Journal of Environmental Science 11 (2024) 39-48

IES University of Rajshahi

Journal of Environmental Science

https://jenvos ci.com

Assessing Production Risks and its Management Strategies in Agriculture: A Comparative Study of Two Districts in Bangladesh

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ARTICLE INFO

Keyword:
Agricultural risk management,
Crop diversification,
Contract farming,
Precautionary savings,
Risk Perception

ABSTRACT

The agriculture of Bangladeshfaces significant risks due to pests and environmental threats,including floods, heavy rains, droughts, hailstorms, cyclones, and extreme weather conditions which cause fluctuations in agricultural output. Farmers adopt various strategies to mitigate these risks. This study examines the risk-related behaviors and risk management strategies of farmers in Sirajganj and Naogaon districts of Bangladesh. To attain the objective, primary data werecollected from 200 farmers and analyzed employing the Arrow-Pratt measurement and Multivariate probit model. The Arrow-Pratt measurement obtained by the ELCL model and cubic utility function, gives risk aversion attitude, and the Multivariate probit regression facilitates to asses risk perception and strategies. Results indicate that farmers in Sirajganjdistrict are more risk-averse (94%) compared to those in Naogaondistrict (61%). This study also revealed that age plays a significant and positive role in both crop diversification and contract farming in Sirajganj district, while in Naogaon district, age only showed a significant impact on crop diversification. Educational status positively affects all outcomes in Sirajganj district, but its effect is mixed in Naogaon district, where it negatively influences contract farming. Land ownership consistently has a negative impact on contract farming in both districts. Off-farm income positively influences crop diversification in both districts but negatively affects contract farming in Sirajganj district, while it was insignificant in Naogaon district. To mitigate the production risk in agriculture, the study suggests strategies that combine technology, crop diversification, contract farming and precautionary savings.

1. Introduction

Risk can be defined as the probability of loss; it depends on vulnerability, hazard and exposure (Crichton, 1999). In the agricultural sector, risk is a particularly significant factor.The unpredictability of livestock and crop growth processes contributes to production risk,as a variety of factors, including weather, disease, pests, and others impact the quantity and quality of commodities produced (USDA, 2023).The agricultural sector faces heightened vulnerability to risks associated with production, market fluctuations, credit, technology, institutions, and human resources. The risk environment is influenced by market liberalization and climate change, which impact output, food availability, security, and social progress (Singh *et al*. 2005; Gallego*et al*. 2007; McIntyre *et al*. 2009). Bangladesh's agriculture sector, employing 47.5% of the workforce and contributing 16.33% to

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Receive 17 October 2024; Revised Received 27 October 2024; Accepted 18 November 2024;
Available Online 12 December 2024;
Published by Institute of Environmental Science, University of Rajshahi.

GDP, is facing challenges due to population growth, food security concerns, and increasing risks. The country's flat terrain and vulnerability to cyclones and flooding make it particularly susceptible to natural disasters resulting in human fatalities, crop destruction, infrastructure damage, and livelihood loss for small-scale farmers (Ruane, 2013;Huq*et al.*, 2015, Fakhruddin*et al.*, 2015, Younus and Harvey, 2014, IFMCP, 2009).

Bangladesh is highly susceptible to flooding, which can take four forms: flash floods, riverine floods, rain floods, and storm surge floods. Flash floods cause significant rises in water level, while riverine floods result in extensive damage and fatalities. Rain floods occur during the monsoon, with severity depending on precipitation and river levels. Storm surge floods occur in Bangladesh's coastal region, causing large inlets, tidal waves, and flooding in lowland islands (Brouwer*et al.*, 2007, Mirza*et al.*, 2003, Rahman, 2014). Precipitation is crucial for Bangladesh's agrarian economy, impacting ecosystems, land productivity, food security, water availability, health, and the livelihoods of 80% of the rural population. Understanding precipitation changes is crucial for the country's economy and society (Sahid, 2011). In Bangladesh, common rice pests include brown planthopper, rice hispa, leaf folder, green leaf hopper, white-backed planthopper, rice gall midge, and stem borer. Major diseases include bacterial leaf blight, sheath blight, leaf blast, tungro, and stem rot. Additionally, Aus rice faces weed invasion and rat infestations during harvest (Alam, 2013, Nasiruddin and Roy, 2012, Fatema*et al.*, 1999, Alam, 1981, BRRI, 2009).

