Health and food security nexus: Evidence from vulnerable rural households in Bangladesh

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Abstract

Health and wellbeing is a crucial enabler for efficient farm and non-farm activities and determines individuals' and households' ability to achieve their livelihood objectives. Health status of household heads (earning member) critically affects household food security, which has important policy implications. This study examines the determinants of household food security. It also focuses on the impact of household head (earning member) physical health status on attaining food security by using the survey data of 380 most vulnerable riparian households in Bangladesh. The results reveal that riverine households' lack of access to many basic necessities and services such as food, safe drinking water, education and health results in increased vulnerability to food insecurity which could lead to an unfortunate vicious cycle of poverty. Model results indicate that household heads' education, household size, adoption of livestock and access to non-farm earnings also affect food security. Importantly, evidence suggests that access to improved health care also needs policy support in parallel with improved access to food to achieve and sustain long-term food security in Bangladesh.

Keywords: Bangladesh, vulnerable household, physical health, food security, policy options

1. Introduction

This is a significant challenge for policy makers in developing countries such as Bangladesh to improve the health conditions of rural households by ensuring access to food and health care. If farming households become sick, which is primarily caused by inadequate calorie intake and a lack of access to health services, they will be unable to perform farm and non-farm jobs which in turn makes them more vulnerable and a burden to their family and society (Alam et al. 2016). The question is whether the government will be able to bring all of those

inactive people into the social safety net programs to achieve its food security challenge. The answer would definitely be negative due to the nature of the economy, which is characterised as poor (a developing country) and is confronted with various other problems such as natural disasters, climate change issues, high population growth and poverty (WB, 2015; WHO, 2013; GoB, 2011).

Bangladesh has achieved marked improvements in food production and the incidence of poverty since the country's independence in 1971. The rate of poverty decreased from 62% in 1988 to 35% in 2011 (BBS, 2012), and the population growth rate has decreased from 2.4 in 1970 to 1.47 in 2011 (BBS, 2012). Production of rice, the main staple food, has more than tripled from 16 million tons in 1970 to more than 50 million tons in 2010 (FAO, 2012). Despite these successes, the country is regarded as one of the seven countries[1] housing some of the two-thirds of the world's 906 million undernourished people (FAO, 2011). A report by USDA (2010) indicated that of the 165 million people in Bangladesh, 33 million were registered as food insecure in 2010, and this is projected to be 37 million by 2020.

In Bangladesh, a growing concern among policymakers is that certain groups within the country do not have access to the quantity of food required for an active and healthy life (GoB, 2011). Particularly the households in the riverine areas (see section 2.1) have limited access to food and other basic needs such as health facilities (WHO, 2013; IFAD, 2013; GoB, 2010). Scholars suggested that food insecurity has negative consequences for people's health, productivity and wellbeing, which can worsen the poverty situation (Harrigan, 2008; Chavas et al., 2005). Consuming less than the daily calorie requirement increases people's vulnerability to sickness and infectious diseases, which results in missed work, hence missed wages (Rice et al., 1985). Scholars have also pointed out that a lower consumption of calories can be a key risk factor for many chronic diseases of later life (Wichstrom et al., 2013; Telema et al., 2005). On the other hand, if the household head has ill health, this household is more likely to be food insecure (Bernell et al., 2006). The reason behind this is that health status has an effect on labour supply and productivity, farm output and earnings (Fisher and Lewin, 2013; Alam and Mahal, 2012; Chavas et al., 2005). Stiglitz (1976) argued that the likelihood of obtaining a job and a fair wage rate depends on the job seeker's health condition. Poor health prevents households from participating in farm and non-farm jobs.

[1] In 2010, about 925 million people globally were undernourished, of which 906 million (98%) resided in developing countries. Two-thirds of these live in just seven countries, namely, Bangladesh, China, Democratic Republic of Congo, Ethiopia, India, Indonesia and Pakistan (FAO, 2011).

This issue has particularly important for the rural households who depend on wage earnings and other non-farm activities for their livelihoods as in the case of this study.

Numerous researches in the past have been emphasized on the access to food to attain food security in Bangladesh (for instance, Mishra et al., 2015; Rich et al., 2015; Ahmed et al., 2012; Dorosh and Rashid, 2010; Faridi and Wadood, 2010; Shahabuddin, 2010; Hossain, 2010; Talukder, 2005; among many). The issue of household earning member's physical health status to attain household food security has received relatively less attention. Vulnerable riverine households have been experiencing less access to food due to loss of productive land coupled with their poor health condition making the challenge of attaining food security more worsen. Therefore, this study explores the new dimension of how household heads' (earning member) physical health status impacts on vulnerable rural households' food security. The research questions posed to investigate are: (i) What is the livelihood status of the riverine households of Bangladesh?, (ii) What factors influence household food security, and how does household heads' physical health status affect food security? and (iii) What are the policy options to improve the food security of these hazard-prone vulnerable rural households in Bangladesh?

The remainder of this paper is organized as follows: Section 2 presents descriptions of the study area and data collection procedures, followed by an empirical model for analysis; results and discussions are presented in Section 3; and Section 4 provides conclusions and policy recommendations.

2. Methodology

2.1 Description of the study area

This study employed a multistage sampling technique to collect data from vulnerable riverbank erosion prone rural households. In Bangladesh, 20 districts out of 64 are prone to riverbank erosion (GoB, 2010); another study asserted that some parts of 50 districts of Bangladesh are subject to riverbank erosion (Elahi et al., 1991). A loss of productive land and other resources on which agricultural practices depend is a common phenomenon in the riverine areas – it causes land loss of about 8,700 ha and displaces approximately 200,000 people annually along the estimated 150,000 km of riverbanks in the country (CEGIS, 2012; GoB, 2010). These hazard-prone, resource-poor households are among the poorest of the poor and are the most vulnerable to food insecurity and poverty (IFAD, 2013; GoB, 2010).

Resource-poor households in the riverine areas are more prone to the impacts of frequent floods and waterlogging due to their proximity to the river, which also increases

their vulnerability. Due to recurring riverbank erosion, large numbers of households have lost their land and homesteads, resulting in a decrease in access to food, safe drinking water, electricity, education, health services, financial institutions and farm and non-farm job opportunities (Alam 2016). Therefore, riverbank erosion-affected districts, Upazilas[2] and affected riverine villages were selected purposively based on the degree of severity of erosion evident through a review of the literature, newspaper reports and consultations with experts. Respondents were then selected randomly within each village. For the field survey, the Chauhali Upazila of the Sirajgonj district and the Nagarpur Upazila of the Tangail district were selected (see Figure 1), which represent the most vulnerable riparian environments in Bangladesh. The area is about 200 km north of Dhaka, the capital of Bangladesh. The Jamuna river[3], which is reported to cause erosion of around 2,000 ha per year (CEGIS, 2012), crosses the study area. Data were collected from six riverine villages, namely, Kash Pukuria, Moradpur, Kairat, Datpur, Kashkawalia and Atapara.

