Department of Economics and Management
University of Helsinki
Finland

Diversification in Bangladesh: From on-farm, income and food consumption perspectives

Sheikh Feroze Rehan

ACADEMIC DISSERTATION

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Supervisors:	Professor John Sumelius, Department of Economics and Management, University of Helsinki, Finland.
	Stefan Bäckman, University Lecturer, Department of Economics and Management, University of Helsinki, Finland.
Reviewers:	Helena Hansson, Professor of Agricultural and Food Economics, Department of Economics, Agricultural and Food Economics; Swedish University of Agricultural Sciences, Sweden.
	Professor Gry Agnete Alsos, Nord University Business School, Norway.
Opponent:	Konstantinos Karantininis, Professor of Business Administration, Department of Work Science, Business Economics and Environmental Psychology; Swedish University of Agricultural Sciences, Sweden.
Custos:	Professor John Sumelius, Department of Economics and Management, University of Helsinki, Finland.

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Abstract

The objectives of this thesis were to make a systematic and detailed analysis of the diversification of farm households in Bangladesh. The thesis, based on three articles, applied data from a survey of 260 farm households in the central, northern, and southwest regions of Bangladesh. The first, second and third papers highlighted on-farm diversification, income diversification and the relationship between farm and food consumption diversification respectively. The first article identified the factors influencing on-farm diversification and, in doing the analysis, the paper compares farm households highly specialized in rice cultivation with more diversified farm households. Results revealed that the age of the head of the household, technical assistance, farm size, access to markets, access to credit and regional dummies are the main determinants of on-farm diversification. The active participation of women in farming activities was a noteworthy determinant that was found to increase diversification in Bangladesh.

The second article investigated the determinants and purpose of income diversification in Bangladesh. The findings showed that the extent of the overall diversification was determined by household endowments of assets such as wealth, higher education, easy access to market, more earners, better infrastructure, and its purpose was accumulation of wealth. However, farm households are involuntarily pushed into off-farm wage diversification for survival, and off-farm self-employment diversification is chosen as an accumulation strategy to capture higher return opportunities. This study pointed out that diversification is linked to agriculture rather than being a condition of departing from it.

Article 3 linked the research gap through presenting empirical evidence on the effect of diversification on household food security in the Bangladeshi context. The study found that diversification positively influences food security, especially from the food consumption diversity viewpoint. Importantly, this suggests that special focus is required on diversified multiple crop and non-crop production and moving out of pure rice cultivation. Moreover, formulating policies that emphasize investment in infrastructure, electrification, and education to facilitate diversification and enhance household food security has been recommended.

Keywords: farm diversification, income diversification, food consumption diversification, food security, off-farm diversification of income, overall diversification of income, motivation for diversification, determinants, purpose; women's participation, Bangladesh.

Tiivistelmä

Tämän väitöskirjan tavoitteena on systemaattisesti ja yksityiskohtaisesti analysoida Bangladeshin maatalouden kotitalousyksiköiden monipuolistamisesta. Väitöskirja perustuu kolmeen artikkeliin. Tutkija käytti aineistona 260 maatalouden kotitalousyksikköä käsittävää kyselyä Bangladeshin keski-, pohjois- ja lounaisosista. Ensimmäinen artikkeli keskittyi maatilalla tapahtuvaan monipuolistamiseen, toinen tulojen monipuolistamiseen ja kolmas maatalouden ja ruoan kulutuksen monipuolistamisen yhteyksiin. Ensimmäisessä artikkelissa tunnistettiin päätekijät, jotka vaikuttivat maatilalla tapahtuvaan monipuolistamiseen. Artikkelissa verrataan riisinviljelyyn vahvasti erikoistuneita kotitalousyksiköitä monipuolisemmilla viljelykasvivalikoimalla viljeleviin kotitalouksiin. Tulokset osoittivat, että perheen pään ikä, tekninen apu, maatilan koko, pääsy markkinoille, mahdollisuudet luoton saantiin ja alueita osoittavat muuttujat olivat tärkeimpiä monipuolistamista määrääviä tekijöitä. Merkillepantavaa oli, että naisten osallistuminen viljelytoimiin todettiin lisäävän viljelyn monipuolistamista Bangladeshissa.

Toinen artikkeli selvitti toisaalta tekijöitä, jotka määräävät tulojen diversifiointia, toisaalta tulojen monipuolistamisen tarkoitusta. Tulokset osoittivat, että kotitalouksien resurssit kuten varallisuus, korkeampi koulutus, helppo markkinoille pääsy, monta tulonsaajaa ja hyvä infrastruktuuri vaikuttivat ratkaisevasti monipuolistamisen laajuuteen. Monipuolistamisen päätarkoitus oli kerätä varallisuutta. Selviytyäkseen jotkut kotitalousyksiköt on vasten tahtoaan ajautuneet monipuolistamaan. Monipuolistamisen tarkoitus ei näille ole varallisuuden keräämistä vaan mahdollisuus päästä osalliseksi korkeimpia tuloja. Monipuolistamisella näin ollen on kaksi eri tarkoitusta. Monipuolistaminen ei ole kotitalouksille ehto jättää maatalouselinkeinoa.

Kolmas artikkeli keskittyi selvittämään, kuinka kotitalouksien monipuolistaminen vaikutti niiden ruokaturvaan. Tulosten mukaan monipuolistaminen vaikuttaa myönteisesti ruokaturvaan, etenkin ruokavalion monipuolisuuteen. Tämä tulos viittaa siihen, että enemmän huomiota olisi kohdistettavaa viljelykasvien monipuolistamiseen ja siirtymisestä pois pelkästä riisinviljelystä.

Lisäksi viljelyn ja ruokatottumusten monipuolistamiseksi tulisi muotoilla politiikkatoimenpiteitä, jotka edistävät investointeja infrastruktuuriin, sähköistämiseen ja koulutuksen.

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List of original publications

This thesis is based on the following publications:

1. Rehan, S.F., Sumelius, J. and Bäckman, S. (2017) 'Determinants of on-farm diversification in Bangladesh', *International Journal of Agricultural Resources, Governance and Ecology,* Vol. 13, No. 3*,* pp.294- 313.

2. Rehan, S.F., Sumelius, J. and Bäckman, S. (2019) 'The determinants and purpose of income diversification of rural households in Bangladesh', *International Journal of Agricultural Resources, Governance and Ecology,* Vol. 15, No. 3*,* pp.232- 251.

Accepted paper:

3. Rehan, S.F., Sumelius, J. and Bäckman, S.; Diversification as a means to improve household food security in Bangladesh, *Journal of Developing Areas.*

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Authors' contribution

The thesis is the summary of three related articles that deal with the same broad topic, diversification, but from different aspects and with different methodologies. The author, Sheikh Feroze Rehan was responsible for the overall research design and data collection. John Sumelius and Stefan Bäckman provided guidance during the process.

In article 1, the first author, Sheikh Feroze Rehan, was responsible for methodology, data collection and analysis, computations, reporting results and writing the manuscript. Sheikh Feroze Rehan also suggested the research question and was the corresponding author of the article. The second author, John Sumelius, and the third author, Stefan Bäckman, contributed to this paper through its theoretical part and revision.

Sheikh Feroze Rehan was the first author of the 2nd paper and suggested the research question. He was also responsible for choosing the appropriate econometric models, methodology, data collection and analysis, computations, reporting results and writing the manuscript. Rehan was also the corresponding author of the article. All the authors jointly contributed to constructing the variables for the model and revising the final manuscript.

Sheikh Feroze Rehan was the first author of the 3rd article, responsible for methodology, data collection and analysis, computations, reporting results and writing the text. The second author, John Sumelius, and the third author, Stefan Bäckman, contributed to this paper through its theoretical part and revision.

Contents

1 Introduction

Throughout the world, farms are facing challenges arising from price volatility, competition and a rise in input prices. Dependence on climatic conditions, production fluctuation, and inadequate returns push farm households into the uncertainty of income variation. A significant approach to adjusting to such an insecure situation is diversification, which is used as a coping strategy by farm households to accommodate income fluctuation through acquiring additional income from other sources. Besides, it could be used as a strategy to enhance farm household income flow. Change in consumer preferences, the decreasing trend in cereal consumption, an increase in purchasing power, technological development, and globalization offer new opportunities for various on-farm and off-farm activities. Diversification as a strategy to engage in on- and/or off-farm income-generating activities incorporates two approaches: i) on-farm diversification refers to engaging in farming activities such as crop production and non-crop food production such as livestock, poultry and fishing (Joshi et al., 2007; Taylor, 1994) ii), while off-farm income diversification represents moving out of pure on-farm activities to off-farm income sources (de Janvry and Sadoulet, 2001; Delgado and Siamwalla, 1997; Reardon et al., 1992).

In a country such as Bangladesh, where per capita consumption of fruit, vegetables, spices, edible oil and animal products is increasing, whereas the proportion of rice consumption has been following a decreasing trend, empirical examinations of diversification are important. Such research helps to determine the factors which allow farm households to identify some prospect of enhancing the extent of diversification. Investigating diversification might suggest the combination of assets which makes successful diversified farms. The findings may have crucial implications for policy makers for developing diversification supportive policy in Bangladesh.

Agricultural production is one of the main driving forces of Bangladesh's economy. Historically, farm production is primarily focused on rice production in Bangladesh. A significant achievement in production was the increase in cropping intensity of rice, high-yielding varieties of seed, chemical fertilizers and irrigation (Rahman, 2015). However, continuous rice monoculture is threatening sustainable crop base agriculture since it is harmful for the soil (Husain et al., 2001). Recently, the government has given priority to reducing excessive dependence on any single crop and turned to diversification. The seventh and current Five-Year Plan (2016-2020) emphasizes

farm diversification by spreading the production of non-cereal crops and non-crop agricultural products among farms.