Bangladeshhas also been significantly impacted by droughts, with severe national and local droughts occurring every five years. Droughts devastate crops, drive famine, and impact nearly half of the population, leading to widespread food insecurity and persistent energy shortages(IOP, 2009).Hailstorms also pose a serious threat to agriculture and briefly placing smallholder farmers in poor nations at risk of destitution (Abdul *et al.*, 2015). The consequence of such events often lead to a period of food insecurity that can occasionally last the entire year (Huq*et al.*, 2015). Therefore, effective risk management strategies are essential to mitigate the adverse effects of production risks in agriculture. One widely recognized approach is crop diversification, wherein farmers cultivate a variety of crops. This strategy spreads the risk and helps buffer against the impact of a specific risk factor affecting one crop or enterprise. Some previous studies emphasize the role of diversification as an adaptive strategy for enhancing food security and reducing production risk (Evenson and Gollin, 2003, Just *et al.*, 1999, Antle*et al.*, 2004). Additionally, some prior studies emphasize the role of contract farming to mitigate the production risk in agriculture (Spielmanand Qaim, 2006, Fafchamps and Hill, 2009) and while some previous studies emphasize on precautionary savings to reduce the production risk in agriculture (Rosenzweigand Binswanger, 1993, Kirsten and Vink, 1996, Karlan andMorduch, 2010, Wang *et al.*, 2009).So,the study of production risk and its management strategies in agriculture is significant issue for people of Bangladesh. This study aims to assess farmers' risk attitudes, evaluate their risk management strategies, and identify key factors influencing the adoption of these strategies, addressing the crucial issue of production risk management in Bangladesh's agricultural sector.

2. Methodology

In the study, primary and secondary data were used.Additionally, quantitative and qualitative data were collected to understand the effect of socio-economic variables on risk management strategies in agriculture.The primary data were collected from 200 farmers in the study area using structured questionnaire and interviews. Primary data have been collected from 8 villages across four Upazilasintwo districts (Naogaon and Sirajganj)within theBarind tract region of Bangladesh. Secondary data were collected through a review of relevant documents, literature, articles, published and unpublished study reports, and other pertinent sources.

The Figure 1 shows the district, Upazila and village wise distribution of the households which were taken for interview.

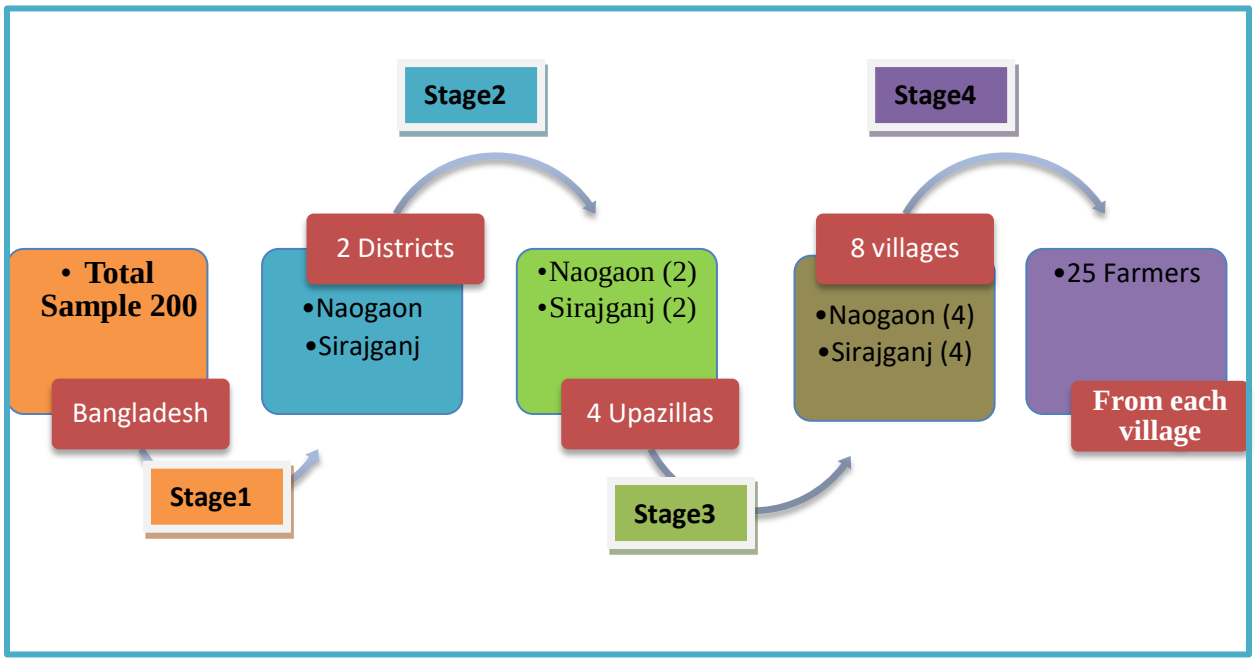

Figure 1. Sampling Design of Present Research

This study included risks associated with hailstorms, heavy winds, pests and diseases, heavy rainfall, drought, and flooding to determine respondents' perceptions. Respondents were asked about the severity and frequency of these hazards, using a Likert scale.This study also used the ELCL model, cubic utility function, and Arrow-Pratt measurement to determine risk attitudes of the respondents in the study area. The Multivariate Probit modelwas used to identifysignificant factors affecting the adoption of risk management strategies in agriculture of Bangladesh.