2.2 Sampling, questionnaire and data collection

A complete list of affected riverine households in the study area was obtained from the Department of Agricultural Extension (DAE). The unit of analysis was rural households[4], and for data collection, the household head (either male or female) was the survey participant. From each village, 15% of household heads were interviewed, which gave a sample size of 380 for the study. For a cross-sectional household survey, 5% of the population is considered to be adequate (Bartlett et al., 2001); notably, a sample size of 350 is considered the optimal size for a structured interview in quantitative research (Perry, 1998). To ensure randomness in the sampling, a computer-generated random number table was applied to the list to select the households surveyed in this study.

[2] Lower administrative unit of the Government below district level but above village level.

[3] Bangladesh is composed of the floodplains and deltas of three main rivers, the Padma (Ganges in India), the Jamuna and the Meghna (Brahmaputra in India). These rivers and their tributaries are prone to continuous erosion.

[4] A household (economic agent) is a domestic unit with autonomous decision-making regarding production and consumption (Ellis, 1988). Household heads have the power to exercise decision-making over their household's resources.

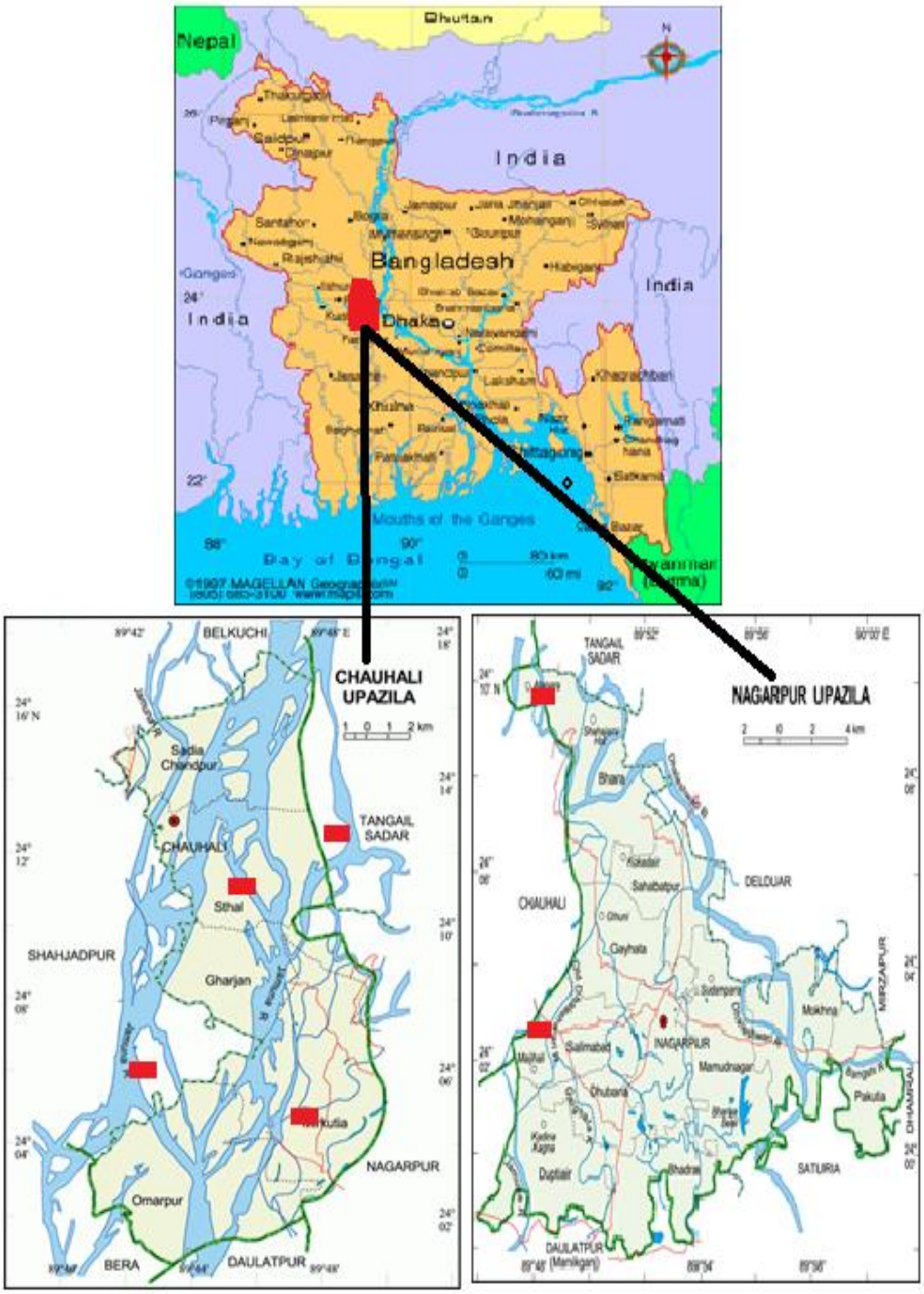

Figure 1. The study area: the Nagarpur and Chauhali Upazilas

The study developed a structured survey questionnaire to collect data using face-to-face interviews between January and May 2014. The survey questionnaire was pilot-tested with 20 respondents to ensure the adequacy of the information obtained and avoid ambiguity of questions. Questions included in the survey questionnaire sought information on socio-demographic characteristics of households such as age, education, income and expenditure

patterns; land holdings; and access to social amenities. Food consumption data were collected at the household level through questions regarding the quantity of different food items (approximately 35 items) consumed over the last three days[5] along with their unit price and sources (home supplied and/or purchased). Several issues were taken into consideration to estimate household calorie supply and demand:

Food supply at the household level was determined by both household supply and purchase. It was converted into calories using the Food Conversion Table of the FAO[6] to measure the available calories for each household.

- Available calories were converted into adult equivalent (AE) ratios, and the values were then comparable across households of different sizes. Household family members and guests were either included or excluded in the calculation of the AE, depending on their presence or absence during the recall period. Household members under the age of six were considered as children, and two children were considered as one adult member in this study (Alam et al., 2010; Omotesho et al., 2006).
- Then, 2,122 kcal per person per day (GoB, 2000) was set as the desirable calorie requirement (demand) to enable an adult to live a healthy and moderately active life (food secure).
- Finally, the difference between calories available and calories demanded by a household was used to determine the food security status of each household. If a household's per capita calories were found to be greater than their demand, they were considered food secure and assigned a score of 1. On the other hand, those households experiencing a calorie deficit were regarded as food insecure and assigned a score of 0.