Existing literature on this issue mostly focused on crop diversification, devoting little attention to on-farm diversification in Bangladesh. Thus, this study reduces the research gap through examining on-farm diversification, including opting for livestock, poultry and fishery activities in addition to changes in crop farming. In Bangladesh, where arable land is decreasing, more attention to on-farm diversification is required for the betterment of the households. For example, the poultry and livestock sectors generate more income from limited areas than cereal growing, and rural families can utilize surplus labor to enhance their incomes. Weinberger and Lumpkin (2007) highlighted the issue, arguing that the staple crop production is less advantageous than non-cereal crops such as fruit and vegetable cultivation given the scarcity of arable land. Meert (2005) pointed out that agricultural diversification incorporates the growing of alternative crops for specific farming environments and raising of animals. Thus, in the context of Bangladeshi agriculture, a major rice producing nation, moving out of rice monoculture into non-rice crop cultivation and/or non-crop agriculture such as livestock, poultry and fishing are considered as on-farm diversification. This study pays special attention to this issue.

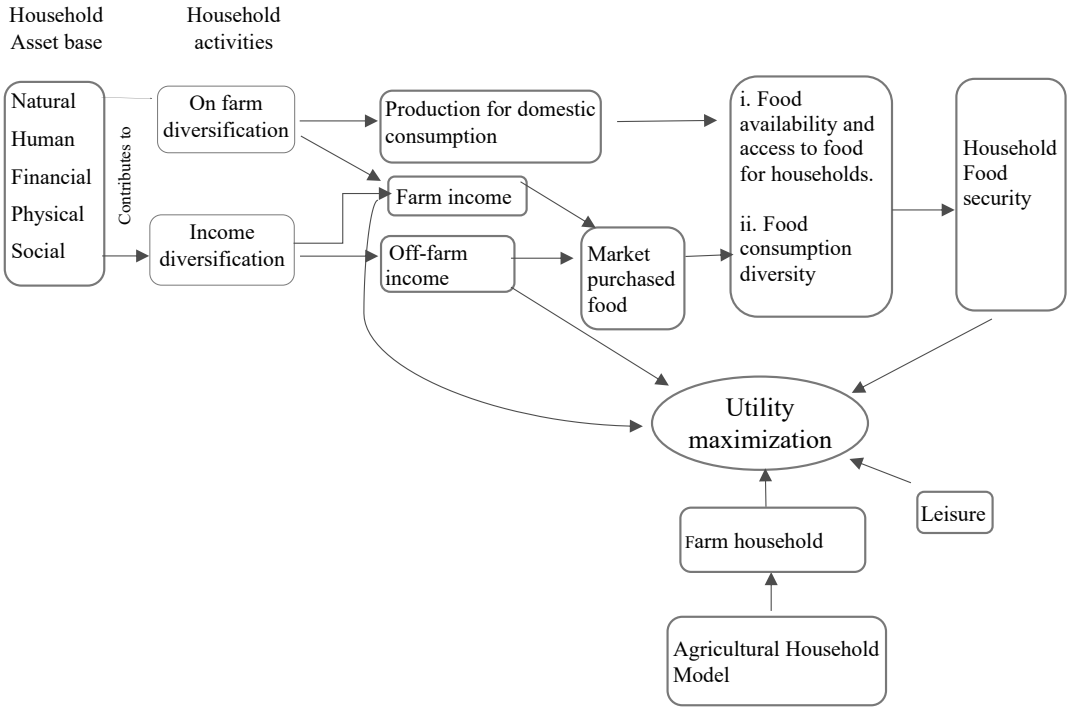
Evidence shows that households diversify income sources both within and outside of farming. The purpose of income diversification is classified as either push or pull reasons (Barrett et al., 2005; Barrett et al., 2001). This inspection will provide an insight into the proper motive of on- and off-farm strategies – voluntary vs. necessity driven choices. Participation in various activities may not be a voluntary choice for the households, which may rather be pushed into diversification for survival and to maintain income flow. Pull motives, in contrast, influence diversification in order to realize higher return opportunities to earn more. Little published evidence exists on how the motives for and determinants of off-farm income diversification conform to or differ from overall income diversification in Bangladesh.

The determinants of and purpose behind diversification may differ depending on the approaches to it. Overall income diversification connects full range of multiple income sources undertaken by a household, which may comprise both on and off-farm activities. On the other hand, off-farm diversification deals with divergence towards off-farm wage employment and self-employed

initiatives. Since diversification takes different characteristic and nature, the study appropriately used different measures for analysis. Identification of the relevant influences of diversification can benefit government policies and guidelines related to the issue. This study aims at synergetic outcomes through a consolidation of farm and off-farm activities.

The thesis relies on the Agricultural Household Model (AHM) as a theoretical framework which is particularly appropriate for an empirical study such as this. The connection between the theoretical framework and the econometric models applied in the study is discussed below:

Figure 1. Conceptual framework for linking on-farm, income and food consumption diversification at household level



Source: Adapted from Ellis (2000) and Feleke et al. (2005)

The Agricultural Household Model provides a theoretical rationale for this thesis related to diversification in that rural households seek to maximize their utility. Households do this from the consumption of food purchased, produced at home, and leisure. In addition, household demand for food is stimulated by income, preferences and price which in turn depends on the farm households'

asset endowment. Singh et al. (1986), claimed that household food consumption and production equations depend on farm, household and market characteristics such as market price, the farm's available production technology, its land size, the capital available to farm households and the market wage rate. According to the household model, a farm household is both a producer and consumer of food. As a producer, an increase in price results in higher household income that eventually influences household consumption. Feleke et al. (2005) followed the model developed by Singh et al. (1986), pointing out that the first-order conditions of the household equilibrium function provided demand and supply functions that facilitated identification of the determinants of household food security. Maximization of utility yields the following form of equation according to Feleke et al. (2005):

$$F_k = F_k[P_i, P_m, w, Y_*(w, A_0, K_0, N), D_h]$$

where P_i and P_m represent the price of goods, w stands for wages, A_0 stands for quantity of land, and K_0 represents capital. In addition, N stands for non-farm income, and D_h represents household characteristics. From the theoretical model, the authors identified several factors such as farm size, household size, per capita aggregate production, technology adoption, farming system, land quality, wealth, off-farm work, and access to the market as the determinants of household food security in Southern Ethiopia.

Escobal (2001) used the model of Singh et al. (1986) in farm household analysis in Peru, deriving a reduced form equation from the model consisting of various assets, such as human-capital, financial, public, fixed farm assets, fixed non-farm assets, and area related assets. These resources could be classified into five groups that shape the capacity and purpose of the farm household's diversity (Ellis, 2000). The assets groups are natural (e.g., land), human (e.g., education, the number of household earners), financial (e.g., wealth, savings), physical (e.g., roads, market and electrification), and social assets (e.g., connection and network). A large number of farm household analyses found that a household's bundle of assets contributes to deriving the key determinants of its involvement in farm and non-farm diversification. For example, Benin et al. (2004) analyzed on-farm diversity at household level in the Ethiopian highlands based on the household model developed by Singh et al. (1986). The study used human assets (age of household head, gender composition of the household, household size) , financial assets (wealth) , natural assets (land size, number of plots, regional dummy) and physical assets (distance to road, distance

to town) for the investigation. On the other hand, Croppenstedt (2006) applied the same model and household asset groups to examine the determinants of income diversification in Egypt.

Households utilize these assets in order to engage in diversified activities that include two approaches such as on-farm diversification and income diversification. However, simply the availability of food in the market is not enough for household food security. People need to consume nutritionally adequate food in terms of variety, indicating that a sufficient income generation is vital in order to be able to acquire the food the household requires. Consequently, it is expected that outcome generated from diversification will translate into sufficient food access and diversity for households. It is expected that diversification will improve household food security status in two ways. 1) production for domestic consumption and 2) income effect, which are discussed below:

On-farm diversification permits households to consume from their own production and allows the availability of various food items to these households throughout the year. Besides, incremental income provides the opportunity to buy more nutritionally enriched food. Sibhatu et al. (2015) found a stronger association between agricultural diversification and diet diversity in Indonesian farm households than on farm households from Malawi and Ethiopia. The authors pointed out that this occurred because most of the farmers in Indonesia in their sample grew only rubber. The farm households often undertook oil palm cultivation in order to diversify. Thus, food diversification improvements were achieved through increased income and the purchase of more diverse food in this case. Other evidence argues that farm diversification benefits diet through direct consumption from the domestic cultivation pathway. Dewey (1981) points to a higher degree of self-sufficiency in food being more valuable than purchased food in farm diversity. In Mexico, nutritional status was negatively associated with lower crop diversity and increased reliance on market purchased food by the author. However, farmer engagement with market-oriented production could be constrained by poor access to market and institutional support (Jones, 2017; Koppmair et al., 2017).

Besides, diversification benefits by reducing income fluctuation and maintaining the required food consumption during unexpected events. Mango et al. 2018 reported that more diversified farms are less likely to adopt coping strategies for food insecurity. The authors argued that farming

households engaged with multiple crop production are more resistant to income and food shortages. Income earnt from one crop compensates income losses from another and ensures a steady return, providing the chance to manage stable consumption in the wake of crises

Table 1: Summary of the results from the articles that used AHM as the theoretical framework

Household-asset categories	Study with objectives			
	To identify the determinants of household food security in Southern Ethiopia using cross-section dataset by Feleke et al. (2005).	To analyze the determinants of crop and variety diversity on farms in Ethiopia by Benin et al. (2004).	To investigate the household income determinants in Rural Egypt using cross-section dataset by Croppenstedt (2006).	To examine the determinants of nonfarm income diversification in Rural Peru by Escobal (2001).
Natural	Farm size, Land quality.			
Human	Household size.	Education, Household labor stock	Age, Education.	Education.
Financial	Wealth, off-farm work income, Per capital aggregate production.	Wealth.	Livestock, off-farm income.	Access to credit.
Physical	Access to the market, Farming system, Technology adoption.			Access to road.
Social				

and protection against food insecurity. Moreover, the households keep the option of maintaining food consumption from their own source while the selling price drops or scarcity affects the market. It is expected that household food security status is improved by these means and thus influences household utility maximization.