According to Rizwanet al. (2019), a Multivariate Probit regression model accounts for the likelihood of simultaneous correlation in choices regarding diversification, contract farming, and precautionary savings as risk management strategies. This model can be expressed as follows:

$$Y_{ij} = X_{ij}\beta_j + \varepsilon_{ij} \qquad (1)$$

The risk management plan is indicated by Yij(j=1,...m), where m=3 and represents the ith producer (i=1,..., n);The vector of observed variables is denoted by Xij=1×k, the unobserved error term is denoted by ij, and cj indicates the k×1 vector of unknown parameters that must be evaluated (Akhtaret al., 2018). With Yijrepresenting binary variables, the following can be said about Equation (1):

$$Y_{11}^{*} = \alpha_{11} + X\beta_{11} + \varepsilon_{11} \qquad (2)$$

$$Y_{21}^{*} = \alpha_{21} + X\beta_{21} + \varepsilon_{21} \qquad (3)$$

$$Y_{31}^{*} = \alpha_{31} + X\beta_{31} + \varepsilon_{31} \qquad (4)$$

Where, the latent variables for each choice of risk management strategy are indicated by the letters Y11*, Y21*, and Y31*. Yij * equals 1 when Yij>0 and 0 otherwise. If the εij were independently distributed, estimating the unobserved parameters would be straightforward.

2.1 Description of Variables

This study included two types of variable. These are dependent and independent variable which are given:

2.1.1 Dependent Variables

Three dependent variables were used in this study. These are crop diversification, contract farming and precautionary savings.Crop diversification benefits farmers by reducing production risks, increasing yields, and promoting sustainable resource use, while also providing employment opportunities and reducing poverty (World Bank, 1990, Deshpandeet al., 2007). Thus, if the farmers use crop diversification to reduce the impact of climatic risk on their income, crop diversification is recorded as 1; otherwise, it is recorded as 0.Contract farming is a vertical coordination between growers and contractors in food value chains, providing specific inputs, controlling production to meet consumer demand, and shaping production decisions through contractual obligations (Swinnen and Maertens, 2007, Little and Watts, 1994). If the farmers use contract farming to mitigateproduction risk on their

income, it is recorded as 1; otherwise, it is recotded as 0. Moreover,farmers with precautionary savings are better positioned to recover from weather-related damages (Morduch, 1990).This study included that if the farmers use precautionary savings to reduce the impact of climatic risk on their income, precautionary savings are recorded as 1; otherwise, they are recorded as 0.

2.1.2 Independent Variables

This study included several independent variables:age,educational status, farming experience, monthly income, farm size, landownership, off-farm income, house size, access to market information, and distance to the local market from the respondents of the study area. Some previous studies showed that these variables were reflected as the main factors to determine the risk attitudes of the farmers (Ullahet al., 2015,Ullahet al., 2016, Lu et al., 2017, Ullah and Shivakoti, 2014). In this study, age, experience, and education were continuous variables representing the total number of years. Additionally, educational status indicates the total years of schooling;for example, if a respondent completed primary school,this equals 5 years of schooling. Additionally, agricultural experience refers to the total years of experience in agricultural farming. Household income includes both farm and non-agricultural income sources. The house size represents family size. The amount of land utilized for farming was used to determine farm size. Additionally, dummy variables were used for land ownership, off farm income, and access to market information,with 1 indicating access and 0 indicating otherwise.

3. Results and Discussion

Descriptive Statistics of the Variables in Sirajganj and Naogaon Districts of Bangladesh

Table 1 highlights key descriptive statistics from the study areas, showing distinct risk patterns between Sirajganj and Naogaon districts. Only 7% of farmers in Sirajganj district report a high flood risk, while this figure rises to 36% in Naogaon district. Conversely, heavy rain risk affects 40% of farmers in Sirajganj district but only 10% in Naogaon district. Both districts have a high prevalence of pest and disease risks (94%). Drought risk is relatively low, affecting 7% in Sirajganj district and 6% in Naogaon district. More farmers in Sirajganjdistrict (16%) report heavy wind risk compared to just 1% in Naogaon district. Hailstorm risk is notably higher in Sirajganjdistrict (93%) than in Naogaondistrict (3%).

