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Crop Diversification to Mitigate Flood Vulnerability in Bangladesh: An Economic Approach

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Abstract

It is hypothesized that more vulnerable farming households are more likely to choose traditional crop varieties over riskier but more profitable new ones. The analysis is based on a cross sectional survey of 1050 rural households, being conducted just two weeks after monsoon and flash floods had occurred in four districts of Bangladesh in 2005. After estimating vulnerability based on the expected poverty method, results show that 58 percent of the rural flooded households are estimated to be poor while 67 percent are estimated to be vulnerable. The monsoon flood causes more damage to cash crops whereas flash flood is riskier for staple crops. This study suggests a mixed cropping system in rural Bangladesh to minimize households' vulnerability to floods.

This paper is an original work form our research and it has not been submitted elsewhere for publication.
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1. Introduction

Bangladesh consists mostly of a low-lying river delta with over 230 rivers and tributaries, situated between the foothills of the Himalayas and the Bay of Bengal. The combination of its geography, population density, and extreme poverty makes Bangladesh very vulnerable to risks and disasters like floods, cyclones etc. In 1998, over 68 percent of the country were inundated by floods (Ninno *et al.* 2001), about 2,400 people died, and 2.2 million tons of crops were damaged (Disaster Management Bureau, 2005). In the year 2004, close to 36 million people were affected, 726 died, and 1.7 million acres of crop area were damaged (Disaster Management Bureau, 2005).

In the literature (Dercon and Krishnan 2000, Glewwe and Hall 1998, Amin *et al.* 1999), vulnerability is defined as the ability to smooth consumption in response to shocks, measured by observed changes in consumption over time. Households reduce their exposure to risks and smooth their income ex ante, as their capacity to smooth consumption ex post is often limited (Barrett *et al.* 2001). Diversification is known to reduce the dispersion of the overall return by selecting a mixture of activities that have net returns with negative correlations (Alderman and Paxson 1992; Reardon *et al.* 2000). Sometimes crop rotation plans maximize expected return (Hardarker *et al.* 2004).

In the year 2005, Bangladesh was affected by two types of floods. A monsoon flood occurred during mid August to September in the eastern and western parts of the country and a flash flood occurred in the northern areas during November. A three stage stratified random sampling technique was applied to the survey aftermath of floods. The analysis is based on a cross sectional survey of 1050 rural households, being conducted just two weeks after monsoon and flash floods had occurred in four districts of Bangladesh in 2005. The four selected districts which were chosen randomly according to the flood proneness and damage are Jamalpur, Shirajganj, Sunamganj and Nilphamari. The first three were affected by a monsoon flood, while the latter was hit by a flash flood.

2. Methodology

In order to estimate the vulnerability of flooded households, the vulnerability to expected poverty (VEP) approach by Chaudhuri *et al.* (2002) is applied. They define a household as vulnerable if it is expected to be poor in the near future. This methodology is also described and used in other studies (Christiaensen *et al.* 2000, Chaudhuri 2003). According to the VEP, the vulnerability level of a household i at time t is defined as the probability that the household will be in income poverty at time $t+1$: $v_{it} = \Pr(y_{i,t+1} \leq z)$ ……………………………………………………………....(1)

Where, $y_{i,t+1}$ is the household's per capita income level (welfare indicator) at time $t+1$ and z is the income poverty line. The assumptions for the stochastic process, generating the income of a household i: $\ln y_i = X_i \beta + e_i$ ………………………………………….(2)

Where, y_i represents the per capita income before flood, and X_i is a set of observable household characteristics, such as: - *demographic factors*: family size, dependency ratio (ratio of the number of household members of 0-14 years and over 60 years to the number of members of 15-59 years), number of male and female members above 18 years, age and age squared of household head, mean educational years of income earners, gender of household head and major source of income; and - *economic factors*: per capita cultivable land, per capita asset value (animals, poultry, trees, household items: chair, table, radio, television, cycle, ornaments, utensils for cultivation: tractor, shallow machine, irrigation pump, tube well etc.), distance and cost to reach nearest market place, access of media and ownership of a dwelling place. Household are asked about the current market price of land and assets.

