 1,2,3 \ldots, 5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$P_0 = \Pr(Y_i = 0) = \frac{1}{1+\sum_{m=1}^{5} e^{\beta_m X_{ij}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The estimated parameters of a multinomial logit system are more difficult to interpret than those in a bivariate (or binomial) choice model. Insight into the effect that the explanatory variables have on the climate change adaptation strategies decision can be captured by examining the derivative of the probabilities with respect to the kth element of the vector of explanatory variables. These derivatives are defined as (Greene, 2000):

$$\frac{\partial \Pr(y_i = j)}{\partial X_{ik}} = P_j\left[\beta_{jk} - \sum_{m=1}^{5} pr(y_i = m)\, \beta_{jk}\right] j = 1, \ldots 5; k = 1, \ldots k \ldots (4)$$

Clearly, neither the sign nor the magnitude of the marginal effects needs bear any relationship to the sign of coefficients.

The Y_i is the probability of choosing a climate change adaptation strategy. The following five are the main climate change adaptation strategies which were used by majority of the respondents. First three strategies were common for both types of farmers.

1. Increased insecticides or pesticides application
2. Used more doses of fertilizer
3. Change in land under pulse cultivation
4. Land fragmentation for chickpea and crop diversification for lentil
5. Seed treatment for chickpea and relay cropping for lentil

X_i= socio-economic, farm-specific and institutional variables. Socio-economic variables that were used partly as independent variables include: Age (X_1) = age of household head in years, Education level of farmer (X_2) = number of years of schooling of household head, Years of climate change awareness (X_3) = number of years of household head's awareness of climate change. Farm-specific variables that were used partly as independent variables include: Farm size (X_4) = measured in hectares. Institutional variables that were used partly as independent variables include: Access to extension services (X_5) = number of formal extension visit in the cropping season.

Stochastic frontier production function

The Cobb-Douglas stochastic frontier production model was used for estimating technical efficiency of the farmers.

Cobb-Douglass production form:

$$lnY_i = \beta_0 + \sum \beta_i \ln(K_i) + (V_i - U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where: β_i = parameters estimates, Σ is the sign of summation, Y_i = Yield (t/ha), K_1=the total labour used (mandays/ha), K_2= Seed used (kg/ha), K_3= the total quantity of fertilizer used (kg/ha), K_4= the total value of other agrochemicals (Tk./ha), The V_is are random errors that are assumed to be independent and identically distributed as N $(0,\sigma_v^2)$ random variables; and the U_is are non-negative technical inefficiency effects that are assumed to be independently distributed among themselves and between the V_is such that U_i is defined by the truncation of the N $(0,\sigma_u^2)$ distribution.

Technical inefficiency effects model

$$U_i = \delta_0 + \sum_{i=1}^{7} \delta_i Z_{ji} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

U_i= inefficiency effect, δ_i= coefficients of climate change adaptation strategies and socioeconomic factors, Z_{ji}= climate change adaptation strategies and socio-economic factors, Z_1= increased insecticide or pesticide application (number of application increased as a result of climate change), Z_2= used more doses of fertilizer (quantity (kg) increased as a result of climate change), Z_3= multiple sowing dates/ different planting dates for chickpea (number of sowing dates as a result of climate change in the cropping season) and relay cropping for lentil (dummy variable 1= used relay cropping strategy, 0= otherwise), Z_4= crop diversification (number of crops cultivated by the farmer as a result of climate change), Z_5= Age of household head (Years), Z_6= level of education in years (number of years of schooling) and Z_7= years of awareness of climate change.

The estimates for all parameters of the stochastic frontier and inefficiency model were estimated in a single stage by using the Maximum Likelihood (ML) method. The econometric computer software package FRONTIER 4.1 (Coelli, 1996) was applied to estimate the parameters of stochastic frontier models using the ML.