Regarding coping strategies, 21% of farmers in Sirajganjdistrict practice crop diversification, compared to 52% in Naogaon. Contract farming is more common in Naogaondistrict (41%) than in Sirajganjdistrict (20%). Precautionary savings are practiced by similar proportions of farmers in both districts (62% in Sirajganj and 61% in Naogaon). Both districts exhibit high levels of risk aversion, consistent with findings from Adnan et al. (2019)and Ullahet al. (2015). The study includes 100 respondents from each district.

Table 1. Descriptive statistics of the variables in Sirajganj and Naogaon district

Type of variable	The name of variable	Description	Sirajganj district		Naogaon district	
			Mean	Std. Dev.	Mean	Std. Dev.
Dependent variable	Crop diversification	1, if practice crop diversification and 0, otherwise	.21	.4093602	.52	.5021167
	Contract farming	1, if practice contract farming and 0, otherwise	.20	.4020151	.41	.4943111
	Precautionary savings	1, if practice precautionary savings and 0, otherwise	.62	. 4878317	.61	.4902071
Independent variable	Age	Age of farmer (years)	46.56	11.28897	45.35	10.99713
	Educational status	Years of schooling	5.87	4.70043	8.05	3.796263
	Farming experience	Farming experience (years)	26.7	12.97745	22.34	10.97768
	Monthly income	Monthly family income(BDT)	15184	15571.79	14792	8836.857
	Farm size	Total farm areas in decimal	141.8	130.9533	176.2568	169.3827
	Landownership	1 if the household is owner of the land and 0, otherwise	.91	.2876235	.95	.2190429
	Off-farm income	1 if the farmer has off farm income and o, otherwise	.29	.456048	.3	.4605662
	House size	Number of a family member	4.45	1.849788	4.18	1.095261
	Access to market information	1 if the farmer has access to market information and o, otherwise	.42	.496045	.94	.2386833
	Distance to local market	Distance of local market (km)	2.05	1.439872	2.74	.8362978

Flood risk	1 if risk value more than 5, otherwise, 0	.07	.2564324	.36	.4824182
Heavy rain risk	1 if risk value more than 5, otherwise, 0	.4	.492366	.1	.3015113
Pest and disease risk	1 if risk value more than 5, otherwise, 0	.94	.2386833	.94	.2386833
Drought risk	1 if risk value more than 5, otherwise, 0	.07	.2564324	.06	.2386833
Heavy wind risk	1 if risk value more than 5, otherwise, 0	.16	.3684529	.01	.1
Hailstorm risk	1 if risk value more than 5, otherwise, 0	.93	.2564324	.03	.1714466
Risk aversion	1 if the individual reflects risk averse attitude and 0, otherwise	.94	0.2374	.61	0.4877

Source: Survey data, 2023

3.2 Correlation Coefficient of Different Risk Management Strategies in Sirajganjand NaogaonDistricts of Bangladesh

Table 2 reveals that all three risk management strategies such as crop diversification, contract farming, and precautionary savings are closely related, with strong positive correlationsin Naogaon district. This suggests that farmers in Naogaondistrict tend to adopt multiple strategies in combination. In Sirajganj district, however, the relationships between these strategies are much weaker, indicating that farmers may adopt these strategies more independently.

Table 2. Estimations of correlation coefficients in different pairs of risk management strategies in Sirajganj and Naogaon district of Bangladesh

Risk management strategies	Estimated coefficients of Sirajganj district	Estimated coefficients of Naogaon district
Crop Diversification and Contract Farming	0.2332 ***	0.6788***
Contract Farming and Precautionary Savings	0.1854***	0.5832***
Precautionary Savings and Crop Diversification	0.0496***	0.7091***

*** indicates the 1% significance level

3.3 Results of Multivariate Probit Model

Table3(Sirajganj district) and Table4 (Naogaon district)present results from a Multivariate Probit model, examining the relationship between various independent variables and three dependent variables: crop diversification, contract farming, and precautionary savings.Table 3 reveals that age has a positive and highly significant effect, suggesting that older farmers are more likely to diversify crops in Sirajganj districtconsistent with the findings of Deressa*et al.* (2010)and Rehima*et al.*(2013).Educational status also has a positive and significant effect, indicating that more educated farmers are more likely to engage in crop diversification, as supported by Tavernier and Onyango (2008)and Kouame (2010). Off-farm income positively influences crop diversification (coefficient: 0.109), aligning with Rehima*et al.* (2013), however, this effect is only weakly significant at the 10% level. Access to market information has a positive, in agreement with the results of Ullah*et al.* (2015; Mesfin*et al.* (2011)and Rehima*et al.* (2013) and significant effect (coefficient: 0.077), indicating that farmers with access to information are more likely to diversify. Distance from the local market has a negative and significant effect, meaning that farmers located farther from markets are less likely to diversify their crops.