2.3 Empirical model

Calories intake is often used as a proxy for all nutritional requirements for health, although there may be serious deficiencies in other nutrients required for health (Aromolaran, 2010). Scholars argued that when calories intake is satisfactory other needs are usually satisfied (Maxwell and Smith 2006; Heald and Lipton 1984). This study applied the calorie intake method to determine household food security (Rahman et al., 2012; Alam et al., 2010; Aromolaran, 2010; Bashir et al. 2010; Kazal et al., 2010; Sindhu et al. 2008; Fleke et al., 2005). To compute the availability of calories (C_i), the Food Calorie Conversion Table was

[5] The accuracy of food consumption data diminishes with the length of the recall period (Bouis, 1994). Hence, we used a three-day recall method, which is common in the literature (Alam, 2010; Reddy, 1997).

[6] Shaheen et al. (2013) prepared a report on 'Food Composition Table for Bangladesh' under NFPCSP.

used. A household is considered to be food secure (C_i*) if the difference between calorie consumption and recommended daily calorie needs (γ_i) is greater than or equal to 0.

Where C_i*= $C_i - \gamma_i$, C_i*≥0 indicates that the household is 'food secure', and C_i*<0 indicates the household is 'food insecure'. Assuming a liner function, household food security status can be written as:

$$C_i* = \sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i \quad \text{(i)}$$

where X_{ij} are explanatory variables and ε_i is the error term, which is assumed to be uncorrelated with the explanatory variables. The observed variable is food security, where Z_i=1 when C_i*≥0 and Z_i=0 when C_i*<0 for i^{th} household. Since the observed dependent variable Z_i is binary/discrete in nature, the food security model can be framed as a response model (logit or probit) of qualitative variables, where $\emptyset_i$ is the probability of food security specified as:

$$\emptyset_i = \text{Prob}\,(Z_i = 1) = \text{Prob}\,(\sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i > 0) \quad \text{(ii)}$$

Now, the logistic regression can be applied to this model because it directly estimates the probability of an event occurring for more than one independent variable, that is, for *k* independent variables (Hailu and Nigatu, 2007; Fleke et al., 2005; Demaris, 1992). The logistic regression model of food security can be written as:

$$Ln\left(\frac{\emptyset_i}{1-\emptyset_i}\right) = \beta_0 + \sum_{j=1}^{n=k} \beta_j X_{ij} + \varepsilon_i \quad \text{(iii)}$$

where $\emptyset_i$ is the conditional probability of food security, β_j's are parameters to be estimated, and X_{ij}'s are the explanatory variables.

In Equation (iii), the dependent variable – food security – is in log odds; the result of the logistic regression can be interpreted in terms of conditional probabilities instead of log odds or odds using:

$$\emptyset_i = \frac{e^{\left(\beta_0 + (\sum_{j=1}^{n=k} \beta_j X_{ij})\right)}}{1 + e^{\left(\beta_0 + (\sum_{j=1}^{n=k} \beta_j X_{ij})\right)}} \quad \text{(iv)}$$

However, the estimated parameters only show the direction of the impact of the explanatory variables on the dependent variable and do not provide the extent of change or probabilities. Marginal effects (MEs), on the other hand, measure the impact on the probability of observing each of several outcomes rather than the impact on a single

conditional mean and are more meaningful and interpretable (Cameron and Trivedi, 2009; Long, 1997). Therefore, we presented the results of marginal effects in the model after testing the stability and robustness of the results.

2.4 Specification of the variables

The selection of variables was based on a review of the literature and field experience. We assumed household food security to be a function of a household's socio-economic status and farming situation, such as age, gender and educational attainment of the household head, size of the household, adoption of livestock, and access to the market and a safety net program. We also included cultivated land size[7] and access to non-farm income as a proxy for household income. Due to limited agricultural land, a large number of households depend on wage earnings or other non-farm income to maintain their livelihoods. Therefore, we also included household heads' self-rated physical health status (Kawachi, 1999) in the model as a dummy, since it has an influence on access to farm and non-farm jobs, where 1 represents good health and 0 represents poor health. To obtain the score, several techniques were adopted to minimise self-reported bias since health status is an unobserved or latent variable. For example, instead of asking about a respondent's health status directly, we asked whether they are fit for farm and non-farm work regularly throughout the year. The answers were then checked with how many days they were absent from their work due to sickness/illness. If it was less than one week[8] then the score is 1, and 0 otherwise. A detailed description of these variables and the summary statistics are presented in Table 1.

Table 1. Summary statistics and description of model variables

Explanatory variables	**Description**	**Mean**	**Std.**	**Expected sign**
Age of household head	Years (Continuous)	45.12	14.43	+/–
Gender of household head	Dummy, 1 = male, 0 otherwise	0.95	0.22	+
Education of household head	Years of schooling (continuous)	3.17	4.63	+
Household size	Number (continuous)	5.21	3.35	–/+
Cultivated land size	Decimal (continuous)	0.56	0.88	+

[7] This study considered cultivated land size instead of farm size, because many households have a large farm but practically most of the land is in the grip of the river and is not suitable for cultivation.

[8] Based on our consultation with local physicians, one week absence from work was considered normal. Diseases such as fever, cough, skin infections and diarrhea are common in the area.

Adoption of livestock	Dummy, = 1 if households have livestock; 0 otherwise	0.84	0.36	+
Access to non-farm income	Dummy, = 1 if households have access; 0 otherwise	0.63	0.31	+
Access to safety net	Dummy, = 1 if households have received; 0 otherwise	0.04	0.20	+
Household head physical health condition	Dummy, = 1 for good health and 0 for poor health	0.57	0.49	+
Household food security	Dummy, 1= secure, 0= insecure	2048	975	

2.5 Econometric consideration

The issues of multicollinearity, heteroscedasticity and the effect of outliers in the variables – which are the inherent characteristics of cross-sectional survey data – were taken care of. Before proceeding with model estimation, we attempted to identify multicollinearity and the correlation matrix with all the explanatory variables after running an ordinary least square (OLS) regression. The correlations were found to be relatively low – below 0.43 in all cases; typically, correlation coefficients of 0.7 or higher are considered high (Kennedy, 1998). Thus, correlation problems between explanatory variables could be ruled out. In order to explore potential multicollinearity, which can lead to imprecise parameter estimates (Gujarati, 2003), we calculated the Variance Inflation Factor (VIF) for each of the explanatory variables. The VIFs range from 1.17 to 1.71, which does not reach the conventional threshold of 10 or higher used in regression diagnosis (Maddala, 1992). The Breusch-Pagan/Cook-Weisberg test confirmed that the model has no heteroscedasticity problem (the null hypothesis of homoscedasticity is accepted, Chi-square 13; $p>0.131$). The Ramsey-RESET test was also performed in order to test the accuracy of the models. The result rejects the null hypothesis of incorrect functional form, which indicates that relevant variables have not been omitted. In order to be sure that household health status is exogenous, we employed the Hausman endogeneity test to verify that the error term is uncorrelated with household heads' health status. The test result rejects the null hypothesis that household heads' health status is endogenous ($F(1, 23)$; $p>0.110$).