III. RESULTS AND DISCUSSION

Climate change adaptation strategies used by the pulse growers

Farmers in the study areas mentioned 13 adaptation strategies they were followed in chickpea and lentil cultivation. Majority of the respondents (90%) increased insecticides or pesticides application as a crop management practice to adapt to climate change while it was being followed by 84% and 96% of the chickpea and lentil growers, respectively. About 85% of the respondents applied more doses of fertilizer as a climate change coping strategy while 80% chickpea growers and 90% lentil growers followed this strategy. About 60% of the respondents diversified their crops in order to adapt to climate change, while 40% and 80% of chickpea and lentil growers, respectively used this strategy (crop diversification) as shown in Table 1. About 25% of the respondents adjusted their farm size (increased or decreased) in order to adapt to climate change while 20% and 30% of chickpea and lentil growers, respectively used this strategy (change in land under pulse cultivation). About 11% of the respondents treated their seed with chemicals before planting to control disease. Multiple planting dates was used by about10% of the respondents. About 9% of the respondents used climate resilient variety in order to adapt to climate change while 10% and 8% of chickpea and lentil growers, respectively used this strategy. About 6% of the respondents used multiple crop types/varieties as a crop management practice to adapt to climate change. About 6% of the respondents followed relay cropping method to reduce production cost and cope with climate change, while it was being followed by 10% lentil and 2% chickpea growers. They broadcast their pulses in the rice field 10 to 15 days prior to harvesting. Approximately 4% farmers followed seed priming method to cope with drought (Table 1). About 6% of the chickpea growers used land fragmentation (i.e., multiple number of farm plots) as a land management practice to adapt to climate change. Exactly 3% of the respondents changed their irrigation practices (increased number of irrigation or introduce irrigation) to adapt to climate change. Mulching as a crop and soil management practice was used by 6% of lentil growers.

Table 1: Percentage distribution of farm level climate change adaptation strategies used by the pulse growers

Sl. No.	Adaptation strategies	% farmers responded		
		Chickpea	Lentil	All
01.	Increased insecticides or pesticides application	84	96	90
02.	Used more doses of fertilizer	80	90	85
03.	Crop diversification	40	80	60
04.	Change in land under pulse cultivation	20	30	25
05.	Seed treatment	14	8	11
06.	Multiple planting dates	8	12	10
07.	Climate resilient variety	10	8	9
08.	Multiple crop type /Varieties	6	6	6
09.	Relay cropping	2	10	6
10.	Seed priming	6	2	4
11.	Land fragmentation	6	-	3
12.	Change irrigation practice	2	4	3
13.	Mulching	-	6	3

Factors that influence the choice of climate change adaptation strategies used by chickpea farmers

In this analysis, the base category is change in land under pulse cultivation. The result of the multinomial logit (MNL) model indicate that different socioeconomic factors (age, education, and years of climate change awareness) farm-specific variable (farm size) and institutional variable (extension contact) affect the farmers' choice of the main farm-level climate change adaptation strategies in chickpea cultivation. Results of the parameter estimates (the estimated coefficients along with the robust standard errors) from the multinomial logit (MNL) models are presented in Table 2. The likelihood ratio statistics as indicated by $\chi 2$ statistics were highly significant ($P < 0.0107$), suggesting the model has a strong explanatory power.

The estimated results indicate that age and education have no significant relation to the probability of choosing any adaptation strategies. But from marginal effect analysis it is explained that one-year increase in the age of the farmers would increase adaptation of increased insecticides and pesticides application by 0.99% (Table 3).

Years of climate change awareness has a positive relationship with the probability of choosing and using land fragmentation and seed treatment (Table 2). This means that if the farmers have awareness about climate change, then they will adopt land fragmentation and seed treatment as climate change adaptation strategies. Marginal effect indicates that a marginal increase in the years of climate change awareness would decrease 1.61% in the probability of choosing and using more doses of fertilizers and increase 0.75% in the probability of choosing and using land fragmentation as adaptation strategy in chickpea farming (Table 3).