Table 3also indicates that age has a positive, which aligns with Adnan *et al.* (2020) and significant effect, suggesting that as farmers grow older, they are more likely to participate in contract farminginSirajganj district. Educational status has a positive, consistent withAdnan *et al.* (2020) and significant effect, indicating that more educated farmers are more likely to engage in contract farming. Land ownership has a negative, supported byAdnan *et al.*, (2020)and significant impact, meaning that farmers who own land are less likely to engage in contract farming. Off-farm income negatively, as reported byAdnan *et al.* (2020) impacts contract farming, with a 5% significance level, suggesting that farmers with income from non-farming activities may be less interested in contract farming. House size negatively affects participation in contract farming, as noted by Adnan *et al.* (2020), with a high level of significance, implying that wealthier farmers may prefer not to enter into contract farming agreements. In case of precautionary savings that age has a negative effect, similar to the findings of Jensen

and Pope (2004)and also significant, meaning that younger farmers are more likely to engage in precautionary savings than older farmers. Monthly incomehas a negative and significant impact on precautionary savings (coefficient: -0.0000167), supported by Adnan *et al.* (2020). This suggests that higher monthly incomes may reduce the perceived need for precautionary savings. Access to market information positively and significantly influences precautionary savings, showing that informed farmers are more likely to save as a precaution. Drought risk has a positive coefficient (0.406), indicating that farmers perceiving higher drought risk tend to save more, though this result is not statistically significant. Moreover, Table 3 indicates that log-likelihood value (-20.854) indicates the goodness-of-fit of the model, with lower values representing better fit. The Wald χ^2 (51) (12.09) is a statistical test that examines the overall significance of the model. A higher value would indicate a stronger model. LR test pkj (2.09) is test for correlation among the three dependent variables, with values greater than 1 suggesting some level of interdependence.

Table 4 reveals that farmers with higher off-farm income are more inclined to diversify their crops, while those with access to market information may feel less need for diversification in Naogaon district. Educational attainment negatively influences contract farming participation at a 1% significance level, suggesting that more educated farmers are less likely to engage in these practices. Conversely, farming experience has a positive and highly significant effect at the 1% level, indicating that experienced farmers are more likely to adopt contract farming. Land ownership shows a negative effect on contract farming participation, significant at the 5% level, implying that land-owning farmers might perceive fewer benefits from engaging in contracts. Moreover, farmers exposed to higher drought risks are more likely to participate in contract farming, as shown by the positive coefficient (0.398). Land ownership also negatively affects the likelihood of farmers engaging in precautionary savings, with a significant coefficient of -0.056 at the 5% level.

In Table 4, the Log-likelihood value (-13.577) reflects the model's fit to the data, with more negative values indicating a stronger fit. The Wald χ^2 statistic (25.70) suggests overall model significance, with higher values indicating a better fit. The LR test (pkj = 1) further confirms interdependencies among the three dependent variables in Naogaon district.

Table 3. Parameter estimations of Multivariate Probit Model in Sirajganj district

Independent variable	Crop diversification	Contract farming	Precautionary savings
Farm and Socio demographic Variables			
Age	.0151*** (.030)	.000*** (.033)	-.007*** (.028)
Educational status	.013*** (.050)	.001*** (.053)	.004 (.047)
Farming experience	-.007*** (.033)	-.000753 (.0356012)	-.006 (.029)
Monthly income	1.74e-06 (.000)	3.19e-06 (.000)	-.0000167*** (.0000166)
Farmsize	-.000186*** (.0017197)	.000 (.001)	.000 (.001)
Landownership	-.224 (.889)	-.096** (.899)	.511 (.863)
Off-farm income	.109* (.538)	-.204** (.561)	.178 (.468)
Housesize	.022 (.119)	-.002*** (.131)	.067 (.103)
Access to market information	.077** (.540)	-.062 (.567)	.184*** (.453)
Distance of local market	-.074** (.233)	.000*** (.254)	-.028 (.220)
Risk perception related variables			
Flood risk	.188 (.881)	.133 (1.006)	-.105 (.905)
Heavy rain risk	-.385 (.740)	-.003 (.778)	.376 (.651)

