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An Economic Analysis of Crop Diversification in Northern Bangladesh

Islam, Mohammad Monirul
University of Rajshahi

AN ECONOMIC ANALYSIS OF CROP DIVERSIFICATION IN NORTHERN BANGLADESH

PhD Dissertation

A dissertation submitted to the Institute of Bangladesh Studies of the University of Rajshahi, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics

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July, 2015

Dedicated

to

My Beloved Mother

SUPERVISOR'S CERTIFICATE

I have the pleasure to certify that the dissertation titled '**An Economic Analysis of Crop Diversification in Northern Bangladesh'** is an original work accomplished by Mohammad Monirul Islam, PhD Fellow of the session 2011-2012 at the Institute of Bangladesh Studies (IBS), University of Rajshahi. So far I know, the entire work is his own achievement and is not a conjoint work. He has prepared this dissertation under my direct guidance and supervision.

I also certify that I have gone through the draft of the dissertation thoroughly and found it satisfactory for submission. Therefore, I recommend and forward the dissertation to the University of Rajshahi through the Institute of Bangladesh Studies (IBS) for necessary formalities leading to its acceptance in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics.

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DECLARATION

I, the undersigned, do hereby declare that this dissertationtitled '**An Economic Analysis of Crop Diversification in Northern Bangladesh'** submitted to the Institute of Bangladesh Studies (IBS), University of Rajshahi, is entirely my original work except the quotations which have been duly acknowledged. This work has not been submitted previously, in part or full, for any academic degree to any University, except at the Institute of Bangladesh Studies (IBS), University of Rajshahi, Bangladesh.

Mohammad Monirul Islam

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Mohammad Monirul Islam

ABSTRACT

The strategy of practicing crop diversification (CD) has significant socio-economic and environmental implications for farm households in Bangladesh. Crop diversification contributes to food and nutrition intake for the households, employment generation for the rural people and sustainable management of available resources. Thus, the main objective of this study is to explore the state of CD and to investigate the determinants of CD in the study area. Moreover the study aims to analyze economic viability and profitability of CD in the context of northern Bangladesh. The study has measured the level of CD applying Entropy and Herfindahl indices. Tobit regression model has been used to identify the determinants of CD. Net return and benefit cost ratio (BCR) approaches have been employed to analyze the economic viability of CD. In addition, two-way ANOVA and independent sample *t* test have been carried out to compare the mean differences of some characteristics of the farms and farmers in the study area. Chi-square (χ^2) test has also been used to test the association between CD and variations of districts and farm size. By random sampling technique, a total of 343 farms were selected from eight villages of four districts of which two from Rajshahi division and two from Rangpur division of northern Bangladesh.

The study found that level of crop diversification in Bangladesh is very low, though it is increasing gradually with some fluctuations. Similarly, northern Bangladesh has made a remarkable progress in practicing crop diversification over the years. Most of the areas in northern Bangladesh produce varieties of crops like vegetables, pulses, spices, etc. including cereals. In the study area, on average, a farm produces 4.46 crops in a cropping year with maximum 17 crops. It is revealed that in the study area only one fourth of total farms are specialized which produce only rice and three fourths of total farms are diversified which produce multiple crops. Level of crop diversification in northern Bangladesh is higher compared to many other areas of Bangladesh. It is also found that likelihood of crop diversification increases with the increase in the household size, defragmentation of land, annual income of the farms and developed infrastructure. On the other hand, probability of diversification decreases with the increase of farm size, non-farm income of the family, irrigation intensity and training exposure. The study also found that growing non-rice crops like vegetables, pulses and spices, etc. offer higher profit than that of rice. Employment generation of non-rice crops like vegetables, spices etc. is also comparatively high. Considering all these aspects of crop production, it is found that economic viability of crop diversification is much higher than that of rice monoculture.

As policy suggestions this study observes that government initiative towards increased practice of crop diversification is required. In this connection, government can extent supports for the farmers to increase *aman* production during the rainy season and cultivate non-rice crops during the *Rabi* season. In addition, to increase practice of crop diversification in Bangladesh, modernization of irrigation system, development of infrastructure, raising frequency of extension activities and specific

training for the farmer, appropriate natural storage and processing techniques of perishable crops,are important.