Farm size had significant negative correlation with probability of choosing increased insecticide or pesticide application, used more doses of fertilizer and land fragmentation as adaptation strategy in chickpea farming (Table 2). Marginal effect indicates that if farm size is increased, the probability of choosing changing land under pulse cultivation would increase by 3.05% (Table 3).

Extension contact/ services significantly and positively correlated with seed treatment and negatively correlated with increased insecticide or pesticide application and used more doses of fertilizer (Table 2). This result supports the innovation theory (Rogers, 1995). This suggest that chickpea farmers followed seed treatment before sowing and did not apply more doses of fertilizer and insecticide or pesticide because of their personal conviction as a result of advice received from extension personnel. Marginal effect indicates that if number of extension contact is increased, the probability of choosing and using insecticides or pesticides application will be decreased by 3.15% and the probability of choosing changing land under pulse cultivation and seed treatment would increase by 2.99% and 3.74% respectively (Table 3).

Table 2: Multinomial Logit (MNL) analysis of climate change adaptation strategies used by the chickpea farmers

Explanatory Variables	Coefficients			
	INCRIPAPP	USDMDOSF	LANDFRG	SEDTRET
Age of household head	0.0517	0.0250	-0.0040	-0.0035
(Years)	(0.0451)	(0.0443)	(0.0489)	(0.0628)
Education (year of schooling)	-0.0107	-0.0289	0.0121	-0.0287
	(0.1003)	(0.0972)	(0.0157)	(0.1442)
Years of climate change	-0.0273	-0.0569	0.0121***	0.1148*
awareness	(0.1315)	(0.1343)	(0.0028)	(0.0585)
Farm size (ha)	-0.7975*	-0.4802***	-0.5128***	-0.6549
	(0.4069)	(0.1324)	(0.1922)	(0.6234)
Extension contact (number)	-0.6979***	-0.3745*	0.5162	1.1381***
	(0.2661)	(0.2095)	(0.2830)	(0.3544)
Constant	2.4453	3.4417***	3.2471**	4.2891**
	(2.2997)	(1.3261)	(1.4797)	(1.6624)
Number of observations	50			
	Wald chi-square (χ^2) (12) = 33.34			
	Prob > χ^2 = 0.0107			
	Pseudo R^2 = 0.1044			
	Log pseudo likelihood = -134.02594			

Note: INCRIPAPP stands for increased insecticide or pesticide application USDMDOSF stands for used more doses of fertilizer; LANDFRG stands for land fragmentation; SEDTRET stands for seed treatment. Figures in parentheses are the robust standard errors.

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Table 3: Marginal effects from Multinomial Logit (MNL) analysis of climate change adaptation strategies used by the chickpea farmers

Explanatory Variables	Marginal effects				
	INCRIPAPP	USDMDOSF	LANDFRG	CHNGLADPC	SEDTRET
Age of household head (Years)	0.0099** (0.0031)	-0.0036 (0.0019)	-0.0042 (0.0046)	-0.0014 (0.0045)	-0.00063 (0.0047)
Education (year of schooling)	0.0024 (0.0129)	-0.0032 (0.0124)	0.0014 (0.0650)	0.0011 (0.0045)	-0.0016 (0.0085)
Years of climate change awareness	0.0086 (0.0097)	-0.0161*** (0.0045)	0.0075*** (0.0026)	0.0019 (0.0066)	-0.0019 (0.0124)
Farm size (ha)	-0.0584 (0.0669)	0.0066 (0.0710)	0.0163 (0.0527)	0.0305* (0.0184)	0.0050 (0.0350)
Extension contact (number)	-0.0315* (0.0179)	0.0298 (0.0342)	0.0130 (0.0313)	0.0299*** (0.0124)	0.0374** (0.0196)
Number of observations			50		

Note: INCRIPAPP stands for increased insecticide or pesticide application USDMDOSF stands for used more doses of fertilizer; CRPDVER stands for crop diversification; SEDTRET stands for seed treatment; CHNGLADPC stands for change in land under pulse cultivation.