3. Results and discussions

The results of the study are presented in two phases: households' livelihood conditions and the econometric results for the determinants of household food security.

3.1 Livelihood conditions

A better understanding of the overall livelihood status of the households can provide information about potential policy interventions and thus make pathways towards improving households' livelihoods and food security. The status of households' socio-economic and livelihood conditions are summarised below:

- All the riverine households have experienced loss of some of their land due to erosion. The study revealed that 39% of households had lost their homestead more than three times and 55% at least once, during the past 10 years.
- More than 93% of households reported a loss of employment opportunities and income from agriculture, caused by erosion. Due to loss of many market places and inadequate road and transport facilities, residents have to travel to distant places to sell their products. Moreover, traders are not able to come to local markets, which reduces their chance of obtaining a fair price for their products.
- Regarding education level of household heads, about 29% of respondents had no education, and the average years of schooling were below primary level (3.17 years). In addition, 17% of households did not send their children to school due to lack of educational facilities (distance to nearest school is more than 2 km and the road network is also inadequate). Respondents reported that they had lost 15 educational institutions, seven religious institutions and many roads and marketplaces during the past 10 years as a result of the erosion.
- The average family size of 5.21 is relatively large compared to the national average of 5.0 (BBS, 2012). More than 46% of households had six members or more, and more than 56% of households did not adopt contraceptive measures.
- Regarding hygiene issues, more than 21% of households were without sanitary latrine facilities and 47% had no safe drinking water; many of them have tube-well facilities but with arsenic contamination. The distance to the next safe drinking water source is more than 1 km.
- Households were also found to be deprived of many standard government services. About 46% of households were without any electricity; availability of health facilities was also limited. Riverbank erosion destroyed the only public hospital in the Chauhali

Upazila in 2015. They now had to travel a longer distance (more than 5 km) to reach the nearest health and veterinary centre, including the public hospital which is supposed to provide free health care. In addition, many households still use their traditional systems to recover from sickness rather than visiting doctors, due to their inability to bear the associated cost. Regarding the issue of health, around 63% of household heads fall into the category of poor health condition; this limits their opportunities to find a job in the farm and non-farm sectors.

- In the case of land holdings, 32% of households in the study area were landless (land <0.5 acres). The average land holding is 0.56 acres (small farm size is a common feature in Bangladesh; as per WB (2015), arable land is 0.123 acres/person).
- Moreover, the existence of government, NGOs and formal financial institutions' activities in the area was reported as inadequate. About 69% of households reported they had no access to government financial institutions and 64% had no access to NGOs from whom they can get credit. This is mainly due to the households' poor economic conditions where the financial institutions' possibility of recovering their credit is somewhat uncertain; riverine households' addresses often change due to changes in homestead position as a result of erosion.
- Due to poor socio-economic conditions and inadequate road transportation facilities, their social networks – the key to social capital – were also found to be limited. About 67% of households have had no contact with the extension service providers from whom they can get advice related to agriculture and rural development. They also had less farmer-to-farmer contacts (43%) and less involvement with different organisations from which they can receive information and assistance.
- Moreover, most of the female-headed households (83%) in the study area were widowed or divorced[9]. They are vulnerable in all aspects of livelihood characteristics in rural Bangladesh (Mallick and Rafi, 2010). Field experience suggested that their opportunities to work in farming and non-farming activities are limited and they are still not well accepted in society, inferring gender inequalities in the labour market. This contributes to increasing the vulnerability of female-headed households to food insecurity.

[9] This area has one of the highest rural-urban migrations in Bangladesh. Many of the husbands who migrate to major cities as their seasonal coping mechanisms to find a job do not return to their families, leading to a high rate of divorce.

3.2 Status of household food security and expenditure

Regarding household food security, more than half (56%) of the households within the study area fall into the food insecure category, with an average per capita calorie consumption of 1,867 kcal/day, which is about 12% less than the standard minimum daily requirement. However, food-secure households exceed the minimum calorie requirement by 5% (2,229 kcal/day). This shortfall of 12% substantially understates the energy deficiency of the poor. The standard deviation of the calorie demand variable is fairly high, which indicates a wide range of variability across sample.

Furthermore, about 71% of the households' total expenditure is on food items and the rest is on non-food items including farming and livestock (15%) and house building and/or repairing (6%) (Table 2). Expenditure on health care is of lower priority – the households spend less than 2% of their earnings on this, mainly due to their low income and the unavailability of health service facilities in the area. Their low income prevents them from cutting back their minimum consumption requirements to pay for health care services. After fulfilling their consumption demand, their target is to invest in farming and house building and/or repairing.

The total market purchase value of food consumed at home stands at 75%; this indicates the vulnerability of the households to price shocks. It is reported that the lower the share of household expenditure on food, the easier it is for households to cope with price increases and shocks (Economist, 2015). In Bangladesh, it is reported that price increases have disproportionate short-term effects on the rural poor (Akter and Basher, 2014). In the case of food expenditure, households spend about 82% on rice/wheat, the main source of carbohydrate. Therefore, it is crucial from a policy perspective to keep the price of rice/wheat reasonable so that poor people can afford it. Increasing the adoption of livestock and poultry by the resource-poor households would not only supplement their income but also provide eggs, milk and meat for their consumption.

Table 2. Household expenditure

Expenditure	**Percentage**	**Food expenditure**	**Percentage**
Food	71	Rice/wheat	82
Farming and livestock	15	Fish and meat	3
Children education and clothing	6	Egg and milk	1
Health care	>2	Pulse, species and oil	9

House building/repairing	6	Vegetables and fruits	5
Total	100	Total	100

3.3 Econometric results

The results of the regression analysis (logit)[10] are presented in Table 3. To test the stability and robustness of the results, we estimated four alternative specifications of the model. In the first model we included core variables and subsequently added other relevant variables in models 2 to 4. In model 3, the non-significant variables were dropped, which did not increase the coefficients and significance level of the remaining variables substantially. Goodness of fit of the models (given by McFadden Pseudo R^2) does not increase substantially from models 1 to 4 and indicates a reasonable explanatory power of the model (Table 3). The last specification (model 4) represents all variables and shows the best model fit in terms of the expected sign and significance level. The likelihood ratio statistics (Chi-square of 242.137) indicate the strong explanatory power of the model. In other words, it rejects the joint null hypothesis that all coefficients of independent variables in the model are 0 ($p<0.00$). The signs and degree of statistical significance of the variables do not change substantially across the different estimates; hence, the estimated results are stable and robust (see discussions below of the results of marginal effects of model 4):