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ABBREVIATIONAND ACRONYMS

AEZ	Agro Ecological Zone
AIS	Agriculture Information Service
ANOVA	Analysis of Variance
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAURES	Bangladesh Agricultural University Research System
BB	Bangladesh Bank
BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
BDT	Bangladesh Taka
BIDS	Bangladesh Institute of Development Studies
BMDA	Barind Multipurpose Development Authority
BRRI	Bangladesh Rice Research Institute
CBA	Cost Benefit Analysis
CD	Crop Diversification
CDP	Crop Diversification Program
CIP	Country's Investment Plan
CEI	Composite Entropy Index
CV	Coefficient of Variance
DAE	Directorate of Agriculture Extension
DDAE	Deputy Director of Agriculture extension
DF	Degrees of Freedom
D-W	Durbin Watson
e.g.	For Example
EI	Entropy Index
ESS	Explained Sum of Square
etal	and others
FAO	Food and Agriculture Organization
FY	Financial Year
FYP	Five Year Plan
GDP	Gross Domestic Product
GLM	Generalized Linear Model
GLS	Generalized Least Square
GM	Geometric Mean
GM	Gross Margin
GoB	Government of the People's Republic of Bangladesh
GR	Green Revolution
hec.	Hectare
HI	Herfindahl Index
HVC	High Value Crop
HYV	High Yielding Varieties
i. e.	that is
IFPRI	International Food Policy Research Institute
Kg	Kilogram
MEI	Modified Entropy Index
MFC	Marginal Factor Cost
MI	Margalef Index

mill.	Million
ML	Maximum Likelihood
MLRM	Multinomial Logistic Regression Model
mm	millimetre
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forest
MP	Muriate of Potash
MS_B	Mean Square between Groups
MS_W	Mean Square within Group
MVP	Marginal Value Product
NAP	National Agriculture Policy
NAFPPA	National Food Policy Plan of Action
NCDP	Northwest Crop Diversification Program
nd	No Date
NGO	Non Government Organization
NM	Net Margin
OI	Ogive Index
OLS	Ordinary Least Square
RMSE	Root of Mean Square Error
ROI	Return on Investment
RSS	Residual Sum of Square,
SAAO	Sub Assistant Agriculture Officer
SCDP	Second Crop Diversification Program
SPSS	Statistical Package for social Science
SS_B	Sum of Square between Groups
SS_W	Sum of Square within Group
STW	Shallow Tube-well
TC	Total Cost
TE	Triennium Ending
Tk.	Taka
TR	Total Revenue
TSP	Triple Super Phosphate
TVC	Total Variable Cost
UAE	Upazila Agriculture Extension
US$	United States Dollar
VIF	Variance Inflation Factors
WHO	World Health Organization
WTO	World Trade Organization

GLOSSARY

Agro Ecological Zone	An Agro-ecological Zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use (FAO, 1991).
Aman Rice	The paddy which is harvested in the month of November and December is said to be *Aman* Rice. Two types of Aman Rice are grown in this country. One is called broadcast *Aman* which is sown in the month of mid March to mid April in the low lands and another is transplant *Aman*, which is planted during late June to August.
Aus Rice	The paddy which are sown in March-April and harvested in July-August is considered to be *Aus* Rice.
Boro Rice	The paddy which is harvested in the month of April and June is said to be *Boro* Rice
Crop Diversification	Crop diversification is a practice of growing more than one crop in the same plot of farm in a cropping year.
Crop Rotation	The practice of growing different crops in succession on the same land to improve soil fertility and help control insects and diseases.
Cropping Pattern	The cropping pattern is a sequence of sowing crops in different seasons of a cropping year, i.e., rotation of crops in a particular area. More specifically, in a cropping year the types of crops farmers grow in the same agriculture plot is called cropping pattern.
Cropping Intensity	Cropping intensity is the ratio of gross cropped area to net cropped area. It shows that how many times a specific piece of land is used for crop production within a cropping year.
Extension Contact	Extension contact is a service offered by the government that assists farmers in improving farming methods and techniques, increasing production efficiency and income, improving their standard of living and lifting social and educational standards.