An assumption is made on the functional form of the variance of e_i (and hence of $\ln y_i$), that is, the variance of e_i depends on the observable household characteristics in the following parametric way: $\sigma^2_{e,i} = X_i\theta$ ………………………………………………….(3)

The estimation of the parameters β and θ can be carried out by the *three-step* Feasible Generalized Least Squares (FGLS) procedure suggested by Amemiya (1977). In FGLS estimation the unknown matrix $\sigma^2_{e,i}$ is replaced by a consistent estimator. The steps are described as follows:

First, the estimation procedure applies the OLS method to equation (2) and estimates the residual. Then, the estimated residual is squared to estimate the following equation:

$$\hat{e}^2_{OLS,i} = X_i\theta + \eta_i \quad \text{……………………………………………………………..(4)}$$

For flooded households, $\hat{e}^2_{OLS,i}$ is regressed on demographic and economic factors, as well as coping factors (such as: per capita loan for flood, withdrawal of savings for flood, membership of the cooperation), shock factors (such as: flood height and duration, loss of working days, loss of asset value, loss of crop value), and community characteristics (such as: availability of electricity, flood shelter, public hospital, primary school).

Second, the estimate $\hat{\theta}_{OLS}$ is used to transform the equation (4) as follows:

$$\frac{\hat{e}^2_{OLS,i}}{X_i\hat{\theta}_{OLS}} = \left[\frac{X_i}{X_i\hat{\theta}_{OLS}}\right]\theta + \frac{\eta_i}{X_i\hat{\theta}_{OLS}} \quad \text{…………………………………………………...(5)}$$

It is also feasible to get a consistent estimate, $X_i\hat{\theta}_{FGLS}$, of $\sigma^2_{e,i}$, the variance of the shock factor of household income. The standard deviation can be evaluated as follows:

$$\hat{\sigma}_{e,i} = \sqrt{X_i\hat{\theta}_{FGLS}} \quad \text{……………………………………………………………..(6)}$$

Third, to estimate β, equation (2) is transformed as follows:

$$\frac{\ln y_i}{\hat{\sigma}_{e,i}} = \left[\frac{X_i}{\hat{\sigma}_{e,i}}\right]\beta + \frac{e_i}{\hat{\sigma}_{e,i}} \quad \text{…………………………………………………………..(7)}$$

An OLS estimation of equation (7) yields a consistent and asymptotically efficient estimate $\hat{\beta}_{FGLS}$ of the parameter β. Therefore, using the FGLS estimates of β and θ, the

methodology finally estimates the expected value and variance of log per capita income as follows:
Therefore, using the FGLS estimates of β and θ, the methodology finally estimates the expected value and variance of log per capita income as follows:

$$\hat{E}\{\ln y_i | X_i\} = X_i \hat{\beta}_{FGLS} \text{ and } Var\{\ln y_i | X_i\} = \hat{\sigma}^2_{e,i} = X_i \hat{\theta}_{FGLS} \quad \ldots\ldots(8)$$

Letting $\Phi(.)$ denote the cumulative density of the standard normal distribution, the estimated probability can be expressed as follows:

$$\hat{v}_i = \hat{\Pr}(\ln y_i < \ln z | X_i) = \Phi\left[\frac{\ln z - \{\ln y_i | X_i\}}{\sqrt{Var\{\ln y_i | X_i\}}}\right] = \Phi\left\{\frac{\ln z - X_i \hat{\beta}}{\sqrt{X_i \hat{\theta}}}\right\} \quad \ldots\ldots(9)$$

The value of $\hat{v}_i$ varies from 0 to 1. The estimate $\hat{v}_i$ thus denotes the vulnerability of the ith household with the characteristics X_i. The vulnerability threshold is assumed to be 0.50. The poverty line used in this study is BDT[1] 594.60 per person per month which is equivalent to about US$ 8.5. This is the line obtained by the Household Income and Expenditure Survey (HIES) of Bangladesh, 2005.

3. Econometric Results

Applying the VEP approach, the following vulnerability estimates are obtained (table I). They are compared with actual poverty levels before and after the flood existing in the surveyed districts.