Table 1 summarizes the results from the articles that used AHM and found the following significant determinants through the econometric models based on the five household-asset groups shown in figure 1. Thus, these articles revealed that the theoretical model (AHM) is connected with the econometric models through the household asset groups and determinants. In a similar way, the asset groups a household possesses have been used in this thesis as a basis for econometric models. Here, the household's decision to diversify is a function of the household's asset possession:

f (household's natural assets, financial assets, human assets, physical assets, social assets).

This connection in relation to the findings of the thesis is shown in the results section (Table 4).

The thesis depends on cross-sectional data that pose a challenge for any causal analyses, which is a recognized limitation of this study. Good panel data are required to assess the effect of the variables over time. However, in the econometric model, reverse causality could exist from the dependent variable to independent variables which causes inconsistency in the estimation. Econometrics analysis investigates the causal relationship between dependent and independent variables and predicts the effects of changes in the independent variables on the dependent variable. But problem arises if the independent variables are affected by the dependent variables, a situation in which the results should be interpreted cautiously. In order to tackle this problem, the instrumental variable estimation technique is used in the analysis. An instrumental variable is highly correlated with the independent variable(s) that may be influenced by the dependent variable in hand but uncorrelated with the error term. It is worth noting that when the instrument is weak the estimator is also inconsistent (Greene, 2012). On the other hand, it is very difficult to find an appropriate instrumental variable in cross-sectional data (Woldenhanna and Oskam 2001). Therefore, instrumental variables are not been used in many studies based on the cross sectional dataset . Table 2 presents a list of studies that have used cross sectional study data without applying the instrumental variable technique in the analysis. Besides, the following papers applied either the ordinary least squares (OLS) or the maximum likelihood estimation (MLE) method for econometric analysis. In this thesis, article 3 used an instrumental variable technique but in article 1 and 2 the models did not test for reverse causality. In the table, the determinants of the left- hand column are the factors that influence on-farm, income or food diversification in Bangladesh identified in the thesis. These factors are also in line with the findings of the following similar types of studies.

Table 2: Determinants of on-farm, income or food diversification in Bangladesh with the supporting references that have used a cross sectional dataset.

Determinants	Supporting references				
	Journal	Authors/date	Focus	Data design	Country
Access to Market	Food Policy	Lanjouw et al. (2001)	To examine non-farm earnings.	Cross-section survey data from 592 farm households.	Tanzania
	Public Health Nutrition	Koppmair et al. (2016)	To analyze farm production diversity, dietary diversity and market access in rural households.	Cross-section survey data from 1482 farm households.	Malawi
Technical assistance	Land Use Policy	Kasem and Thapa (2011)	Crop diversification in Thailand: Status, determinants, and effects on income and use of inputs.	Cross-section survey data from 245 farm households.	Thailand
	Agricultural Systems	Van den Berg et al. (2007)	To assess the effects of increasing farm size and the transition from rice to vegetable production on rural income.	Survey.	China
Farm size	Agricultural Economics	Feleke et al. (2005)	To identify the determinants of household food security.	Cross-section survey data on 365 household.	Ethiopia
	Outlook on Agriculture	Ullah and Shivakot (2014)	To investigate the impact of various factors on farmers' decisions to adopt on-farm and off-farm diversification.	166 farm households were interviewed.	Pakistan
Access to credit	African Journal of Agricultural Research	Aneani et al. (2011)	Extent and determinants of crop diversification by cocoa farmers.	Cross-section survey data from 300 farmers.	Ghana
	Quarterly Journal of International Agriculture	Komarek (2010)	Crop diversification decisions.	Cross-section survey data. from 70 households.	Uganda

Higher level of education	World development	Corral and Reardon (2001)	To investigate rural nonfarm incomes.	Cross-section nationwide survey.	Nicaragua
	ESA Working Paper	Croppenstedt (2006)	Household income structure and determinants.	Cross-section household survey data.	Egypt
Age of household head	World development	de Janvry and Sadoulet (2001)	Income strategies among rural households.	Cross-section nationwide survey.	Mexico
	Journal of Tropical Agriculture, Food, Environment and Extension	Ibrahim et al. (2009)	Diversification among farming households in a rural area.	Cross sectional data on 100 households.	Nigeria
Wealth	Food Policy	Block and Webb (2001)	The dynamics of income diversification.	Cross-section survey data from 300 households.	Ethiopia
	Quarterly Journal of International Agriculture	Beyene and Muche (2010)	To identify the determinants of household food security.	Cross section survey of 196 farm households.	Ethiopia
Non-agricultural income	Food Policy	Babatunde and Qaim (2010)	Impact of off-farm income on food security and nutrition.	Survey of 220 farm households.	Nigeria.
	PNAS (Proceedings of the National Academy of Sciences of the United States of America)	Sibhatu et al. (2015)	To examine the association between production diversity and dietary diversity in smallholder farm households.	Cross-section surveys of farm Households.	In Indonesia, Kenya, Ethiopia, and Malawi.
Regional dummies	Agricultural Economics	Feleke et al. (2005)	Determinants of household food security.	Cross-section survey data on 365 households.	Ethiopia
	World development	de Janvry and Sadoulet (2001)	Income strategies among rural households.	Cross-sectional nationwide survey.	Mexico

As Table 2 shows, many studies on diversification are based on results without considering the reverse causality issue. The same approach has been adopted here, although the limitation must be kept in mind. In support of the above-mentioned papers and discussion, this thesis insists on the resulting determinants as the factors that influence diversification in Bangladesh. The study would have benefited from having some additional variables that could be used as instrumental variables but were not included in the survey.

The principal contribution of this thesis is to draw attention to some neglected aspects of diversification, especially from the perspective of Bangladesh. Table 3 shows that little attention has been dedicated to analyzing diversification, especially from the aspects of i) moving into non-cereal crops instead of cereal production, ii) examining overall diversification of farm household income portfolio and iii) determining the relationship between diversification and food security. Given the limitations of these studies, the thesis has focused on and analyzed those aspects. This thesis aims to fill the gap through increasing the understanding of diversification progression in farm households in three ways: first, the study considers alternative non-traditional production strategies within farming (Article 1). Second, the thesis focuses on alternative off-farm activity strategies and identifies their determinants and purpose (Article 2). Third, the thesis investigates the relationship between alternative production strategies and household food consumption (Article 3).

Table 3: List of studies related to diversification in Bangladesh

Author	Focus	Data design
Mahmud et al. (1994)	Crop diversification in Bangladesh.	Census of agriculture, 1983-84.
Rahman (2009)	Crop diversification analysis.	Based on a sample of 406 households.
Rahman (2008)	Determinants of crop choices in Bangladesh.	Farm-level cross-section data for crop year 1996 collected from three agroecological regions of Bangladesh.
Miah and Haque (2013)	Agricultural diversification in Bangladesh.	Cross-section data with a total sample size of 960 farm households.
Akanda (2010)	Crop diversification under changing climate, hydrology and food habit in Bangladesh.	Based on secondary data.
Hossain (2004)	Rural non-farm economy in Bangladesh.	Household income and expenditure survey, 2000.
Nargis and Hossain (2006)	Income dynamics and pathways out of rural poverty in Bangladesh.	Nationally representative longitudinal survey in 1988, 2000, and 2004.
Malek and Usami (2010)	Non-farm incomes for small households in rural Bangladesh.	Field survey with data from about 175 small households.
Faridi and Wadood (2010)	Assessment of household food security focusing only on the calorie requirement dimension.	Household income expenditure survey (HIES) for 2005.
Rashid et al. (2006)	Determinants of dietary quality.	Nationally representative household expenditure survey conducted in 2000.
Thorne-Lyman et al. (2010)	To examines associations between household dietary diversity and food expenditures.	Based on data collected for 3 years.

Article 3 of the thesis used multiple farm diversity measures that allowed evaluation of the consistency of the relationship between food diversity and farm production diversity. It is innovative in that the analysis includes a diversification index as one of the indicators capturing the effect of moving out of rice monoculture on dietary diversity which refers to an important contemporary issue. As a large number of farm households are engaged in rice production in Bangladesh, diversification means production of non-cereal crops and non-crop products like livestock, poultry and fishing in this context. Globalization complemented by an increase in income creates demand for fruit, vegetables, fats, protein and offers market opportunities for non-cereal diversification. Thus, inclusion of this measure in the analysis is the main contribution of this paper. Besides, the study incorporated Simpson's Index of Diversity, which takes into account the number of species present, as well as the relative abundance of each species in the production process. It is important to note that nutritional content of household food consumption has been affected by lack of diversity in production activities in Bangladesh. Food consumption needs to be balanced and its security depends on availability, access to food, utilization and stability at household level (Ashby et al., 2016). Food security becomes an issue for concern and for possible policy response when it relates to nutritional deficiencies and access to food in Bangladesh. The previous papers related to food security in Bangladesh focused primarily on the calorie availability dimension and do not investigate the effect of farm diversification on dietary diversity, considering diversification of production beyond cereals, especially rice production at household level. The present study contributes to the literature through filling this gap.

Besides, article 1 highlighted the determinants of an on-farm diversification strategy that generates alternatives to rice production while most of the studies emphasized crop diversification only. The active participation of women in farming activities is a noteworthy determinant that is found to be significantly connected with diversification. Article 2 segregates income diversification into off-farm diversification and overall diversification of the income portfolio. This approach of observing them from different angles has been neglected and this paper's contribution remains its identification that the purpose of diversification is distinct subject to the natures of the strategies adopted.