Green Revolution	Green revolution is nothing but a movement of producing more food crops with the help of high yielding varieties of seed, especially rice and wheat, chemical fertilizer and modern irrigation system. It is also called plan breeder and agricultural scientist is the architect of green revolution (Mandal, 2012).
High Valued Crops	Crops that offers comparatively high returns to the farmers.
High Yielding Varieties	Varieties of crops that offer higher yield than the natural varieties of the same species.
Intercropping	Intercropping is the cultivation of two or more crops simultaneously on the same field.
Kharip1	Crop season starts on 16th March and lasts until 30th June is called *Kharip*1.
Kharip2	Crop season starts from 1st July and ends 15th October is called *Kharip*2
Rabi	Crop season starts from 16th October ends 5th March is called *Rabi* season.
Monoculture	Monoculture in agriculture is a practice of producing a single crop in the same plot of a farm over the consecutive seasons for a long term.
Sustainable Agriculture	Sustainable agriculture is a practice of growing food, feed and fodder for human beings and other animals using principles and techniques of farming keeping protected the environment, public health, human communities and other animals' welfare.

CHAPTER ONE

INTRODUCTION

1.1 Overview

Crop Diversification is a contemporary issue all over the world especially, in the context of developing countries like Bangladesh. It has been universally recognized as a strategy for attaining food and nutrition security for the population of the countries. It is also a widely prescribed means of agricultural and rural development (Acharya *et al*, 2011; Malik & Singh, 2002; Pattanayak & Nayak, 2003; Pingali & Rosegrant, 1995; Vyas, 1996). Similarly, it is believed to be an effective approach to utilize scarce land and valuable water resources, and it makes agriculture sustainable and environment friendly (Braun, 1995; De & Chattopadhyay, 2010; Joshi *et al*, 2007; Kumari *et al*, 2010 Singh, 2001). In addition, by minimizing price and yield risk created by climatic variability and price volatility of agricultural production, it offers comparatively high return from crops. Again, it offers higher labor productivity, optimizes use of resources and utilizes the land efficiently (Ashfaq *et al*, 2008; Mehta, 2009; Mukherjee, 2012). It also creates opportunities for more employment and higher income through efficient use of resources (World Bank, 1990).

Gunasena (2000), Singh *et al* (1985) and Singh (2001) observed that crop diversification is a very important means for food and nutrition security, income growth, poverty alleviation and employment generation and it helps to use the land, water and other resources more effectively. It has a beneficial food security impact especially on the low-income earning farm households who spend a major portion of their income on basic food items such as cereal, pulse, etc (Birthal *et al*, 2007; De & Bodosa, 2014). Moreover, it is a strategy to protect the environment and is a profitable way to increase the export and competitiveness in both domestic and international market. Crop diversification as a socially beneficial policy can be complimented by extensive infrastructural facilities, financial and technological support, etc. especially for the localized micro (labor-intensive) enterprises that are engaged in processing, storing, grading and packaging activities (Chakrabarti & Kundu, 2009; De & Bodosa, 2014).

By diversification of crop, we simply mean producing higher numbers of crops, i.e. growing different crops in different plots of a farm in the same season. In another context, it refers to production of different crops in the same plot of a farm in the consecutive seasons. Similarly, it implies that shift from single crop farming to multiple crop farming, from subsistence farming to commercial farming, from low food value to high food value crops, and from less profitable to more profitable crops (Mukherjee, 2012; Vyas, 1996). In other words, it refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different return from value-added crops with complementary marketing opportunities. In general, crop diversification is a process, which on the one hand helps the grower to get better per capita income and to mitigate risk, and on the other hand, offers more diverse food items to the consumers. It minimizes the risk connected with production of single crop and helps the farmer to unshackle from the poverty trap (Deshpande *et al*, 2007).

The concept of crop diversification can be looked at from two points of view. First view tells that the degree of crop diversification increases with the increase of the number of crops grown. The other view tells about the comparative importance of each crop in the cropping system. From this point of view, a more diversified farm is the one which does not depend too heavily on any single crop. That is, diversification is seen not only in terms of the number of crops but also in terms of the balanced distribution of cultivable land among different crops. The concept can be explained by considering minimum diversification as the practice of having a single crop and maximum diversification as equal distribution of land to all crops (Grosskopf *et al*, 1992). In the context of Bangladesh, shift of area or production to crops other than rice is often regarded as an indication of crop diversification (Rahman & Talukder, 2001**)**. Metzel and Ateng (1993) used 'rice share index' (rice acreage) as a measure of crop diversity that means the lower the acreage of rice the higher the magnitude of crop diversification.