Pest and disease	.2794 (1.161)	-.231 (1.106)	-.577 (1.013)
Droughtrisk	-.219 (1.022)	-.064 (.972)	.406 (.7149)
Heavy wind	-.093 (.713)	-.021 (.691)	.140 (.5672)
Hailstorm	.050 (1.034)	-.130 (.978)	-.434 (.913)
Log-likelihood value	-20.854		
Wald χ 2 (51)	12.09		
LR test pkj	2.09		
Total sample size	100		

Normalized standard errors are indicated by numbers in parenthesis. At the 10, 5, and 1 percent levels, respectively, the symbols *, **, and *** denote statistical significance.

Table 4. Parameter estimations of Multivariate Probit Model in Naogaon district

Independent variable	Crop diversification	Contract farming	Precautionary savings
Farm and socio demographic features			
Age	-.001*** (.033)	-.006 (.035)	.004 (.034)
Educational status	-.009 (.067)	-.019*** (.066)	.033 (.064)
Farming experience	.005 (.032)	.010*** (.033)	-.006 (.033)
Monthly income	-4.85e-06 (.000)	2.84e-06 (.000)	2.92e-06 (.000)
Farm size	.000 (.001)	4.34e-06 (.001)	-.0003893 (.0020003)
Land ownership	-.006 (1.125)	-.020** (1.142)	-.056 ** (1.146)
Off-farm income	.069** (.503)	-.081 (.526)	-.072 (.539)
House size	.067 (.204)	-.0009682 (.2102969)	-.028 (.212)
Access to market information	-.051** (1.067)	.431 (1.089)	-.0927755 (1.109)
Distance of local market	.037 (.322)	-.025 (.329)	-.074 (.336)
Risk perception related variables			
Flood risk	-.110 (.484)	-.057 (.501)	.117 (.487)
Heavy rain risk	.218 (.617)	-.064 (.747)	-.0512 (.750)
Pest and disease	.119 (1.063)	-.275 (.934)	.021 (1.026)
Droughtrisk	-.217 (1.112)	.398 (.974)	.022 (1.082)
Heavy wind	-.276 (2.231)	-.048 (2.273)	.158 (2.285)
Hailstorm	-.235 (1.355)	-.078 (1.333)	.125 (1.396)
Log-likelihood value	-13.577		
Wald χ 2 (34)	25.70		
LR test pkj	1		
Total sample size	100		

Normalized standard errors are indicated by numbers in parenthesis. At the 10, 5, and 1 percent levels, respectively, the symbols *, **, and *** denote statistical significance.

4. Conclusion

The agricultural sector faces significant production risks due to unpredictable factors such as weather conditions, pests, diseases, and market fluctuations,which can greatly impact both livelihoods of farmers and the sector's stability. The present study reveals a substantial risk aversion among farmers, with 94% in Sirajganj district and 61% in Naogaon district. This study also found that agehad a significant and positive influence on both crop diversification and contract farming in Sirajganj district, whereas in Naogaon district, it showed a significant but negative impact on crop diversification. Additionally, educational status positively affected all outcomes in Sirajganj district, though it had a mixed impact in Naogaon district, where it negatively influences contract farming. Land ownership consistently had a negative impact on contract farming across both districts. Moreover, off-farm incomewas found to support crop diversification in both districts,although it negatively influenced contract farming in Sirajganj district, while it was insignificant in Naogaon district. In summary, implementing proactive risk management strategies in agriculture such as integration of technology, crop diversification, contract farming, precautionary savings, and supportive policies can mitigate production risks, strengthen resilience, and promote sustainable agriculture practices.

References

Abdul, A.K.M.; Biswas, A.; Islam, T.; Sattar, A.; Mili, S.N.; Jahan, T. 2015. Community Based Risk Assessment of Agriculture Sector in Sreerampur Union of Bangladesh. *J. Food Secur*., **3**, 125–136.

Adnan, K.; Ying, L.; Sarker, S; Hafeez, M.; Razzaq, A. and Raza, M. 2019. Adoption of Contract Farming and Precautionary Savings to Manage the Catastrophic Risk of Maize Farming: Evidence from Bangladesh. *Sustainability*, 11, 29.