The summarizing report of the thesis is organized as follows: section two presents the background information on diversification from the farm income and food diversity perspective. The core concepts of the stated matters are also described in this section. Section three discusses the objectives of the study. Section four includes the data and methods used, covering the description of the study area, detail of the data collection process along with the modelling methods. The results and key findings are outlined in section five and the thesis ends with section six, which covers concluding remarks, policy implications and suggestions for further research.

2 General Background

2.1 The agriculture sector in Bangladesh

Farm production is one of the main driving forces of the Bangladesh economy. Agriculture contributes 14.10 percent of country's GDP and 40.60 percent of total employment (BBS, 2018). The overall economic development is affected by the achievement of the agricultural sector, though its proportion of GDP is falling. Bangladesh produces grain, vegetables, fruit, oil crops, sugar crops, fiber, pulses, and roots and tubers. The area under cultivation of different crops is given in Figure 2. Rice is grown on over 74 percent of the total cropped area.

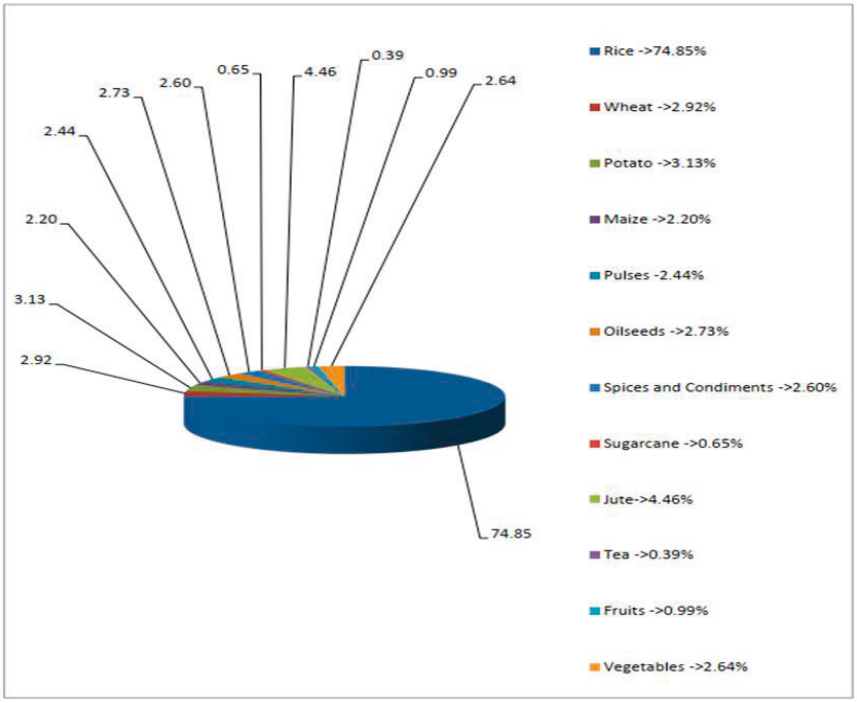


Figure 2: Area under cultivation of different crops in Bangladesh, 2015-2016

Source: Statistical Yearbook of Bangladesh, 2017

In addition, the contribution of the livestock and fisheries sub-sectors to the overall agricultural sector is 35-40 percent alone. This contribution is about 7-8 percent of the total GDP, among which 1.53 percent comes from livestock and 3.57 percent from the fisheries sub-sector (Bangladesh Economic Review, 2019).

2.2 Crop diversification in Bangladesh

Increasing crop production has traditionally been emphasized in Bangladesh. The government had launched Green Revolution programs back in the 70's, intending to increase cereal production through high yielding rice varieties and extended utilization of fertilizers, irrigation and chemical inputs. These actions resulted in vastly increased rice production but the harvest for other crops such as oilseed, vegetables, fruit, and pulses had decreased. These output driven approaches tended to focus on food energy but contributed to a deterioration in the nutritional quality of diets. In addition, rice monoculture reduced soil fertility and diseases broke out in the fields. However, the government initiated the first Crop Diversification Program (CDP) after understanding the significance of growing other crops than rice in 1989 (Miah 2011). CDP improved the production of tubers, pulses and oilseed though diversification, but remained low in comparison to requirements. It was paramount to change existing policy and put more emphasis on meeting human nutritional requirements. In response to this, the Seventh Five-Year Plan (General Economics Division and Planning Commission, 2016), has stressed the importance of diversification.

A few studies have investigated crop diversification in Bangladesh. Mahmud et al. (1994) investigated agricultural growth and crop diversification in Bangladesh, finding that producing many non-cereal crops under irrigated conditions is more profitable in Bangladesh. The same researchers suggested that cultivation of non-cereal crops such as vegetables, potatoes, and spices are advantageous for small-scale farmers. Later Rahman (2008) investigated the factors affecting crop diversification using a bivariate probit model, and found that farm asset ownership, land without irrigation, farming experience, non-agricultural income and the educational level of farmers are the main factors of crop diversification. Surprisingly, very few empirical studies have investigated on-farm diversification, which incorporates selection for non-crop undertakings such as livestock, poultry and fisheries activities in addition to changes in crop farming.

To the best of our knowledge, the only study on agricultural diversification in Bangladesh has been conducted by Miah and Haque (2013) in recent times. The authors concluded that agricultural training, irrigated land, access to credit, extension linkage and family influence affected diversification positively. In order to fill the research gap, this thesis performs empirical studies on diversification with a full range of farming activities. Integration of the key factors of this research into diversification policy will promote production diversification and improve the lives of farm households in Bangladesh. The extent of diversification has been assessed through the diversification indices, which are discussed in the following part.

2.3 Crop diversification indices

In the diversification literature, there are several types of measurement indices such as the Herfindahl index, the Shannon index, the Entropy index, the Simpson index, etc. These diversification indices include evaluations of richness and evenness. These are enhanced under conditions in which the number of land cover types (richness) rises, or the distribution of land amongst the various cover types (landscape evenness) increases, or both. A brief description of these indices is given below:

2.3.1 Herfindahl index

The Herfindahl index is formulated as:

$HI=(1-\sum_{i=1}^{N} P_i)$

where N = Total number of crops, and

P_i = Proportion of acreage of the i^{th} crop to total cropped area.

The value of HI always falls between 0 and 1. The value moves to one as N becomes larger, while it tends to zero when only one crop is cultivated. An increasing value of HI thus indicates an increase in diversification.

2.3.2 Shannon index

$SHDI = (1-\sum_{i=1}^{N} p_i \text{ X } \ln p_i)$

where N is the number of cultivated crops, p_i expresses the proportion of area covered by a specific crop and 'ln' is the natural logarithm. The index is zero when there is only one crop, meaning no diversity. The value increases with the number of cultivated crops and when the cultivated areas under various crops become more even.

2.3.3 Entropy index

The mathematical formula of EI is given below:

$EI = \sum_{i=1}^{n} P_i^2 \log {}^{1}/_{P_i}$

P_i = Proportion of i^{th} crop

The Entropy index is applied to acreage proportion to measure the crop diversification. The values of the index vary from 0 to 1. A value of zero indicates perfect specialization while a value of one indicates perfect diversification.

2.3.4 Simpson Index of Diversity (SID)

This has been used to measure the crop diversity which is defined as:

$SID = 1 - \sum_i P_i^2$,

where P_i is the proportion of cropped area of the i^{th} crop.

The value of SID falls between '0' and '1'. A value of zero indicates that just one crop is being cultivated, while an increasing SID value expresses an increase in diversification.

2.4 Farm diversification

Farm diversification is defined as the distribution of a farm's capital, land or labor resources into new nontraditional crops and/or animals attached to the farm (Ilbery, 1991). In contrast to this on-farm centered approach, researchers such as Shucksmith et al. (1989) and Fuller (1990) reconceptualize the farm diversification definition, stressing incorporation of the off-farm occupations of farm households into on-farm activities, which is termed as pluriactivity. This means farm households depend on multiple full-time or part-time income sources.

The combination of farm-based accommodation and recreation activities offered on farms is another type of farm diversification. This also includes purchase of agricultural products on-site, processing of primary agricultural product, and recreational harvesting of farm products such as fruit and flowers (Barbieri and Mahoney, 2009; Barlas et al., 2001). In addition, farmers providing contract services is considered as diversified farms (Ilbery, 1991). The author discussed agricultural diversification as organic farming, unconventional crops and animal products, farm woodland and agricultural contracting. Besides contracting, renting out the farm's resources in order to take advantage of any opportunity could be considered as diversification (Mcnally, 2001).

Previous studies have revealed the importance of on-farm diversification in developing countries. For instance, Joshi et al. (2007) pointed out that production of fruit, vegetables, dairy, poultry, and aquaculture products—in addition to or as a substitute for rice and wheat—enhance farm income in South Asian countries. In addition, Jaffee (1992) found that demand driven farm diversification combined with effective support enable farmers to gain a high level of productivity in many African countries. Similarly, Adriano and Cedillo (1992) researched the Philippines and suggested that an integrated approach, taking into account the livestock, poultry and fisheries sectors, contributes to that country's economic growth.

This study takes on-farm diversification as involvement in crop and/or livestock that is non-traditional for farmers in a given region (Damianos and Skuras, 1996). Traditionally, farmers are engaged with rice cultivation that accounts for 75 percent of the gross cropped area in Bangladesh (BBS, 2018). Recently, the government has taken initiatives to encourage farmers to diversify from rice mono-cultivation to other alternatives. Thus, moving out of rice production and engaging in unconventional non-rice crop cultivation and/or non-crop agriculture such as livestock, poultry and fisheries is considered here as on-farm diversification in the context of Bangladeshi agriculture. Similarly, Goletti (1999) characterized agricultural diversification from the South-east Asian perspective as a gradual movement out of rice growing into more diversified production.