Table I: Vulnerability estimates by the VEP approach (in %)

Sample	**Districts**	**Poverty before flood**	**Vulnerability**		
			Overall	**Idiosyncratic**	**Covariate**
Flooded	Total	57.8	67.0	66.9	77.2
	Jamalpur	58.8	68.2	50.3	15.6
	Nilphamari	72.3	78.6	76.4	87.9

Note: Vulnerability threshold point is 0.5. Source: Own compilation from survey data

For the flooded households, the vulnerability was estimated to 67 percent which is 9 percent higher than the before flood poverty level, about 58 percent. Households from the Nilphamari district, who faced the flash flood in the year 2005, have the highest poverty and vulnerability rates. Idiosyncratic risks affect only households or individuals like in the case of a death of a household member, and covariate risk affects a group of households or the whole community. Households facing a monsoon flood have been found to be on average more vulnerable to idiosyncratic shocks. This study also examines vulnerabilities according to different income sources. The following table II shows the income sources, poverty levels and vulnerability estimates for the surveyed households. It is found that farmers are the most vulnerable to flood shocks, followed by day laborers.

[1] BDT means Bangladeshi Taka or currency

Table II: Major sources of income and vulnerability by the VEP approach (in %)

Major source of income	**Flooded**			
	Poverty before flood	*Poverty after flood*	*Change in poverty*	*Vulnerability*
	(1)	*(2)*	*(2) - (1)*	
Agriculture	61.1	85.7	24.6	93.8
Service	30.8	41.0	10.2	39.5
Business	38.8	53.8	15.0	45.8
Day labor	72.3	87.0	14.7	90.0
Dairy and Poultry	30.8	53.8	23.0	50.0
Remittance	56.9	62.7	5.8	26.7
Boatman and Fisherman	52.8	69.8	17.0	61.5

Source: Own compilation from survey data

Percentages of farmers for Sirajganj, Jamalpur, Sunamganj and Nilphamari districts are 6.5, 63.3, 4.1 and 43.9, respectively. Hence, only farmers from the Jamalpur and Nilphamari district are considered for econometric analyses due to larger sample sizes. In the Jamalpur district, 53 percent of the farmers reported to produce jute (cash crop) as major crop and 42 percent produce paddy rice (staple crop) as major crop. The major crop is defined by the response of the surveyed households in terms of the amount of land, labor allocations and input costs devoted to a certain crop. The households were asked to indicate their expected (normal) yields of jute and paddy rice production without any adverse effects of floods. These expected yields were subtracted from their actual crop yields after the flood in 2005. The total yield loss of the cash crop (jute) was higher in proportion (86%) than that of the staple crop. The proportion of yield damage in the staple crop (paddy rice) was reported to 54 percent. The farming households in the Jamalpur district, who reported paddy rice to be their major crop, mainly produce Aus paddy which is a special type of rice from Bangladesh. However, jute producers (White and Tossa) also affected by the inundation of flood, since jute is harvested during July to September. Table III shows the socioeconomic and vulnerability differentials of the Jamalpur farmers distinguishing between those who produce jute and those who produce paddy rice as their major crops.

Table III: Vulnerability differentials for different crop producers in Jamalpur

Crop	**Yield loss due to flood in kilo per household**	**Value (yield x market price) loss due to flood in Taka**	**Asset value in Taka**	**Land holding in acre**	**Poverty before flood (%)**	**Vulner-ability (%)**	**Vulner-ability to Poverty ratio**
	(1)	(2)	(3)	(4)	(5)	(6)	(6)
Jute (cash)	59.12	866.04	3584.16	0.142	61.92	73.54	1.19
Paddy (staple)	98.87	844.51	3327.74	0.133	63.81	69.03	1.08

Note: Column 1, 2, 3 and 4 represent the mean values; Vulnerability is measured by Chaudhuri *et al.* 2002; number of households for jute = 39 and for paddy = 50; Source: Own compilation from survey data

The vulnerability estimates include the before flood per capita income as dependent variable; household member, dependency ratio, age and gender of household head, educational year of highest educated member, ownership of dwelling place, per capita asset value, and per capita arable landholding are included as independent variables. The additional variables, yield and value (yield x market price) loss in crops are included for estimating the error term (to catch the inter-temporal income variability). From the above table III, it is depicted that on the one hand, households with larger assets and more arable land area, go for more profitable but riskier cash crop production (value per kilo jute is 18.12 Taka, whereas value of per kilo paddy is 11.05 Taka). But in case of flood inundation, cash crop is much more vulnerable in terms of average value loss in nominal value terms, though the average yield loss for jute is even 40 percent lower than that for paddy rice. On the other hand, the poorer farmers tend to grow paddy rice which is relatively less profitable. Thus, the results support the hypothesis that poorer households, in imperfect insurance markets, prefer to cultivate traditional or staple crops over riskier cash crop like jute or more profitable new varieties (Morduch 1994). The poverty rate is 2 percent higher in paddy cultivating households but the vulnerability to poverty ratio is lower than that of the cash crop producers. So, it could be better for jute producers to cultivate mixed crops (jute and paddy) instead to minimize their vulnerability or future risk.