Adnan, K M M., Ying,L., Ayoub, Z., Sarker,S. A., Menhas, R., Chen, F., Yu, M. M. 2020. Risk Management Strategies to Cope Catastrophic Risks in Agriculture: The Case of Contract Farming, Diversification and Precautionary Savings. *Agriculture* , **10**(8), 351; https://doi.org/10.3390/agriculture10080351

Akhtar, S.; LI, G. C.; Ullah, R.; Nazir, A.; Iqbal, M.A.; Raza, M.H.; Iqbal, N. and Faisal, M. 2018. Factors influencing hybrid maize farmrs'risk attitudes and their perceptions in Punjab Province, Pakistan.*J. Integr. Agric*, **17**, 1454-1462

Alam S, Catling HD, Karim ANMR, Alam MS, Quraishi N. 1981.Checklist of Rice Insects in Bangladesh.*Bangladesh Journal of Zoology* **9**: 91–96.

Alam, MZ. 2013.Survey and Assessment of Insect Management Technologies and Environmental Impact on Rice Ecosystem of Bangladesh. *International Journal of Applied Research Studies* **2**: 1–16.

Antle, J.M., Capalbo, S.M., Elliott, E.T., Paustian, K.H. 2004. Adaptation, spatial heterogeneity, and thevulnerability of agricultural systems to climate change and CO2 fertilization: An integrated assessment approach. *Climatic Change*, **64**(3), 289-315.

Brouwer, R., Akter, S., Brander, L. and Haque, E. 2007. Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh. Risk Analysis **27**(2):313-26. DOI:10.1111/j.1539-6924.2007.00884.x

BRRI (Bangladesh Rice Research Institute) 2009. Proceedings of the BRRI Annual Research Review for 2007–2008, held on 15–18 March 2009, Gazipur, Bangladesh.

Crichton D. 1999.The risk triangle. In: Ingleton J, editor... Natural disaster management. London: Tudor Rose, 102-103.

Deshpande, R.S., Mehta, P.K. and Shaha, K. 2007. Crop diversification and agricultural labour in India.Research gate.

Deressa, T.T.; Ringler, C. and Hassan, R. M. 2010.Factors affecting the choices of coping strategies for climate extremes.Case Farmers Nile Basin Ethiop.Ifpri Discuss. Pap.1032, 25.

Evenson, R.E., Gollin, D. 2003. Assessing the impact of the Green Revolution, 1960 to 2000.*Science*, **300**(5620), 758-762.

Fafchamps, M., & Hill, R. V. 2009. Contract Farming and Smallholder Incentives to Produce High-Quality: Experimental Evidence from the Vietnamese Dairy Sector. *American Journal of Agricultural Economics*

Fakhruddin, S. H. M., Babel, M. S., and Kawasaki, A. 2015.Assessing the vulnerability of infrastructure to climate change on the Islands of Samoa, *Nat. Hazards Earth Syst. Sci*., **15**, 1343–1356, https://doi.org/10.5194/nhess-15-1343-2015.

Fatema A, Ahmed I,Afzal M, Naqvi, SNH, Ahmed M. 1999. Diversity, Abundance and Seasonal Occurrence of Rice Leafhopper Fuana of Pakistan, Bangladesh and India.*Journal of Biological Science* **7**: 1–5

Gallego, J.F.,Bielza, M.,ConteC., DittmannCH., Stroblmair, J. 2007. Mapping Climatic Risks in the EUAgriculture, Paper prepared for presentation at the 101 EAAE Seminar, Management of Climate risks in Agriculture', Berlin, Germany, July 5-6,2007

Huq, N.; Hugé, J.; Boon, E.; Gain, A. 2015. Climate change impacts in agricultural communities in rural areas of coastal Bangladesh: A tale of many stories. Sustainability, **7**, 8437–8460.

Integrated Flood Management Concept Paper, IFMCP (2009).ISBN**:**978-92-63-11047-3

IOP 2009.Adaptive measures for coping with increased floods and droughts in Bangladesh, IOP Conf. Series: Earth and Environmental Science **6** (2009) 292001.

Jensen, F. E. and Pope, R. D. 2004. Agricultural precautionary wealth.*J. Agric.Resour. Econ*. , **29**, 17-30.

Just, R.E., Calvin, L., Quiggin, J. 1999. Adverse selection in crop insurance: Actuarial and asymmetric information incentives. *American Journal of Agricultural Economics*, **81**(4), 834-849.

Karlan, D., &Morduch, J. 2010. Savings, Shocks, and Sacrifices: Evidence from Rural Kenya. Review of Economics and Statistics

Kirsten, J. F., &Vink, N. 1996. Agricultural Production Risk, Insurance, and Income: A Study of the Limpopo Province Farming Systems. Agrekon.