2.5 Income diversification

Farmers do not rely solely on cultivation for income any longer. Rather, they generate earnings from a portfolio of income activities with different returns. Thus, the farm households allocate

their resources to different income generating activities both within and external to the farming sector. In this case, overall diversification of income reflects farm households' involvement with more than one activity. Besides, evidence reveals that a significant proportion of rural households earn from off-farm sources, and diversification away from agriculture is increasing (Davis et al., 2010, Reardon et al., 1994). Uncertainty in agriculture or some lucrative opportunity in non-agricultural activity motivates farm households to leave farming activities. Researchers defined this situation of moving out of pure on-farm activities to off-farm income sources as off-farm income diversification (de Janvry and Sadoulet, 2001; Delgado and Siamwalla, 1997; Joshi et al., 2003; Reardon et al., 1992). Instead of increasing the number of economic activities, off-farm diversification focuses more on off-farm activities. It is important to understand the nature of income diversification and distinguish the factors driving households into diversification. Earning income from multiple sources by farm household is also known as pluriactivity (Ronning and Kolvereid, 2006; Hawkins et al., 1993).

The purpose of diversification can broadly be grouped into push and pull factors. The pull strategy sees households as attracted into diversification to get a higher return. Diversification driven by pull factors stimulate households with available resources such as land, labor, or skills to pursue higher return opportunities, permitting the farm to grow larger as higher income allows capital accumulation and reinvestment in farming. Households with limited asset endowments, however, are pushed into diversification for income smoothing over time (Barrett et al., 2005). The lower risk produced by off-farm income reduces income fluctuation and acts as a means of survival during a crisis. Income diversification plays a vital role in smoothing consumption where functional credit and an insurance market is absent (Barrett et al., 2001). Thus, diversification is considered as a risk management strategy when it is a deliberate ex-ante initiative in response to anticipated possible future events. On the other hand, diversification expresses coping behavior when it is an enforced ex-post strategy against an unexpected loss in household income or some natural catastrophe (Ellis 1998).

The household's asset bundle that influences the nature and extent of diversification strategy is categorized as natural (e.g., land), human (e.g., education, the number of household earners), financial or its substitutes (e.g., savings, credit), physical (e.g., roads, market and electrification),

and social assets (e.g., connection and network) (Ellis, 2000). Abdulai and Crole-Rees (2001) conducted an analysis in Southern Mali to investigate the overall portfolio diversification of household income, finding that the wealth of the household and market proximity positively influenced diversification. Dercon and Krishnan (1996) determined that the household's location, financial capital, and the skills of its members affected participation in diversified portfolio income sources. Besides, off-farm income diversification is also influenced by a household's asset base. For instance, Rahut et al. (2014) reported that the quantity of land owned by the household, the number of earners, the distance to facilities such as schools and health centers, and regional dummies have significant impacts on off-farm diversification. In the present study, we applied the same assumption that household assets were specified as variables for income diversification analysis.

2.6 Food diversification

Household consumption patterns in Bangladesh, as well as in other South and Southeast Asian countries is highly cereal based since food diversification in those countries is not yet widespread. Food diversification is intended to change household consumption patterns in order to improve nutritional content and thus food security status through consuming more diverse types of food in those countries. Essentially, ensuring household food security is one of the main challenges of Bangladesh and consumption diversification is one of the main pillars of household food security. Food security exists when all people at all times have constant access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). This definition posits four dimensions of food security: availability, access, utilization and stability. First, availability at household level relies on the households' ability to acquire or produce food and the obtainability of food at the local markets. Availability is however not enough, since people need to have the resources for acquiring sufficient quantities of food. Access to food refers to whether the household earns enough to buy food or possesses enough land with other resources to produce its own food. Income enhancement ensures better access to food and contributes to improving the household food security situation. In addition, the definition includes that food be nutritionally adequate in terms of quantity, quality and variety. Moreover, food security implies the absence of vulnerability and the capacity to acquire food over time.

In Bangladesh, household diets are predominantly based on starchy staples and often include little animal products and few fresh fruits and vegetables (Ruel, 2003; Murshid et al., 2008). Rice monoculture still being so popular in the region may be because of convention and the habit of relying upon rice in all meals. Moreover, in-depth knowledge of rice cultivation accumulated over the years probably inhibits farmers from moving out of rice farming to less familiar production systems. But rice specialization is causing a severe barrier to household food security, especially from a dietary diversity and nutritional point of view. Specialization may give economies of scale but diversified production offers organizational profits because of reduced transport and marketing costs, so that production may influence diet and nutrition. Recently, it has been observed that the constant growth in GDP, increasing personal income, and change in consumer preferences have pushed up demand for non-cereal food and opened up favorable conditions for shifting away from cereal production. In this situation, food consumption diversity needs to be prioritized through promoting production diversity in Bangladesh immediately, in order to ensure household food security. Consumption diversity could be enhanced through improving economic access to food by reducing income variability or by increasing incomes through higher return opportunities. Incremental earnings and a reduction in income variability from production diversity have the potential to secure access to sufficient food and thus to improve household food security. Besides, diversified production of` crops, animal products, fish and other products offers an opportunity to consume from their own various production. It may ensure the supply of food during natural and/or market shocks.

Food adequacy and diversity is examined through dietary variety instruments which are useful as these capture nutrient intakes and are easier to collect (Hooshmand and Udipi, 2013; WFP, 2009; FAO 2010). These measurements consider food frequency, meaning how often the various food groups are consumed in a given period of time, as well as how many different food types or food groups are included within a diet. Hoddinott and Yohannes (2002) investigated the relationship between energy adequacy and dietary diversity scores in ten countries. The study results show that household food diversify positively improves energy availability as well. Thus, dietary diversity at the household level is considered as an indicator of food security and/or diversification.

In this thesis, we applied a comprehensive approach through measuring dietary diversity in two ways. First, a Household Dietary Diversity Score (HDDS) was constructed for the analysis, based on the number of different food groups consumed by each household in the previous 24 hours. The food items are classified into 12 food groups such as cereals, root and tubers, vegetables, fruits, meat, eggs, fish and seafood, pulses/nuts, milk and milk products, oil/fats, sugar/honey and miscellaneous. Secondly, dietary diversity was assessed through calculation of the household Food Consumption Score (FCS). The FCS is a frequency weighted diet diversity score calculated using the frequency of consumption of various food groups consumed by a household during the previous 7 days. The eight food groups used to calculate FCS are cereals, pulses, vegetables, fruit, meat and fish, milk, sugar, oil, and condiments. The consumption frequency of each group is multiplied by an assigned weight based on its nutrient content, and those values are then added to obtain the Food Consumption Score (FCS). This approach permits us to recommend that contribute to develop policies with the objective of ensuring food security through emphasizing diversification.

3 Objectives of the study

The main aim of this study is to make a systematic and detailed empirical analysis of diversification at household level in Bangladesh. The thesis focused on on-farm diversification, income diversification and the relationship between farm and consumption diversification, which have all been analyzed in article 1, article 2 and article 3 respectively. The first paper of the thesis measured the contribution of alternatives to rice cultivation in Bangladesh and identified the factors influencing on-farm diversification. The objective was to support development and policy interventions that will permit diversifying household on-farm production into those with higher income achieving potential and into nutritionally improved foods. In doing the analysis of farm diversification, the paper compares farm households very specialized in rice cultivation with more diversified farm households.

In Article 2, the aim was to explore the pattern of various income sources to the household's total income in Bangladesh. The main objective was to assess the factors that affect the nature and extent of household income diversification in Bangladesh and the purpose behind the diversification approach adopted. The article considered it important to differentiate the household's diversification nature if determinants and purposes differs through such approaches. A further objective was also to recognize whether wealthier households diversify to a larger extent than less wealthy households.

The goal of the third paper of the dissertation was to address the association between farm diversity and food security, specifically focusing on the nutritional dimension. Dietary diversity was considered as an indicator of food security at household level. If food diversification differs among producers, it is essential to determine the factors that affect diversification. The paper therefore attempted to identify the determinants of food diversification. The terms "dietary diversity", "food diversity" and consumption diversification have been used interchangeably in this paper.

4 Data and methods

4.1 Study areas and data collection

Bangladesh was chosen as a case study because the socioeconomic conditions of the country are typical of most developing countries. It is a populous agrarian economy with limited land resources. Ensuring food security for all, especially from a nutritional point of view, is one of the main challenges that Bangladesh faces today. Like many other developing countries, over the years food security has often been equated with achieving self-sufficiency in cereal production and energy availability. Recent agricultural development policies have begun to emphasize diversification, assuming that agricultural diversity will assist with many issues, including nutritional food security. This research provides empirical evidence to validate this shift by offering insights into the diversification and food security relationship.

Data used in this article are from a comprehensive survey of farm households in central, northern, and southwestern regions of Bangladesh, which was conducted in June-September 2014. These regions cover both the wet agro-ecology and dry agro-ecology zones of Bangladesh. Two hundred and sixty farm households from three regions were selected through a multi-stage random sampling method. The first stage was the purposive selection of three districts (Dinajpur, Joypurhat and Pabna) from the northern region, two districts (Tangail and Kishoregonj) from the central region, and two districts (Jessore and Shatkhira) from the southwestern region. These districts had good production of at least one selected product. At the second stage, a total of 10 villages were randomly selected. Two villages each were selected from Tangail, Pabna, Jessore districts and village one each was chosen from Kishoregonj, Joypurhat, Dinajpur and Shatkhira districts, which made up the total of 10 villages. Farm households within these 10 villages were selected randomly. Out of 260 farm households, 90 household heads from the central region, 90 from northern region and 80 from the southwestern region were selected for interview.