Figures in parentheses are the robust standard errors.

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Factors that influence the choice of climate change adaptation strategies used by lentil farmers

From the estimates of multinomial logit (MNL) model it is appeared that farmers' choice of farm-level adaptation strategies in lentil cultivation was influenced by different socio-economic factors (age, education, and years of climate change awareness), farm-specific variable (farm size) and institutional variable (extension contact,). Estimated coefficients along with the robust standard errors from the multinomial logit (MNL) models are presented in Table 4. The likelihood ratio statistics as indicated by $\chi2$ statistics were highly significant ($P < 0.0017$), suggesting the model has fitted good by the predictors included.

The coefficient of age indicates that it has no significant relation to the probability of choosing any adaptation strategies. But marginal effect analysis shows it has significant positive relationship with using increase amount of increased insecticide and pesticide. It indicates a unit increase in the age of the farmers would increase the probability of adopting this strategy by 1.20% (Table 5).

Education of the household head has positive relationship with the probability of choosing and using crop diversification as climate change adaptation strategies (Table 4). This implies that one-year increase in education level would lead to 0.23% in the probability of choosing and using crop diversification as an adaptation strategy to climate change (Table 5).

Climate change awareness has a positive relationship with the probability of adopting crop diversification and relay cropping as adaptation strategy (Table 4). This means that if the farmers have awareness about climate change, then they will adopt crop diversification and relay cropping as climate change adaptation strategies. Marginal effect indicates that a marginal increase in the climate change awareness would decrease 2.65% in the probability of choosing and using more doses of fertilizers (Table 5).

Farm size had significant negative correlation with probability of choosing increased insecticide or pesticide application, used more doses of fertilizer and had significant positive relation with probability of choosing crop diversification as adaptation strategy in lentil farming (Table 4).

Connection to extension services significantly and positively correlated with the probability of choosing and using relay cropping as adaptation strategy (Table 4). Marginal effect indicates that if number of extension contact is increased, the probability of choosing and using insecticide or pesticide application will be decreased by 2.34% and the probability of choosing changing land under pulse cultivation and relay cropping would increase by 1.56% and 4.32% respectively (Table 5).

Table 4: Multinomial Logit (MNL) analysis of climate change adaptation strategies used by the lentil farmers

Explanatory Variables	Coefficients			
	INCRIPAPP	USDMDOSF	CRPDVER	RELYCROP
Age of household head (Years)	0.0115	0.0550	-0.0440	-0.0145
	(0.0551)	(0.0643)	(0.1489)	(0.0429)
Education (year of schooling)	-0.0234	-0.0089	0.0021**	-0.0347
	(0.2004)	(0.4072)	(0.0010)	(0.4444)
Years of climate change	-0.0123	-0.0459	0.0031**	0.0248***
awareness	(0.2325)	(0.1243)	(0.0016)	(0.0093)
Farm size (ha)	-0.0975*	-0.2890***	0.0513***	-0.3456
	(0.0591)	(0.1078)	(0.01912)	(0.8281)
Extension contact (number)	-0.2345	-0.2543	0.1524	0.1381***
	(0.8661)	(0.4595)	(0.2963)	(0.0514)
Constant	3.3421	2.4432***	4.2074***	5.0892***
	(3.2997)	(0.8261)	(0.2797)	(0.6624)
Number of observations	50			
	Wald chi-square (χ^2) (12) = 24.56			
	Prob > χ^2 = 0.0017			
	Pseudo R^2 = 0.2040			
	Log pseudo likelihood = -69.02594			

Note: INCRIPAPP stands for increased insecticide or pesticide application USDMDOSF stands for used more doses of fertilizer; CRPDVER stands for crop diversification; RELYCROP stands for Relay cropping; Change in land under pulse cultivation (CHNGLADPC) is the base category. Figures in parentheses are the robust standard errors.