The Nilphamari district data show that 66 percent of the farmers cultivated paddy rice (staple) and 32 percent produce groundnuts (cash crop) as major crops. The yield loss of the staple crop (paddy) was higher in proportion (95 percent) than for the cash crop. The proportion of yield damage in cash (groundnut) crop was reported to 84 percent. The Nilphamari district was affected by flash flood (caused by unexpected rain and sudden overflow of river basin) in early November and field survey was conducted during November 25th to December 5th. The average duration of the flood was three days, and the average flood water height was 0.78 feet in the homestead as reported by the affected households. Most of the farmers faced crop damage due to the flood. The farmers reported that they mostly ploughed the Aman paddy rice and that the flood inundation occurred just before their harvesting time. According to the farmers, Aman paddy and groundnut both share a similar pattern of sowing and harvesting times. Thus, groundnut producers faced similarly the disastrous effect of the flood but less than the paddy producers, because of the height of the paddy plants is bit higher that the groundnuts. The vulnerability and socioeconomic differentials of the two groups of farmers in the Nilphamari district are shown in the following table IV.

Table IV: Vulnerability differentials for different crop producers in Nilphamari

Crop	**Yield loss due to flood in kilo per household**	**Value (yield x market price) loss due to flood in Taka**	**Asset value in Taka**	**land holding in acre**	**Poverty before flood (%)**	**Vulner-ability (%)**	**Vulner-ability to Poverty ratio**
	(1)	(2)	(3)	(4)	(5)	(6)	(6)
Nut (cash)	35.67	1557.60	2619.06	0.156	66.71	68.38	1.03
Paddy (staple)	85.25	827.20	1175.65	0.096	70.0	78.41	1.12

Note: Column 1, 2, 3 and 4 represent the mean values; Vulnerability is measured by Chaudhuri *et al.* 2002; number of households for nut = 21, and for paddy = 44; Source: Own compilation from survey data

In the Nilphamari district, the pattern of crop loss in yield and values for staple and cash crops are similar to that of Jamalpur district. The cash (groundnut) crop takes the higher loss in values than the staple one but mean losses in yield are lower. Households with higher asset values and more arable land prefer to cultivate groundnuts more than paddy because of the higher market value. From the sample survey, the average value of per kilo paddy is calculated as 11.05 Taka and for groundnuts as 39.57 Taka. The better-off households have the option and ability to spend more money on more profitable crops like groundnuts. But opposed to the above mentioned jute producers, the nuts producers are found to be less vulnerable to flash flood inundation. Comparatively poorer households have generally fewer options in terms of crop diversification and they rather prefer to grow staple crops due to the low input cost and to ensure their own household's rice supply. However, staple crop producers are found to be more vulnerable to flash flood in the Nilphamari district. It might be concluded that poorer households may allocate a small share of their land also to cash crop (e.g. groundnut) cultivation, which is likely to be more profitable and less prone to losses for floods.

4. Conclusion

Flooded households have the high risk of falling below the poverty line due to monsoon and flash floods. From two different flooded districts (Jamalpur and Nilphamari), econometric results show that farmers who grow either cash or staple crops may be vulnerable due to the downside effects of monsoon or flash floods. Thus, this study suggests a mixed cropping system in rural Bangladesh to minimize households' vulnerability to floods as the irrigation facilities are already exist in the arable lands of two sampled districts.

From the econometric results, it is depicted that crop diversification or mixed cropping systems have high potentials to reduce the flood risk for the rural farming households in Bangladesh. There are ample opportunities to mitigate flood risk, disasters and aftermaths by crop diversification which can balance the production of major crops with that of minor crops. In this way, the agriculturists recuperate the aftermath flood damage and reduce the vulnerability to floods.

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