Questionnaires that encompass items such as household characteristics, production, expenditure, consumption, revenue disaggregated by source, investment, credit and other issues were used to conduct personal interviews. The data from the study areas were collected through trained

enumerators along with a principal project researcher using a pre-tested interview schedule. The minimum educational background of the enumerators was an undergraduate degree from a

Figure 3: Map showing the study areas in Bangladesh

Adapted from http://www.un.org/Depts/Cartographic/map/profile/banglade.pdf (accessed 26 October 26, 2019)

university. Before they conducted the field survey, the enumerators were given two days' training that included class lectures and field visits to minimize data collection errors. Continuous supervision of the data collection process confirmed the validation of the response.

Detailed data were collected on crops, which were jute, potatoes, pulses, vegetables, fruit, flowers, spices, oilseeds, wheat and rice. The vegetables included tomato, cauliflower, radish, cabbage, grounds, eggplant, beans, arum, and leafy vegetables. The rice included the Aus, Boro and Aman varieties. Additionally, non-crop products such as livestock, poultry and fisheries were incorporated into the study.

4.2 Measurements of variables and modeling procedures

The estimation method in the first article was based on maximum likelihood estimation (MLE), and the Probit model was used to investigate the determinants of on-farm diversification. In the paper, diversified farms are those that are involved in non-rice agricultural production in addition to, or as a direct substitute for rice cultivation. In contrast, non-diversified farms are defined as those that only produce rice. Thus, the dependent variable takes only two values in the research: the value '0' when the farm is only producing rice; otherwise the value is '1'.

The 2nd article, which focuses on income diversification, used the Tobit model for data analysis. Households have the freedom to engage in any earnings generating activities indicating that there are some income sources, which will obtain zero income figure from it. Therefore, a model for censored variables could be applied. Censored variables mean those observed in only some of the ranges. In such a case, a censored regression Tobit model formulated as below was applied in this article

$y^* = \beta' x + \varepsilon$, (Tobit model censored from below at the value of 0)

$y = 0$ if $y^* \leq 0$, $y = y^*$ otherwise.

Since this study has focused on two approaches of diversification: off-farm income diversification and overall diversification, two models with two different dependent variables were used in this analysis.

To investigate overall diversification, in model (1), y measures the Simpson Index of Diversity (SID), which captures the extent of overall diversification by taking into account the full range of economic activities adopted by a household. However, diversification is assessed through several indices, which calculate both evenness and richness features of diversity (Patil and Taillie, 1982). Richness refers to the number of income sources and evenness means the distribution of income between sources. The Shannon-Weaver and Simpson indices have been the most commonly known measures of diversity (Gorelick, 2006). Routledge (1979) concluded that among the several indices that explain diversification, Simpson is the best single measure of diversity. Magurran (1988) preferred Simpson's index over the Shannon index as Simpson is less sensitive to the degree of richness and sample size. Instead, the author stressed that Simpson index is more sensitive to the degree of evenness than the Shannon index. Thus, a similar approach has been applied in investigating farm and income diversification in several research projects (see Jones et al., 2014; Ibrahim et al., 2009; Minot et al., 2006; Joshi et al., 2003). This give grounds for applying SID in this study, which is defined as:

$SID = 1 - \sum_i P_i^2$,

where P_i is the proportion of income derived from source i. The index is created by calculating each source of income weighted by its contribution to the total income. The value of SID falls between '0' and '1'. A value of zero indicates there is just one source of income. As the number of sources increases, SID approaches 1. In addition, the more uniformly distributed the income from each source is, the more SID approaches 1. For instance, a household that earns 80 percent of its income from source A and 20 percent from source 2, would obtain a lower score on the SID than a household that earns equal income from each source.

On the other hand, off-farm diversification assessed by the income earned from off-farm activities such as self-employment and wage earnings determine the movement to activities other than pure cultivation. To investigate, Off-farm diversification, in model (1), y measures the income level from off-farm activities.

In article 2 for income analysis, household income was divided into eight activity categories: cereals, non-cereals, livestock, poultry, fisheries, self-employment, wage income, and other

sources. Crops and non-crop products were considered in the income, either sold or consumed by the household. The net income was calculated as gross returns minus related costs. Similarly, the self-employment income was estimated by subtracting related expenses from the gross return. Other sources comprise off-farm income activities that do not fall into the abovementioned list in the measurement of income. Moreover, valuable assets such as radios, bicycles, livestock, farm equipment, and others in the household's possession were used to measure the wealth status of the household. The article has also clarified the difference between on-farm and off-farm income. On-farm income consisted of earnings from farming activities such as crop production and non-crop food production including livestock, poultry and fishing. All other income sources were considered as components of off-farm income. A similar approach was adopted by Haggblade et al. (2007); and Davis et al. (2010).

The third article measured the contribution of diversification on food security by using the Ordered Probit Model since HDDS and FCS both are categorical ordered dependent variables. In this case, FCS was classified into four-level categorical variables using standard guidelines provided by the World Food Programme (WFP, 2009). The four categories are: i) poor dietary diversity if FCS is below 29 ii) borderline dietary diversity if FCS is within the range of 29 to 42, iii) acceptable dietary diversity if FCS is within the range of 43 to 52, iv) high dietary diversity if FCS is above 52.

The 3rd article also applied three different farm diversity measures to evaluate the impact: 1) a crop and livestock count variable which is the sum of the total of different crops cultivated and the number of animal species reared by the households 2) In addition to number, evenness of farm production diversity may also be important for food diversity. Therefore, the Simpson Index of Diversity (SID) has been used in the paper, which estimates each agricultural source of income weighted by its contribution to the total farm income 3) The agricultural diversification index (ADI) has been applied that takes the value '0' when the farm is non-diversified and the value '1' when the farm is diversified. In the context of Bangladesh, shifting out of rice production and being involved in non-rice crop cultivation and/or non-crop agriculture such as livestock, poultry and fisheries can be considered as on-farm diversification. Therefore, the paper assumed that non-diversified farms are only producing rice and diversified farms are otherwise.

The NLOGIT software package (version 5.0) was used for the data analyses in Article 2 while the Stata software package (version 11.1) was used to analyze data in Articles 1 and 3.

5 Results and discussion

The aim of the research was to provide answers to the questions associated with on-farm diversification, income diversification and the role of diversification on household consumption, especially in relation to food diversity in Bangladesh. Thus, the thesis consists of three articles related to diversification. The discussions in each article are interconnected as the study used the same data set to investigate the research question linked to corresponding article. This section summarizes the key findings associated with the research questions of each article and discusses the results.

5.1 Determinants of on-farm diversification in Bangladesh (Article I)

On-farm diversification is an important strategy, especially in developing countries that have the potential to increase revenues and reduce income fluctuations. Since agricultural insurance schemes are ineffective in many developing countries, diversification of farming activities has the potentiality to become a key strategy to provide protection from the risk of variations in prices and/or yields for specific commodities. Much of the attention in the agricultural sectors of developing countries has therefore been focused on diversification. Examination of determinants may identify the elements related to farm and household characteristics and resource endowments, since those need to be addressed by the policies to expand diversification. It also signifies the potential to produce alternatives to rice cultivation that provide more protection against natural and/or market uncertainties.

The first article determines the factors that cause diversification among farm households in the study areas. We aim to encourage farmers to diversify cropping from rice monoculture to various kinds of crop production and non-crop food production such as livestock, poultry and fishing. In doing this, farm households that rely absolutely on rice cultivation are compared with households involved in various forms of cultivation in the article. The Probit model was used to examine the impact of various household, farm and market characteristics upon on-farm diversification. The article defined non-diversified farms as those that only produce rice. Diversified farm households are those involved in non-rice agricultural production in addition to or as a direct substitute for rice cultivation. The research examined whether farm size, access to credit, technical assistance, access

to markets and regional variation explained the differences in household diversity. In addition, a new explanatory variable is used to identify the association between the active participation of women in farming activities and diversification, which had not been used previously as a potential determinant of non-rice mono cultivation in Bangladesh.

The results show that farms with access to credit facilities are more diversified than others. Thus, there is a need to offer credit at a reasonable rate in order to promote diversification. In Bangladesh, farmers do not have smooth access to credit as a majority of farmers remain outside of formal credit channels, depending largely on the NGOs involved in micro-finance activities. Moreover, the vigilance of private commercial banks in this arena is poor. Our finding suggests that agricultural credit should offer seasonal financing with a one-off payment facility after realizing returns at the end of the season. The added flexibility encourages farmers into non-crop diversified farming activities, indicating a joint policy effort that includes government along with non-government organizations and commercial banks to ensure access to credit.

We found that the active participation of women in farming encourages farm households to diversify more. Women were found to grow different non-cereal crops, vegetable and poultry because of the nature of the job. These tasks are labor intensive, but activities are less laborious than rice cultivation. Activities such as poultry rearing, and vegetable cultivation can be performed within the boundary of their own households. The study also revealed a positive association between diversification and farm size. Larger farms are more diversified than smaller farms as they hold more valuable useable resources to deploy in a range of on-farm activities. The findings suggest that diversification is a strategy adopted by the larger farms to grow and develop. Resources and income from one activity provide the opportunity to invest in another, which makes entry into a new endeavor easier.

It is evident from the study that farmers who received training and used advisory services were more diversified than those without such technical assistance. Modern farming is more competitive and challenging than ever. Thus, extension education in every aspect of farming such as production harvesting, processing and transportation is crucial for successful cultivation. Access to extension services is a key way for these farmers to gain technical advice and effectively utilize them in farming. The findings suggest that younger farmers should be targeted and given technical

assistance for efficient outcomes. Moreover, repetitive farmer level long training sessions with some intervals may promote and stimulate non-cereal diversification in Bangladesh. Developing such measures might lead to more effective distribution of resources in various on-farm production, which may in turn contribute to reducing income variability and increase diversity in food consumption.