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Table 5: Marginal effects from Multinomial Logit (MNL) analysis of climate change adaptation strategies used by the lentil farmers

Explanatory Variables	Marginal effects				
	INCRIPAPP	USDMDOSF	CRPDVER	CHNGLADPC	RELYCROP
Age of household head (Years)	0.0120** (0.0061)	-0.0040 (0.1019)	-0.0012 (0.1046)	-0.0024 (0.1045)	-0.0037 (0.2047)
Education (year of schooling)	0.0012 (0.0129)	-0.0012 (0.0124)	0.0023** (0.0012)	0.0023 (0.0045)	-0.0045 (0.0285)
Years of climate change awareness	0.0065 (0.6097)	-0.0265*** (0.0095)	0.0056 (0.0827)	0.0098 (0.0966)	-0.0023 (0.0524)
Farm size (ha)	-0.0676 (0.1679)	0.0034 (0.5710)	0.0145 (0.3527)	0.0234 (0.1139)	0.0010 (0.0450)
Extension contact (number)	-0.0234* (0.0148)	0.0435 (0.8342)	0.0230 (0.9413)	0.0156*** (0.0052)	0.0432** (0.0216)
Number of observations	50				

Note: INCRIPAPP stands for increased insecticide or pesticide application USDMDOSF stands for used more doses of fertilizer; CRPDVER stands for crop diversification; RELYCROP stands for Relay cropping; CHNGLADPC stands for change in land under pulse cultivation.
Figures in parentheses are the robust standard errors.
*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Cobb-Douglas stochastic frontier production functions for chickpea

Maximum likelihood estimates for parameters are presented in Table 6. Seed and other agro-chemicals are significant at 5% and 1% level of probability respectively. The estimated value for the γ parameter is 0.2871which is significant at 1% level of probability. This value indicates that technical inefficiency is highly significant in chickpea production activities. Theγ parameter shows the relative magnitude of the variance in output associated with technical efficiency. δ_0^2 indicates the goodness of fit and correctness of the distributional form assumed for the composite error term. The coefficient of seed (-0.0305) is negatively significant implying that if the farmers increase the use of seed by 1% then their yield will be decreased by 0.03%. As they followed broadcasting method of sowing, they used overdoses of seed. The coefficient of other agrochemicals (0.0202) is positively significant implying that if the farmers increase the use of agrochemicals by 1% then their yield will be increased by 0.02%.

Cobb-Douglas stochastic frontier production functions for lentil

Estimated parameters of the stochastic frontier production function are shown in table 7. Total variance δ_0^2 is highly significant which indicates the goodness of fit and correctness of the distributional form assumed for the composite error term. The estimated value for the γ parameter is 0.3045 which is significant at 1% level of probability. This value indicates that technical inefficiency is highly significant in lentil production activities. The γ parameter shows the relative magnitude of the variance in output associated with technical efficiency. The coefficient of seed (-0.0416) is negatively significant implying that if the farmers increase the use of seed by 1% then their yield will be decreased by 0.04%. As they followed broadcasting method of sowing and relay cropping strategy, they used overdoses of seed. The coefficient of other agrochemicals (0.0202) is positively significant implying that if the farmers increase the use of agrochemicals by 1% then their yield will be increased by 0.04%.

Table 6: Maximum Likelihood Estimates (MLE) of the stochastic frontier production function for chickpea farmers