Kouamé, E.B.-H. 2010. Risk, Risk Aversion and Choice of Risk Management Strategies by Cocoa Farmers in Western Cote D'ivoire. In Proceedings of the University of Cocody-AERC Collaborative PHD Program.

Little, P.D.; Watts, M. 1994.Living under Contract: Contract Farming and Agrarian Transformation in Sub-Saharan Africa; University of Wisconsin Press: Madison, WI, USA.

Lu, W.; Latif, A.; Ullah, R. 2017. Simultaneous adoption of contract farming and off-farm diversification for managing agricultural risks: The case of flue-cured Virginia tobacco in Pakistan. *Nat. Hazards*, *86*, 1347–1361.

McIntyre, B.D., Herren, H.R.,Wakhungu, J. and Watson, R.T. 2009. Agriculture at a Crossroads: The Global Report. The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), ISBN: 9781597265386

Mirza, Q.M.M., Dixit, A. and Nishat, A. 2003. Flood Problem and Management in South Asia. Internationaljournal of disaster prevention and management. Vol.12, Issue: 5, p. 467-467.

Morduch, J. 1990. Risk, Production and Saving: Theory and Evidence from Indian Households. draft manuscript, Harvard University, Cambridge, MA.

Nasiruddin, M. and Roy, R.C. 2012. Rice Field Insect Pests During the Rice Growing Seasons in Two Areas of Hathazari, Chittagong. *Bangladesh Journal of Zoology* **40**: 89–100.

Rahman, S.U. 2014. Impacts of flood on the lives and livelihoods of people in Bangladesh: a case study of a village in Manikganj district. A Dissertation for the Degree of Master in Disaster Management.Brac University, Dhaka, Bangladesh

Rehima, M.; Belay, K.; Dawit, A. and Rashid, S. 2013. Factors affecting farmers' crops diversification: Evidence from SNNPR, Ethiopia. *Int. J. Agric. Sci*., **3**, 558-565.

Rizwan, M.; Ping, Q.; Saboor, A.; Ahmed, U.I.; Zhang, D.; Deyi, Z. and Teng, L. 2019.Measuring rice farmers'risk perceptions and attitude: Evidence from Pakistan.*Hum. Ecol. Risk Asses Int. J.*, 1-16.

Rosenzweig, M. R., and Binswanger, H. P. 1993. The Role of Savings in Agricultural Household Models: Evidence from Rural India. *The Economic Journal*.

Ruane, A. C. *et al.* 2013.Multi-factor impact analysis of agricultural production in Bangladesh with climate change.*Global Environ. Change*

Shahid, S. 2011. Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh.*Climatic change*, 105(3-4), 433-453.

Singh, S.,Barto, A.G. and Chentanex, N. 2005. Intrinsically motivated reinforcement learning, Advances in Neural Information Processing Systems 17 (NIPS), pp. 1281-1288.

Spielman, D. J. and Qaim, M. 2006. Contract Farming, Risk, and Agricultural Commercialization in Developing Countries: Theory and Evidence. *Agricultural Economics*

Swinnen, J. and Maertens, M. 2007. Contract Farming in Staple Food Chains: The Case of Potatoes in India. Food Policy.

Tavernier, E. M. and Onyango, B. M. 2008.Utilization of farm management risk strategies at the rural/urban fringe.*African Journal of Agricultural Research*, **3**(8), 554-565.

Ullah, R. andShivakoti, G.P. 2014.Adoption of on-farm and off-farm diversification to manage agricultural

risks: Are these decisions correlated? *Outlook Agric.*, **43**, 265–271.

Ullah, R.; Jourdain, D.; Shivakoti, G.P. and Dhakal, S. 2015. Managing catastrophic risks in agriculture: Simultaneous adoption of diversification and precautionary savings. *Int. J. Disaster Risk Reduct.*, 12, 268-277.

Ullah, R.; Shivakoti, G.P.; Kamran, A.; Zulfiqar, F. 2016.Farmers versus nature: Managing disaster risks at farm level. *Nat. Hazards*, **82**, 1931–1945.

US.Department of Agriculture (USDA) 2023. Risk in Agriculture. Economic Research Service, US.Department of Agriculture.

Wang, H., Zhang, Y. and Yip, W. 2009. Precautionary Saving and Health Insurance: A Portfolio Choice Perspective. *The Journal of Risk and Insurance*

World Bank 1990. World Development Report: Poverty. (Oxford University Press, New York).

Younus, M.A.F. and Harvey, N. 2014. Economic consequences of failed autonomous adaptation to extreme floods: A case study from Bangladesh.*Journal of Local Economy* 2014, Vol. **29**(1-2) 22-37.