5.2 The determinants and purpose of income diversification of rural households in Bangladesh (Article II)

The objective of the 2nd article was to explore income generation and diversification patterns in Bangladesh. The findings showed that, on average, 69 percent of the total household income comes from farm income, compared to 31 percent generated from off-farm activities. Besides, non-cereal farm income, which generated about 37 percent of the total, is the main single source of income. The pattern shows that low-earning households (tertile I) depend more on off-farm income than higher income families. Thus, as the income progresses, households rely more on on-farm income. In respect to on-farm income, households of the higher income group (tertile III) gained the highest returns from non-cereal crop cultivation, whereas for low-income households (tertile I) the main farm income was derived from cereal farming. Off-farm income basically disaggregated into wage income and self-employment earnings in the paper. The findings reveal that a household's involvement in wage income declines with the income level. By contrast, participation increases with income rises in self-employment. It is to be noted that highest income group (tertile III) is the most diversified.

Nowadays, rural inhabitants rely on multiple earning sources and create a portfolio of diverse income-generating activities both within and external to the farming sector. In the paper, overall diversification captures the extent of diversification by taking into account the full range of economic activities adopted by a household. The study confirms that overall diversification of income escalates with household income level, and the purpose of diversification is accumulation of wealth. Moreover, the study highlighted that a greater level of diversification is influenced by household endowments of assets such as wealth, access to market, and better infrastructure. In the study, access to the market was specified as the distance from the household to the nearest market in kilometers. The minimum distance from the household to the nearest market was synonymous

with greater access to the market. The wealth status of the household was determined by valuable assets or household possessions such as livestock, farm equipment, radios, and bicycles. In addition, we found that a larger number of earners and higher education facilitated overall diversification. The results suggest that addressing the determinants by the government could support growing income and improve the living standard of rural households in Bangladesh.

The study recognizes that since farm and off-farm income are interconnected, progress in agriculture cannot be achieved in segregation because income and skills garnered from one activity may be invested in another activity, which has the effect of relaxing entry barriers. It is difficult for farm households to rely solely on farming because of various uncertainties related to agriculture. Thus, off-farm income allows households to meet the cost of operation and inputs associated with farming. Winters et al. (2002) showed that income gained from outside of agricultural activities contributes to financing farming activities. Thus off-farm income yields benefits by raising household on-farm activities. However, in Bangladesh, households are widely involved in agriculture. Accordingly, profit earned from farming activity facilitates households participating in more lucrative off-farm activities, more specifically in self-employment. Farming income helps to finance self- employment earnings and contributes to rural development. Thus, this study highlights that diversification is linked to agriculture rather than being a condition of departing from it. Therefore, there is a need to adopt integrated approaches for developing complementary programs and policies to capitalize best on collaboration and linkage across agriculture and off-farm sectors.

Since agriculture is experiencing challenging times, off-farm income shares an important portion of the total household income. Thus, the main motive behind off-farm diversification and influencing factors have been identified in this paper. Off-farm diversification has been classified into wage employment and self-employed activities separately as the two activities exhibit different characteristics. A noteworthy finding is that off-farm diversification serves a two-fold purpose. Richer households are pulled into off-farm self-employment for higher returns through easy access to financial assets, and labor endowment. Capital constraints on poor households are influenced by endowment in the form of education and labor to diversify into off-farm wage activities as a mean of survival.

The results show that self-employment is encouraged by younger household heads, the number of household earners, the wealth of the household, access to credit, and electrification and better infrastructure. On the other hand, the factors that positively affect wage diversification are number of household earners, education of the household head, proximity to town and a younger household head. It is noted that there are some dissimilar factors those differentiate the determining factors of off-farm diversification.

5.3 Diversification as a means to improve household food security in Bangladesh (Article III)

A central policy issue for food-insecure regions is how best to respond to food insecurity. It is significant to note that current studies on diversification reveal inconclusive evidence and further research on the topic has been recommended. Some studies reported positive significant links between farm and diet diversity (see Jones et al., 2014); on the other hand, a farm diversity strategy has been identified as not the most efficient way to increase dietary diversity (see Koppmair et al., 2017). Moreover, available studies focus mostly on sub-Saharan Africa and emphasize the importance of further studies in different contexts (Jones, 2017). Islam et al. (2018) argued that to understand the connection between farm diversity and diet outcomes properly, more research is required from the Asian perspective as the strength of associations varies with context. This study contributes to bridging the research gap by providing quantitative evidence on the impact of diversity in agriculture on household food security in the Asian context, Bangladesh in particular.

We assume that farm households are able to enhance food security through diversification. Notably, the paper used a diversification index in order to capture the effect of moving out of rice monoculture on dietary diversity. In Bangladesh, achieving food security through self-sufficiency in rice production was prioritized over the years. Thus, this finding will highlight the effectiveness of the strategy of shifting out of only rice production for household food security. In addition, the study incorporated Simpson's Index of Diversity to consider the number and evenness of the species produced. The application of several measures ensures the reliability and consistency of the assessed relationship between farm and consumption diversification. The mean value of Simpson's Index of diversified farms was 0.43, whereas for the non-diversified farms the mean value was 0.25, demonstrating that the diversified farms had significantly a higher level of consumption diversification than non-diversified farms. More specifically, consumption of pulses,

vegetables, fruit, meat, fish, and milk food groups is significantly higher in diversified farms than non-diversified farms.

The econometric analysis showed a significant and positive association between farm and food diversity at household level. Food diversity measures such as the Household Dietary Diversity Score (HDDS) and the household Food Consumption Score (FCS) assess the extent to which energy and nutritional needs are being met. Besides, dietary diversity is treated as an indicator of household level food security (Swindale and Punam, 2005; WFP, 2009; FAO 2010). The usage of these two measures provides trustworthy assessment of the linkage. The results revealed that shifting to non-rice cultivation instead of rice monoculture increases the probability of the HDDS to 35.54 percent and the FCS to 31.68 percent when production diversification rises by 100 percent. Similarly, the positive relationship between farm diversity and Simpson's Index suggests that farms with a diversified production have a greater variety of food consumption in a more balanced way than non-diversified farms.

Diversification yields benefits for dietary variety in different ways. It is worth mentioning that availability of food is important but access to food is a greater constraint for food security. Incremental earnings and a reduction in income variability from diversification allow securing access to sufficient food. Dewey (1981) mentioned that subsistence farming can no longer meet the family income needs, which leads the farmers to diversify income sources. Market-oriented farm households, which place more emphasis on cash crop cultivation, have better access to food consumption through incremental income generated from selling their output at a premium price. In addition to higher income, production of non-cereal crops can more easily be incorporated into a combination of wage labor and work on the family plot than the production of subsistence crops. Besides, diversified production of crops, animal products, fish, and other products offers the opportunity to farmers to consume their own production, ensuring a secure supply of food during natural and/or market shocks and thus improve household food security.

We have included several other measures that could influence food security. This is also important since the determinants of food security are often location specific and may differ from country to country (Iram & Butt 2004). Understanding the determinants will help to enhance food security in Bangladesh. Our study also found that factors such as higher education level, better market access,

household size, production per capita, non-farm income diversification, and land size have effects on food security.

It is evident from these results that, from a policy standpoint, in order to improve consumption diversification there is a need to step out of rice cultivation and spread production across multiple crop and non-crop farming. Our result demonstrated that strengthening market access through developing infrastructure or reducing travel time could improve food diversification. The findings suggest that policy geared toward increased and continuous investment in infrastructure is necessary in this regard. The study found that the education level of a household is a significant contributor to household food security as educated households put effort into diversified food consumption. In order to promote access to education, policies that enhance household education status are vital.

5.4 Connection between theoretical and the empirical models

The introductory part of the thesis has shown that the econometric models used in the articles are based on a household assets bundle that has been derived from AHM by Escobal (2001). Moreover, the introductory part pointed out that econometric models could be linked with the theoretical model (AHM) through the household asset groups and determinants. Similar to table 2, the significant determinants found in the articles of this thesis through the household-assets framework are given in the table 4.

According to the level of endowment in these asset groups, households adopt possible diversification strategies that contribute to improving household food security through enhancing access to food and dietary diversity for households, which thus has an effect on the household utility maximization behavior. Moreover, farm and off-farm income through diversification could influence the household utility maximization. However, the institutional policies can influence household access to these assets.

It is worth noting that the theory is selected properly for the study. The pursuit of on-farm diversification through emphasizing non-cereal and non-crop income could be considered rational from the utility maximization perspective when the expected returns on non-cereal and non-crop production are higher than cereal cultivation or when non-cereal and non-crop income provides

Table 4: Connecting the significant factors identified in the articles with the household-assets framework

Household assets category	Article 1	Article 2	Article 3
Human	Age of household head, Participation of household head's spouse.	Education of the household head, Age of the household head, Number of household earners.	Education level of household head, Household size.
Natural	Farm size, Regional dummies.	Size of agricultural land holding, Regional dummies.	Farm production diversity, Land size, Production per capita, Regional dummies.
Physical	Technical assistance, Access to market.	Distance to the nearest town.	Access to market.
Financial	Access to credit.	Access to credit, Wealth of the household.	Nonagricultural Income, Wealth.
Social			

more stable overall income. In addition, in this study, the self-employment activities were seen as a choice for farm households to increase income. Thus, the farm households utilize assets to adopt income diversification strategy to assure the maximum level of consumption. Furthermore, we found that better market access through less distance affects income and food consumption, indicating that a major portion of food crops was purchased for consumption. The need to ensure food security, preferably through market purchased food, motivates the households to emphasize their resource allocation towards profit. The basic principle of AHM is valid in this study as income is determined by the households' production activities, implying that changes in variables influencing production also change income, which in turn affects consumption behavior. The decision concerning production, consumption and resource allocation were interlinked through the profit maximization effect. Note that the study areas have agricultural extension services, good access to credit through NGOs; market information through mobile phones, radio and NGOs; better access to markets and electrification. Therefore, separability is empirically applicable in this

study. The assumption of separability has been used to model agricultural households in developing countries in previous studies (see Lau et al.,1978; Feleke et al., 2005).