Table 3. Regression results for the likelihood determinants of food security

Variables	**Maximum likelihood estimates (coefficient)**				**Marginal effect of model 4**	
	Model 1	Model 2	Model 3	Model 4	Coeff.	Std. error
Age of household head (years)	–0.217** (0.103)	–0.215** (0.102)	–0.211** (0.098)	–0.213** (0.101)	–0.091*	0.048
Gender of household head (dummy)		0.101 (1.402)		0.105 (1.027)	0.071	0.874
Household size (AE)	1.316*** (0.470)	1.312*** (0.463)	1.317*** (0.468)	–1.310*** (0.461)	–1.041***	0.379
Education of	1.725***	1.723***	1.728***	1.721***	1.134***	0.402

[10] We used STATA 12 to estimate our model.

household head (years)	(0.572)	(0.570)	(0.575)	(0.569)		
Cultivated land size (decimal)	1.197*** (0.411)		1.216*** (0.407)	1.192*** (0.402)	1.082***	0.371
Access to non-farm income (dummy)	1.151*** (0.413)	1.148*** (0.411)	1.153** (0.415)	1.150*** (0.410)	1.013***	0.375
Livestock ownership (dummy)		1.165*** (0.410)	1.167*** (0.413)	1.163*** (0.431)	1.087**	0.513
Access to safety net (dummy)		0.139 (0.345)		0.102 (0.647)	0.074	0.023
Access to market (dummy)		0.023 (0.109)		0.016 (0.103)	0.010	0.093
Household heads' physical health condition (dummy)	1.210*** (0.371)		1.237*** (0.376)	1.211*** (0.349)	1.110***	0.391
Constant	10.587***	11.451***	11.461***	11.563***		
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	
Goodness of fit (Pseudo R^2)	0.721	0.727	0.729	0.730		
Log likelihood	–80.129	–81.514	–81.461	–81.921		
LR (chi-square)	237.07	241.142	241.512	242.137		
Degrees of freedom	06	08	07	10		
Number of observations	380	380	380	380		

Note: Dependent variable: Food security. ***p<0.001; **p<0.05 and *p<0.10.

Educational attainment

Education is often used as an indicator of human capital (Alam et al., 2016; Lutz et al., 2008; Goujon and Lutz, 2004). Results of marginal effects of model 4 yielded, as expected, a significant positive relationship between household heads' educational attainment and food

security (1.134; p<0.001). Past research also yielded the same results (Anik, 2013; Alam, 2010). It is expected that household heads with more education have greater access to non-farm jobs and the capacity to adopt better adaptation strategies in their farming, which in turn increases their production and contributes to food security for these households. It is reported that household heads' education level is associated with the adoption of modern agricultural technology, fertilizer and better agronomic management, which is key to offsetting the negative effects of a changing climate (Gebrehiwot and van der Veen, 2013; Deressa et al., 2009; Lin, 1991). The marginal effect of education implies that a one unit (year) increase in a participant's level of education will increase the probability of household food security by 1.134, while the effect on the remaining options is negligible. The same interpretation holds true for other variables.

Age of household head

We found a negative association between household head's age and food security (-0.091; p<0.10). Similar results were also found in past research (Balagtas et al., 2014; Mannaf and Uddin, 2012). These results are mainly due to household heads' inability to do relatively hard work in the farm and non-farm sectors as their age increases. In the study area, most of the farmers, particularly small and landless farmers, migrate for a few months to improve their livelihoods and food security, due to the limited opportunities for both farming and non-farming activities during the rainy seasons. However, it is less likely that an older household head will undertake this type of migration, which increases their vulnerability to food insecurity.

Household size

This study found an inverse relationship between family size and food security (–1.041; p<0.001). This result is consistent with previous findings (Feleke et al., 2005; Bashir et al., 2010). Households with more family members tend to have lower food security; however, households endowed with more earning members are more likely to be food secure. In this study, large families mainly include members who are not able to earn an income, such as children and aged people. Many of the younger people earning an income were found to be separated from their family. There is a higher number of children in the households who had a lower education level and did not adopt contraceptive methods. Despite tremendous progress in reducing population growth in Bangladesh, this finding indicates the need for a more significant role for family planning activities of government and NGOs among these vulnerable communities.

Cultivated land size

Access to land – the most important natural resource – is considered the key determinant of the livelihood strategies of the rural poor. Rural households' incomes are mainly derived from the land. While 32% of households in the study area are landless, this study found a significant positive relationship between cultivated land size and food security (1.082; $p<0.001$). In Bangladesh, a positive relationship between farm size and household food security is well registered (Faridi and Wadood, 2010; Kazal et al., 2010). However, the irony of this fact is that riverine households' experience loss of some of their land every year. Policy intervention is required for the emerging *char* land[11], which was previously fallow due to lack of suitable crop varieties for such land. Scientists need to respond by developing and improving crop varieties and production technologies suitable for the *char* lands in the riverbank erosion-affected areas.

Livestock ownership

This study found that livestock adoption has a significant positive impact on household food security (1.087; $p<0.05$); this result is in line with the findings of Rahman and Poza (2010) and Amaza et al. (2006). Livestock is an important source of supplementary family income. It is indeed encouraging that households in the area are beginning to adopt mixed farming activities to be more resilient and risk-averse to natural hazards. However, many farm households were found to use animal power for agricultural purposes including cultivation of land. This indicates their backwardness as well as inability and reluctance to adopt modern agricultural practices.

Access to non-farm income

Access to non-farm income offers an important pathway towards addressing food insecurity and represents income diversification opportunities of households. Results of marginal effects of model 4 indicate a significant positive association between non-farm earnings and food security (1.013; $p<0.001$). Access to rural non-farm income is well documented to be an important factor in food security (Murungweni et al., 2014; Reardon, 1997); however, all households do not have equal access to non-farm income. It is reported that the poor and

[11] *Char* land (sandbars/sand and silt landmasses) have emerged as islands within the river channel or attached land to the riverbanks. The *char* area covers about 5% of the total land area of the country and accommodates about 6.5 million people (5% of the total population) (EGIS, 2000).

uneducated households, and others lacking social ties, rarely enjoy access to remunerative opportunities in non-farm earnings (Barrett et al., 2010). Public services such as education and credit facilities, and communication and transport infrastructure, are crucial to enable participation in non-farm activities, and these were found to be inadequate in the study area. Households' limited access to institutional facilities, coupled with limited agricultural activities due to land loss, serve as substantial barriers to participation in non-farm activities.