Variable	Parameter	Coefficient	Standard error	t-ratio
Production model				
Constant	β_0	10.861***	0.3061	35.44
Ln (Labour)(K_1)	β_1	0.4012	0.3151	1.275
Ln (Seed) (K_2)	β_2	-0.0305**	0.0148	-2.056
Ln (Fertilizer)(K_3)	β_3	0.0078	0.0076	1.019
Ln (Other agrochemicals) (K_4)	β_4	0.0202***	0.0059	3.493
Technical Inefficiency Model				
Constant	Z_0	0.3440**	0.1620	2.127
Increased insecticide or pesticide application	Z_1	0.3311	0.3560	0.929
Used more doses of fertilizer	Z_2	0.0930	0.0940	0.987
Multiple planting dates	Z_3	0.1331***	0.0474	2.802
Crop diversification	Z_4	-0.0119	0.0383	-0.310
Age	Z_5	0.2570	0.564	0.456
Education level	Z_6	-0.1040***	0.039	-2.639
Awareness of climate change	Z_7	-0.0183**	0.00879	-2.078
Variance Parameters				
Total Variance	δ_0^2	0.1830***	0.0208	8.833
Gamma	γ	0.2871***	0.0937	3.064
Log likelihood function			-165.505	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Technical efficiency estimates of chickpea and lentil farmers

The technical efficiency shows the ability of farmers to derive maximum output from the inputs used. Given the results of the model the technical efficiency estimates are presented and discussed subsequently (Table 8). The results show high variability in technical efficiency among the chickpea and lentil growers in the study area. The computed technical efficiency varies between 0.48 and 0.98 with a mean of 0.83 in case of chickpea and technical efficiency varies between 0.45 and 0.94 with a mean of 0.82 in case of lentil. Average technical efficiency of the farmers was 0.83 and 0.82 for chickpea and lentil respectively implies that there is a scope of increasing productivity of chickpea and lentil by 17% and 18% respectively using current level of inputs only by increasing the farmers' efficiency (Table 8).

Table 7: Maximum Likelihood Estimates (MLE) of the stochastic frontier production function for lentil farmers

Variable	Parameter	Coefficient	Standard error	t-ratio
Production model				
Constant	β_0	8.971***	0.3509	25.5630
Ln (Labour)(K_1)	β_1	0.3110	0.2920	1.0650
Ln (Seed) (K_2)	β_2	-0.0416***	0.0151	-2.7560
Ln (Fertilizer)(K_3)	β_3	0.0058	0.0037	1.5630
Ln (Other agrochemicals) (K_4)	β_4	0.0450***	0.0150	3.0010
Technical Inefficiency Model				
Constant	Z_0	0.2331***	0.0781	2.9840
Increased insecticide or pesticide application	Z_1	0.1234	0.1026	1.2030
Used more doses of fertilizer	Z_2	0.0340	0.0346	0.9840
Relay cropping	Z_3	-0.2340***	0.0835	-2.8020
Crop diversification	Z_4	-0.0345	0.1113	-0.3100
Age	Z_5	0.4530	0.9934	0.4560
Education level	Z_6	-0.4080***	0.1546	-2.6390
Awareness of climate change	Z_7	-0.0253**	0.0122	-2.0780
Variance Parameters				
Total Variance	δ_0^2	0.1950***	0.0389	5.0120
Gamma	γ	0.3045***	0.1140	2.6710
Log likelihood function			-145.340	

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

Table 8: Distribution of technical efficiency estimates

Efficiency index	Percentage	
	Chickpea	Lentil
≤0.50	1	2
0.51≤0.60	5	7
0.61≤0.70	8	15
0.71≤0.80	11	17
0.81≤0.90	43	40
0.91≤1.00	25	19
Total	100	100
Mean	0.83	0.82
Minimum	0.48	0.45
Maximum	0.98	0.94

The influence of climate change adaptation strategies on technical efficiency of chickpea farmers

In technical inefficiency model multiple planting dates had significant positive relationship with technical inefficiency while years of climate change awareness and education had significant inverse relationship with the technical inefficiency (Table 6).

The positive coefficients imply that the variables have the effect of decreasing the level of technical efficiency. Any increase in the value of such variables would lead to an increase in the level of technical inefficiency. The inverse relationship implies that any increase in the value of the variable would lead to an increase in technical efficiency.

Multiple planting dates

The estimated coefficient of multiple planting dates was positive and statistically significant as seen in table 6. This implies that a further increase in multiple planting dates tends to increase technical inefficiency.