6 Conclusions and policy implications

6.1 Conclusion

The aim of the thesis was to explore and understand the gradual movement from subsistence farming to alternative non-conventional production and non-farm activities. The study focused on providing empirical evidence of 1) on-farm diversification and its determinants in farm households in Bangladesh, 2) the factors influencing income diversification and its purpose, 3) the association between the on-farm diversification and food security. In the current turbulent situation of the agricultural sector, the diversification strategy could facilitate households in increasing their income-generating opportunities to their benefit and permit poor households to enhance their living standards. Data used in the study are from farm level cross-sectional data in the central, northern, and southwestern regions of Bangladesh. The main conclusions of the study are summarized below.

The results of this study show that diversification is linked to food consumption diversity. Diversification through moving out of cereal production, especially rice cultivation, is an effective strategy to improve food diversity and thus enhance household food security status. Besides, other factors such as higher education of household heads is positively associated with food diversity. Better educated household heads have greater access to multiple information sources that stimulate families to consume a diversified diet. The wealth of the households affects consumption as wealth allows farm households to invest more resources in higher return market crops and raise more livestock and fish. On the other hand, during unanticipated events, wealth helps to maintain consumption. Furthermore, easier access to market ensures the availability of a variety of foods for household consumption and allows the farm to sell its own production at a good price. The factors such as household size, production per capita, and land size are also positively associated with household food diversity.

Analysis of on-farm diversification showed that diversified farms were owned by younger farmers, were larger, and received more technical assistance from extension agents than the non-diversified farms. The results also revealed that the diversified farm owners who enjoyed the active participation of a spouse obtained better access to credit and cultivated more fields than the non-diversified farms. In addition, access to market influences farmers to diversify.

The results from income diversification investigation indicate that the affluent households adopt diversification more than the less wealthy farm households. Since wealthier households increase the magnitude of diversification with the intention of gaining wealth, overall diversification is a strategic choice of wealthier households with the purpose of accumulating wealth rather than a survival strategy. On the other hand, less wealthy households with limited access to credit are pushed into off-farm wage diversification as a means of survival, while wealthier households are pulled into self-employment diversification to enable growth in wealth, similar to overall diversification. Importantly, this study specifies that agriculture is necessary for the promotion of diversification in contrast to the view that diversification is a syndrome of agricultural shrinkage in Bangladesh.

6.2 Main contribution of the research to the applied economic literature

The contributions of the study are the following. This study addresses a prioritized current issue and serves to capitalize the potential for diversification out of cereal production. Consumers gradually reduce cereal consumption over time and the consumption pattern has been shifted towards non-cereal items. Growth in income accompanied by globalization has caused rice to become an inferior food but created demand for fruit, vegetables, fats and protein in Bangladesh. More than 80 percent of production is rice in Bangladesh. Thus, in this research, diversification refers to production of non-cereal crops and non-crops products like livestock, poultry and fishing. The government of Bangladesh and the FAO both have emphasized diversification, given its importance for food security and poverty alleviation. Identification and analysis of the factors influencing adoption of diversification helps to respond to this market opportunity and obtain financial betterment. Very few studies have focused on the determinants of a firm diversification strategy that generates alternatives to rice consumption (article 1).

The study confirms that a farm diversification strategy improves diversity in household food consumption and thus helps to ensure household food security. The contribution of this investigation is that it tested the relationship between diversification and food security, highlighting the nutritional aspect as household food security attainment not only includes availability, but also incorporates consumption of diversified nutritionally adequate foods, which was not focused on in Bangladesh over the years. To the best of this researcher's knowledge, this

study represents the first attempt to compare farm households very specialized in rice cultivation with more diversified farm households to recognize the association between farm diversity and diet consumption in Bangladesh properly (article 3).

Another contribution of this study is that it found positive and significant connection between the active participation of women in farming activities and diversification strategies in Bangladesh. Women are not generally known as effective farmers and are not familiar with their important role in farm production in Bangladesh. The opportunity to access and control useful resources related to on-farm farming are developing women's capacity to take part in decision making. Besides, improved training and education can help them in this regard. The findings indicate that women's role in farm diversification requires attention at the policy level. Steps to decrease the involvement gap between women and men in farming is required and the challenges women face need to be removed.

This study also provided a detailed investigation of income diversification through quantitative analysis (Article 2). The research investigated the ambiguity between "asset accumulation" and "survival" motives for adopting an income diversification strategy, highlighting in particular the differences between off-farm diversification and overall diversification of the income portfolio. The nature of the two categories of diversification is different, and somewhat less attention has been given to observing them from disparate angles. A comprehensive approach has been followed in this article through which diversification is examined. The important contribution of this study is its determination that the motive of diversification differs depending on the types of strategy adopted. We found that the motive for overall diversification is opportunity driven accumulation of assets, but farmers move out of pure on-farm activities and shift into off-farm wage diversification involuntarily for survival. Households with available resources deploy capital that is produced from on-farm farming to advance into profitable off-farm self-employment endeavors. Thus, households with resources available choose to diversify into multiple on and off-farm income generating activities with an intention to earn more. This research specifies that diversification is not a strategy to escape from agriculture, but overall portfolio diversification incorporating both agricultural and non-agricultural activities. This study proposes that diversification is linked to agriculture, against the widely held perception that diversification is a

syndrome of a diminishing agricultural sector in Bangladesh. Therefore, policy based on the assumption that agriculture is unnecessary will hinder development. On the other hand, off-farm diversification, especially off-farm wage diversification acts as an alternative to agriculture where the households are pushed to move, leaving agriculture behind, for survival. Therefore, the research specifies that there is a need to formulate different policies depending on the nature of diversification.

6.3 Policy implications

Further research with appropriate instrumental variables and a panel dataset would facilitate better targeting of policy guidelines. In spite of the limitations, the findings of the study suggest some vital policy recommendations that could potentially advance diversification in Bangladesh. Policies should emphasize diversification, since food security is significantly affected through it. Special focus on diversified production in multiple crop and non-crop farming and moving out of pure rice cultivation is necessary. The factors such as credit access, higher education level, comprehensive programs that include both farm and off-farm activities, market access, women's participation, etc. promote diversification.

We found that improved credit access increases farm diversification, indicating that extension of credit facilities to the farmers taking their needs into account will improve diversification. The policy makers need to look into the possible causes limiting easy access to the credit benefits. In order to foster on-farm diversification further, the credit offerings should consider seasonal loan facilities, faster processing times and flexible repayment schedules for the benefit of the farmers. Besides, the Bangladeshi government should arrange credit schemes at affordable rates for the benefit of the farmers.

The study also recognized technical assistance as an important determinant of farm diversification in Bangladesh. The advisory services have been significant in the transfer of knowledge about the use of modern methods of farming. These support services also guided the farmers to realize the marketing aspects of being involved in non-cereal diversified farming activities. Stressing the advancement of these activities in rural areas is thus a vital policy instrument that is likely to allow farmers to choose crops other than rice. Thus, a useful program that maximizes the number of

farmers reached by technical assistance and education must be developed as a vital step. Education prepares farmers to gain the required technical knowledge and understand the modern diversified farming methods. It also assists by improving household food consumption diversity. To attain a higher level of education, policies may include increasing the number of schools in rural areas, tuition-free schooling, a food for education (FFE) program for motivating children to go school at the right age and more investment in education by way of public-private partnerships (PPPs).

This suggestion that women's role in farm diversification is important thus highlights the need to improve the involvement of women in farming by appropriate measures. Providing training and education facilities may improve their ability to participate. Besides, farm households should look to capitalize the underutilized women. In addition, policy focused on continuous investment in infrastructure such as roads and electrification will allow households to earn on-farm income to carry out the transition to overall portfolio diversification. Better road networks and transportation provide mobility and ensure easy access to market for perishable non-cereal goods. Besides, initiatives such as locating trading markets nearer to the farmers' locations may be considered for easier access to market.

However, partial development policies focusing only on increasing agricultural production or concentrating solely on advancing off-farm activities are inconceivable to earn benefit for farm households. Instead an interdependence policy that includes both farm and off-farm activities should be formulated to consolidate the link between them. In addition, the study points out that off-farm activities such as wage income and self-employed activities show different purposes and determinants. Thus, there is a need to offer separate programs targeting those activities. For instance, since less resource-endowed farm households are pushed to diversify into off-farm wage activities, government should encourage and sponsor the supply of off-farm labor opportunities in order to benefit such households. On the other hand, government incentives to expand small-scale business will directly benefit through self-employment opportunities.

6.4 Suggestions for further research

Main obstacles and threats for increasing diversification and cultivating non-rice crops need to be researched further. Besides, the availability of off-farm diversification opportunities and the

related hurdles that would better explore diversification possibilities should be analyzed. It would be very informative to see how collaboration between local industries, processors, farmers and farmers' associations could diversify the incomes of agricultural producers and improve food security. Another area for additional research would be to examine how new technologies in agriculture based on genome editing, nitrogen fixation or targeted micro-organisms could increase or diversify agricultural incomes.

There is an opportunity to influence diversification decisions through attitudes to risk. A method for measuring household risk attitudes would benefit by applying risk factors in future analysis. It is useful to consider that cross-section data could be influenced through period specific abnormalities. Therefore, based on cross-sectional data, it is possible that a particular farm is less diversified in any one year but could become more diversified over a longer period. Panel datasets could allow capture of the extent of diversification between years for each farm household. Thus, further research using panel datasets will made it possible to assess the changes in the food security status over periods of time.

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