Household heads' physical health condition

We found a significant positive impact of household heads' health status on household food security (1.110; $p<0.001$). The marginal effect suggests that household heads' good health would result in an improvement in the likelihood of household food security by 0.822. It is reported elsewhere that if the household head has ill health, this household is more likely to be food insecure (Fisher and Lewin, 2013; Bernell et al., 2006). Households, particularly small and wage labour have reported that due to poor health condition they were missed out work for several occasions. They were even not able to go to distance places to do work especially during the rainy seasons when the scopes of employment become limited in the area which resulted in increased food insecurity. Scholars have pointed out a range of negative health outcomes due to food insecurity, including lower calorie consumption, iron deficiency anemia, obesity, and poor physical and mental health (Carter et al., 2010; Stuff et al., 2004; Vozoris and Tarasuk, 2003; Che and Chen, 2001). Therefore, it can be said that if the observed food insecurity situation (low calorie intake) is prolonged, the households will lose their productive capacity and thus fall victim to food insecurity, leading to increased vulnerability to poverty. In other words, this food insecurity and low affordability of medicines makes poor household members prone to disease that could lead to an unfortunate vicious cycle of poverty shown in Figure 2.

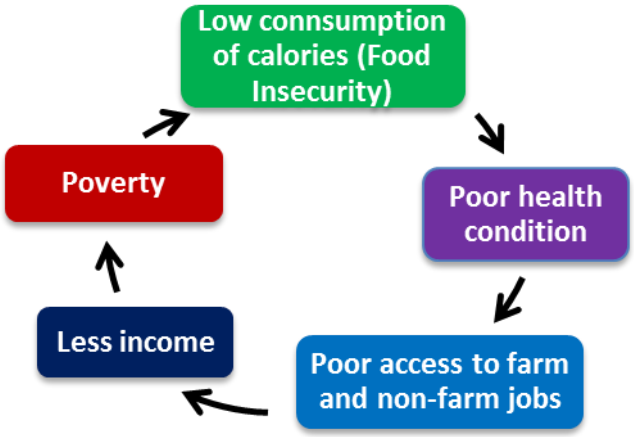

Figure 2. A vicious circle of food insecurity and poverty

Poor health conditions limit the poor household access to farm and non-farm jobs, and further reduces the income-generating competencies. This is ultimately leading to forming a vicious circle of poverty and malnutrition. This issue will in turn be the main hurdle to achieving long-term food security challenge in Bangladesh unless appropriate policies are put in place.

Access to safety net

It is important to note that previous research, for example, Kazal et al. (2010), indicates the effectiveness of safety net programs on household food security. Our estimates, however, show a positive but insignificant relationship, even at the 10% level of significance (marginal effects of model 4). This statistical insignificance may be due to the small number of households (4%) included in the safety net program. This may have important policy implications for household food security, which underpins the coverage of the safety net program in the study area. Contrary to this, Ahmed et al. (2012) argued that access to microfinance is more effective than safety net programs in helping poor households cope with the shocks. Households in the erosion-prone areas, however, reported having limited access to financial institutions, and this needs appropriate attention.

4. Conclusions and policy recommendations

Bangladesh is one of the most densely populated countries in the world and is confronted with many challenges, including climate change issues, attainment of food security and eradication of poverty. This study goes beyond simply examining the determinants of household food security for most vulnerable riparian households in Bangladesh. It also focuses on the impact of household head (earning member) physical health status on attaining food security. The model does not suffer from the potential multicollinearity, heteroskedastacity and endogeneity problem confirmed by the statistical tests.

Study results reveal that the riverbank erosion-prone areas are deficient in a number of areas such as infrastructure, access to education and health services, access to markets and non-farm activities, and availability of public utilities like electricity and safe drinking water; all of these factors contribute to households' increased vulnerability to food insecurity. This study also found several other related factors that serve as drivers of households' food insecurity such as household heads' level of education, household size and cultivated land holdings, livestock ownership and access to non-farm income. We also found new evidence

which suggests that physical health status of the household head is a key significant factor influencing household food security. The rest of the variables tested are not statistically significant but have the expected sign.

A broad range of actions are necessary to improve and sustain the food security of these particular vulnerable communities. First, since these resource-poor households have limited access to food due to loss of productive land and subsequent effects on income and other resource endowments, direct food transfer through food aid programs is one mechanism that could boost access to food in the short-term. The coverage of the safety net programs in the study area seem to be inadequate, and an appropriately targeted food policy intervention is yet to be developed for these vulnerable communities. Female-headed households should receive priority as they have fewer opportunities to enter into farm and non-farm jobs, which can make them more vulnerable to food insecurity. Interventions through income-generating activities such as tailoring, handicrafts or embroidery where women can be engaged need to be facilitated through proper training, which is currently not in place.

The findings of this study clearly show that education – which is an indicator of human capital – has a significant impact on household food security. In the riverbank erosion-prone areas, many educational institutions have closed due to the erosion and this, coupled with fragile road networks, limits households' access to education. Targeted programs are required in order to boost primary school enrolments and human capital development in the area.

Increased livestock ownership by the resource-poor households emerged as one of the important methods that could be used to address household food insecurity. Since the crop production environment in the erosion-affected areas is somewhat unfavourable, livestock rearing should be encouraged with enabling policy support. For instance, government organisations and NGOs could provide households with livestock support or credit for having livestock, as the poor households suffer from a lack of capital. Increased livestock ownership can serve as an important source of supplementary income.

Health status of household heads critically affects household food security, and this leads to a vicious cycle of poverty which has important policy implications. Farming households will be unable to perform farm and non-farm jobs if they become sick, which is primarily caused by inadequate calorie intake and a lack of access to health services. It is hardly possible for the government to bring all of those inactive people into the social safety net programs to achieve its food security challenge due to the nature of the economy. Therefore, access to health services should receive top policy priority in parallel with access

to food in order to achieve and sustain long-term food security in Bangladesh. Provision of adequate community health services, which are currently lacking, is one option to ensure households' access to health care; poor households are actually supposed to get free health care from the public hospital. Both the government and NGOs could set up mobile health (m-health) services in the area along with their microcredit programs. It was found that most of the households (more than 89%) own a mobile phone, which enhances the opportunity to provide them with a variety of information related to agriculture and health services. In the era of the wide spread use of cell phones in rural areas in many developing countries, providing information on health care might contribute to improve the poor household health condition and thus enable them to find job in both farm and non-farm sectors.

The challenge for Bangladesh and also for many other developing countries is how to include marginalized and health impacted inactive people into the social safety net program and meet the Sustainable Development Goals of eradicating poverty and improving food security. Properly targeted income transfers and credit programs along with improved infrastructure and health care services, and human development programs in the riverbank erosion-affected areas across the country may have very high potential to improve food security and reduce poverty in the long run, and this demands well-targeted policy interventions.

References

Ahmed, A., Ahmad, K., Chou, V., Hernandez, R., Menon, P., Naeem, F., Naher, F., Quabili, W., Sraboni, E., Yu, B., 2012. The status of food security in the feed the future zone and other regions of Bangladesh: Results from the 2011–2012 Bangladesh integrated household survey. International Food Policy Research Institute, Washington, DC.