Education level

The estimated coefficient of education is negative and statistically significant at 1% level of probability. This implies that an increase in the level of education tends to decrease the level of technical inefficiency.

Years of climate change awareness

A negative and statistically significant relationship is found between years of climate change awareness and technical inefficiency. This implies that an increase in the years of awareness tends to increase technical efficiency (i.e., decrease technical inefficiency).

The influence of climate change adaptation strategies on technical efficiency of lentil farmers

The positive coefficients in the technical inefficiency model imply that the variables have the effect of increasing the level of technical inefficiency. Any increase in the value of such variables would lead to an increase in the level of technical inefficiency. The inverse relationship implies that any increase in the value of the variable would lead to an increase in technical efficiency. In table 7 it is seen that relay cropping, years of climate change awareness and level of education had significant inverse relationship with the technical inefficiency.

Relay cropping

The estimated coefficient of relay cropping was negative and statistically significant as seen in table 7. This implies that adaptation strategy relay cropping had significant effect on decreasing technical inefficiency that means if farmers in the study area follow relay cropping method in lentil cultivation, their technical efficiency will be increased.

Education level

Level of education has negative and statistically significant effect at 1% level of probability on the technical inefficiency. This implies that an increase in the level of education tends to decrease the level of technical inefficiency. So, it can be mentioned that if the farmers are becoming more educated, they will be more efficient in lentil cultivation under the changing climatic condition.

Years of climate change awareness

Climate change awareness has negative and significant correlation with technical inefficiency. This implies that if the farmers' awareness about climate change is increased, their technical efficiency in lentil cultivation will be increased (i.e., decrease technical inefficiency).

IV. CONCLUSION AND RECOMMENDATIONS

The study assessed the effect of climate change adaptation strategies on production efficiency of selected pulse crops in Bangladesh. The most common strategy followed in the study areas was increased insecticides or pesticides application due to climate change. Farmers also followed used more doses of fertilizer, crop diversification, change in land under pulse cultivation, land fragmentation, relay cropping and seed treatment as main adaptation strategies to climate change. Climate change awareness had positive, and farm size had negative, but extension contract had both positive and negative significant relationship with choosing and using different climate change adaptation strategies in chickpea cultivation. Education, climate change awareness and extension contact had significant positive relationship and farm size had both positive and negative significant relationship with choosing and using different climate change adaptation strategies in lentil cultivation. Seed had negative and other agrochemicals had positive and significant effect on the yield of both pulses. Average technical efficiency of the farmers was 0.83 and 0.82 for chickpea and lentil respectively implies that there is a scope of increasing productivity of chickpea and lentil by 17% and 18% respectively using current level of inputs only by increasing the farmers' efficiency. Adaptation strategy 'multiple planting dates' had positive and significant effect on technical inefficiency of chickpea growers. Adaptation strategy relay cropping had negative and significant effect on technical inefficiency of lentil growers. Pulse production efficiency can be increased by eliminating the constraints to adopt climate change adaptation strategies. With the use of different climate change adaptation strategies, the farmers are still underutilizing their present resources, and this make them to be technically inefficient. Right combination of different adaptation rather than using one of these strategies through their wealth of experience and making judicious use of their resources at the present technology level will make them to be more efficient.

There is need for putting in place policies and programs that will make the farmers to be proactive in the use of resources and at the same time adapting to climate change. To be technically more efficient, government and non-governmental organizations should help them in the provision of input-based adaptation strategies (e.g., multiple crop varieties) so that their production and profit can be enhanced in the face of changing climate. The extension personnel should work more closely to the farmers so that the indigenous and the emerging adaptation strategies and technologies can be focused. Research organizations should contribute to increase farmers' efficiency by making climate resilient variety and technology available. Financial institutions should work efficiently in the local level to reach its service (specialized agricultural credit on pulse production) to the farmer.

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