Akter, S., Basher, S.A., 2014. The impact of food price and income shocks on household food security and economic well-being: evidence from rural Bangladesh. Global Environmental Change 25, 150-162.

Alam, K., Mahal, A., 2012. Economic effect of angina on households in south Asia: a propensity score matching approach. *The Lancet*.

Alam GMM (2016) An assessment of the livelihood vulnerability of the riverbank erosion hazard and its impact on food security for rural households in Bangladesh. PhD thesis, School of Commerce, University of Southern Queensland, Australia.

Alam GMM, Alam K, Shahbaz M (2016a) Influence of institutional access and social capital on adaptation choices: empirical evidence from vulnerable rural households in Bangladesh. Ecological Economics 130: 243–251.

Alam GMM, Alam K, Shahbaz M, Clarke ML (2016b) Drivers of vulnerability to climatic change in riparian char and river-bank households in Bangladesh: Implications for policy, livelihoods and social development. Ecological Indicators 72: 23-32.

Alam, Q.M., Miah, M.A.M., Mohabbatullah, M., 2010. Land use patter, nutritional status and food security of indigenous people in hill areas of Bangladesh. NFPCSP, FAO.

Amaza, P.S., Umeh, J.C., Helsen, J., Adejobi, A.O., 2006. Determinants and measurement of food insecurity in Nigeria: some empirical policy guide, Paper presented at International Association of Agricultural Economists Annual Meeting, August 12-18, Queensland, Australia.

Anik, A.R., Manjunatha, A.V., Bauer, S., 2013. Impact of farm level corruption on the food security of households in Bangladesh. Food Security 5, 565–574.

Aromolaran, A.B., 2010. Does increase in women's income relative to men's income increase food clorie intake in poor households? Evidence from Nigeria. Agricultural Economics 41, 239-249.

Balagtas, J.V., Bhandari, H., Cabrera, E.R., Mohanty, S., Hossain, M., 2014. Did the commodity price spike increase rural poverty? Evidence from a long-run panel in Bangladesh. Agricultural Economics 45, 303-312.

Barrett, C., 2010. Measuring food insecurity. Science 327, 825–828.

Bartlett, J.E., Kotrlik, J.W., Higgins, C.C., 2001. Organizational research: determining appropriate sample size in survey research. Infor Tech, Lear and Perform 19(1), 43–50.

Bashir, M.K., Naeem, M.K., Niazi, S.A.K., 2010. Rural and peri-urban food security: a case of district Faisalabad of Pakistan. World Applied Science Journal 9(4), 403-411.

BBS, 2012. Yearbook of Agricultural Statistics, Bangladesh Bureau of Statistics, Dhaka.

Bernell, S., Edwards, M., Weber, B., 2006. Restricted opportunities, unfortunate personal choices, and ineffective policies? What explain food insecurity in Oregon. Journal of Agricultural and Resource Economics 31(2), 193-211.

Bouis, H.E., 1994. The effect of income on demand for food in poor countries: are our food consumption databases giving us reliable estimates? Journal of Development Economics 44(1), 199–226.

BRAC, 2013. BRAC Annual report: 2013. Bangladesh Rural Advancement Committee, Dhaka.

Cameron, A.C., Trivedi, P.K.2009. Microeconometrics using STATA. Stata Press, Texas.

Carter, K.N., Lanumata, T., Kruse, K., Gorton, D., 2010. What are the determinants of food insecurity in New Zealand and does this differ for males and females? Australian and New Zealand Journal of Public Health 34(6), 602–608.

CEGIS, 2012. Prediction of River Bank Erosion along the Jamuna, the Ganges the Padma and the Lower Meghna Rivers in 2012, Centre for Environment and Geographic Information Services, Dhaka.

Chavas, J.P., Petrie, R., Roth, M., 2005. Farm household production efficiency: Evidence from the Gambia. American Journal of Agricultural Economics 87(1), 160–79.

Che, J., Chen, J., 2002. Food insecurity in Canadian households. Health Reports 12(4), 11-22.

Cleaver, K., 1993. A strategy to develop agriculture in Sub-Saharan Africa and a focus for the World Bank, World Bank Technical Paper 203, Washington DC.

Demaris, A., 1992. Logit Modeling: Practical Applications, International Educational and Professional Publisher, London.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change 19, 248–255.

Dorosh, P.A., Rashid, S., 2013. Trade subsidies, export bans and price stabilization: lessons of Bangladesh–India rice trade in the 2000s. Food Policy 41, 103–111.

Economist, 2015. Global food security index 2015. An assessment of food affordability, availability and quality. London: The Economist Intelligence Unit, The Economist.

EGIS, 2000. Riverine Chars in Bangladesh-environmental dynamics and management issues. Environment and GIS support project for Water Sector Planning (EGIS), Dhaka.

Elahi, K.M., Ahmed, K.S., Malizuddin, M. (Eds), 1991. Riverbank erosion, flood and population displacement in Bangladesh. Riverbank Erosion Study, Jahangirnagar University. Dhaka.

Ellis, F., 1988. Peasant Economics. Cambridge University Press, Cambridge.

FAO, 2011. The state of food insecurity in the world: addressing food insecurity in protracted crises, Food and Agriculture Organization, Rome.

FAO, 2012. The state of food insecurity in the world: how does international price volatility affect domestic economies and food security? Food and Agriculture Organization, Rome.

Faridi, R., Wadood, S.N., 2010. An Econometric Assessment of Household Food security in Bangladesh. The Bangladesh Development Studies 30(3 & 4), 35–62.

Feleke, S., Kilmer, R.L., Gladwin, C., 2005. Determinants of food security in Southern Ethiopia. Agricultural Economics 33, 351–363.

Fisher, M., Lewin, P.A., 2013. Household, community, and policy determinants of food insecurity in rural Malawi. Development Southern Africa 30(4-5), 451–467.

Gebrehiwot, T., van der Veen, A., 2013. Farm level adaptation to climate change: the case of farmer's in the Ethiopian highlands. Environmental Management 52, 29–44.

GoB, 2000. Report of the Task Force on Comprehensive Food Security Policy for Bangladesh, Government of the Peoples' Republic of Bangladesh, Bangladesh.

GoB, 2010. Comprehensive disaster management programme, Phase II (2010-14), Ministry of Food and Disaster, Bangladesh.

GoB, 2011. The Sixth Five-year Plan, 2011-2015. Ministry of Planning, Government of Bangladesh. Dhaka.

Goujon, A., Lutz, W., 2004. Future Human Capital: Population Projection by level of Education. In: Lutz W, Sanderson W (eds) The end of world population growth, human capital and sustainable development in the 21st century. Earthscan, London, 121-157.

Gujarati, D.N., 2003. Basic Econometrics, McGraw-HiII, New York.

Hailu, A., Nigatu, R., 2007. Correlates of household food security in densely populated areas of southern Ethiopia: does the household structure matter. Stud. Home Comm. Sci. 1(2), 85–91.

Hamelin, A.M., Habicht, J.P., Beaudry, M., 1999. Food insecurity: consequences for the household and broder social implications. Journal of Nutrition 129, 525S-528S.

Harrigan, J., 2008. Food insecurity, poverty and the Malawian Starter Pack: Fresh start or false start? Food Policy 33, 237–249.

Heald, C & Lipton, M 1984, *African food strategies and the EEC's role: an interim review.* Commissioned study, no. 6, Institute of Development Studies, Brighton.

Hossain, M., 2010. 'The 2007-08 Surge in Rice Prices: The Case of Bangladesh', in S. Ahmed & H.G.P. Jansen (eds), Managing Food Price Inflation in South Asia, Dhaka: University Press Limited.

IFAD, 2013. Rural poverty in Bangladesh, International Fund for Agricultural development, Rome.

Kazal, M.M.H., Villinueva, C.C., Hossain, M.Z., Das, T.K., 2010. Food security strategies of the people living in haor areas: Status and prospects. NFPCSP Final Report, National Food Policy Capacity Strengthening Programme, Dhaka.

Kawachi, I., Kennedy, B.P., Glass, R., 1999. Social capital and self-rated health: a contextual analysis. American Journal of Public Health 98 (8), 1187–1193.

Kennedy, P., 1998. A Guide to Econometrics, 4th edition. The MIT press, Cambridge.

Lin, J., 1991. Education and innovation adoption in agriculture: evidence from hybrid rice in China. American Journal of Agricultural Economics 73 (3), 713–723.

Long, J.S., 1997. Regression models for categorical and limited dependent variables. Sage Publications, UK.

Lutz, W., Goujon, A., Wils, A., 2008. The population dynamics of human capital accumulation. Population Development Review 34, 149–187.

MacFarquhar, N., 2011. Food prices worldwide hit record levels, fueled by uncertainty, UN. Says. NYT, February 3, 2011.

Maddala, G.S., 1992. Introduction to Econometrics, Macmillan Publishing Company, New York.

Mallick, D., Rafi, M. 2010. Are female-headed households are more food insecure? Evidence from Bangladesh. World Development 38(4), 593–605.

Mannaf, M., Uddin, M.T., 2012. Socioeconomic factors influencing food security status of maize growing households in selected areas of Bogra district. Bangladesh Journal of Agricultural Economics. XXXV (1&2), 177–187.

Maxwell, S & Smith, M 2006, *Household food insecurity: A conceptual review*, Institute of Development Studies, University of Sussex.

Mishra, A.K., Mottaleb, K.A., Mohanty, S., 2015. Impact of off-farm income on food expenditures in rural Bangladesh: an unconditional quantile regression approach. Agricultural Economics 46, 139–148.

Murungweni, C., van Wijk, M.T., Giller, K.E., Anderson, J.A., Smaling, E.M.A., 2014. Adaptative livelihood strategies employed by farmers to close the food gap in semi-arid south eastern Zimbabwe. Food Security 6, 313–326.

Omotesho, O.A., Adewumi, Lawal, M., Ayinde, O., 2006. Analysis of food security among rural households in Kwara State, Nigeria. African Journal of General Agriculture 2(1), 7–15.

Perry, C., 1998. A structured approach for presenting theses. Australian Marketing Journal 6(1), 63–85.

Rahman, K.M.M., Poza, A.S., 2010. Food consumption and nutritional status of vulnerable people rearing livestock in Bangladesh. Bangladesh Journal of Agricultural Economics XXXIII (1 & 2), 41–56.

Rahman, R. I., Begum, A., Bhuyan, H.R., 2012. Household food insecurity in Bangladesh: concepts, estimates and determinants. Bangladesh Institute of Development Studies (BIDS). Dhaka.

Reardon, T., 1997. Using evidence of household income diversification to inform study of the rural nonfarm labor market in Africa. World Development 25, 735–747.

Reddy, V. 1997. Diatery assessment Methodologies Relevent to the Development of Food-based Interventions. Published by Food and agricultural Organization, Regional Office for Asia and The Pacific.

Reji, E.M., 2013. Community grain banks and food security of the tribal poor in India. Development in Practice 23(7), 920–933.

Rice, P., Dorothy, Thomas, A., 1985. The economic costs of illiness: a replication and update. Health Care Financing Review 7(1), 61–80.

Rich, M., Lesley, O., Kavita, S., Golam, K., Setara, R., 2015. USAID Office of Food for Peace, Food Security Country Framework for Bangladesh (FY 2015–2019). Washington, DC.

Schmidhuber, J., Tubiello, F.N., 2007. Global food security under climate change. Proceedings of National Academic Science, USA, 104(50), 19703–8.

Shahabuddin, Q., 2010. The Right to Food: Bangladesh Perspectives. The Bangladesh Development Studies XXXIII (1&2), 91–134.

Shaheen, N., Rahim, A.T.M.A., Mohiduzzaman, M., Banu, C. P., Bari, M.L., Tukun, A.B., Mannan, M.A., Bhattacharjee, L., Stadlmayr, B., 2013. Food Composition Table for Bangladesh. NFPCSP Final Report, National Food Policy Capacity Strengthening Programme, Dhaka.

Sindhu, R.S., Kaur, I., Vatta, K., 2008. Food and nutritional insecurity and its determinants in food surplus areas: The case study of Punjab state. Agricultural Economics Research Review 21, 91–98.

Stiglitz, J.E., 1976. The efficiency wage hypothesis, surplus labour, and distribution income in LDCs. Oxford Economic Papers 28(2), 185–207.

Stuff, J.E., Casey, P.H., Szeto, K.L., Gossett, J.M., 2004. Household food insecurity is associated with adult health status. Journal of Nutrition 134(9), 2330–35.

Talukder, R.K., 2005. Food Security, Self-Sufficiency and Nutrition Gap in Bangladesh. The Bangladesh Development Studies 30(3 & 4), 35–62.

Telema, R., Yang, X., Viikari, J., Valimaki, I., Wanne, O., Raitakari, O., 2005. Physical activity from childhood to adulthood: a 21-year tracking study. American Journal of Prevent Medeicine 28, 267–273.

USDA, 2010. Bangladesh Grain and Feed Annual, United States Department of Agriculture, Washington, DC.

Vozoris, N.T., Tarasuk, V.S., 2003. Household food insufficiency is associated with poorer health. Journal of Nutrition 133(1), 120–6.

Wichstrom, L., von Soest T, Kvalem I.L., 2013. Predictors of growth and decline in leisure time in physical activity from adolescence to adulthood. Health Psychology 32, 775–784.

World Bank, 2015. World Development Indicators. The World Bank, Washington DC.