Again, crop diversification can be considered as either horizontal crop diversification or vertical crop diversification (Singh, 2001). Horizontal crop diversification is the increase of different number of crops with the existing crop or cropping pattern. On the other hand, vertical crop diversification refers to the increasing of backward and forward linkage enterprise with crop enterprise. In this study, crop diversification is considered to add more non-rice crops with the existing crops or cropping patterns. In short, it refers to growing a number of non-rice crops with rice based monoculture in order to avoid the risk of monoculture.

The extent of crop diversification in any region depends upon several factors including market forces (relative price, profitability of crops), technological advancement (inputs and implements available), agro-climatic condition, development of infrastructure (marketing facility, road and storing infrastructure etc.) and institutional factors like government's policy decision, protection and risk factors (De & Chattopadhyay, 2010; De & Bodosa, 2014; Pattanayak & Nayak, 2003; Pingali, 2004). In general, it is assumed that the higher the level of agricultural technology the lower the degrees of diversification (Pattanayak & Nayak, 2003). In a less developed region, as agriculture is more dependent upon nature, the risk of crop loss is very high. In many areas, farmers grow different crops in each season due to irregular rainfall and lack of sufficient irrigation so that farmers can get something from their land. Diversification of crops also generates more employment opportunities as the farmers and agricultural workers remain busy in preparing land, seeding, weeding, spraying, harvesting, threshing, crushing, drying and marketing of different crops throughout the year (Pattanayak & Nayak, 2003).

Successful crop diversification depends on structure and pattern of consumers' demand for agricultural production. In general, diversification is inspired as consumers change their food habit from necessary cereals to higher-valued crops. Consumers change their food habit as their income increases along with the development of market infrastructure. A well-developed agro-processing sector offers a vital link in the motivation of agricultural diversification. Bangladesh has a number of agro-industrial enterprises, which process a wide range of agricultural commodities. These enterprises are grain milling, sugarcane crushing, oil-seed crushing, jute processing, cotton ginning, processing tobacco leaves and leather tanning. Besides, there are freezing, canning and some other processing activities, which are of course limited to a few products.

Although favorable agro-climate generally prevails throughout the year for agricultural activities, traditionally in Bangladesh, cropping pattern is practiced primarily to meet the needs of the farmers i.e. subsistence farming. Although agriculture of the country traditionally used to depend on nature, gradual increase of water use in crop production, rapid decline of surface water and aberrant rain that mounts pressure on ground water, is subjects of concerns in our agriculture. Moreover, to attain self sufficiency in food grain, heavy pressure is created on the soil and ground water. Crop diversification can reduce the pressure on soil and ground water. Bangladesh government has also given emphasis on crop diversification to increase various minor crops with major ones. As a result, government has taken various initiatives in the five years plans. Thus, the introduction of crop diversification program (CDP) in Bangladesh has created awareness among the farmers about growing and consuming a variety of crops like pulses, oilseeds, vegetables, fruits and spices. Producing chickpea, field pea, *mung* bean, lentil, etc. can give reasonably good yield through better management including irrigation, fertilization and weed control. The profit gained from these crops is higher than that of high yielding varieties (HYV) of rice and wheat (Shome, 2009).

The HYVs of crops like potato, tomato, beans, mustard, sunflower, watermelon and banana are giving maximum yield when they are provided with irrigation, fertilization and better management. The promotional program is being extended to spices and some country vegetables and fruits that do not have HYV, but do have high comparative profitability and incentives for the farmers (Hoque, 2000). However, Pingali and Rosegrant (1995) have identified two major areas of concern of the government in all countries especially in the developing countries. The areas of concern are (a) availability of food for the ever-increasing population, and (b) poor condition of the people engaged in agriculture. They also proposed that to solve the problems, volume of crop production need to be increased. But increase in crop production by increasing the cultivable land has become very difficult task in Bangladesh. The other alternative is increase in intensity of cultivation and also increase in yield per unit area to meet future demand of food to feed an ever-increasing population and also improving the conditions of the poor farmers.

The state and feasibility of crop diversification depends on the economic consideration of the farmers. So, it must be analyzed from economic point of view, whether farmers will practice crop monoculture or tend to produce multiple crops in their land depending on the return of their production activities. Therefore, an economic analysis of crop diversification practices is needed in the context of Bangladesh.

From the above discussion, it is clear that crop diversification is a contemporary issue for Bangladesh. It requires in-depth study in the context of economic viability. However, so far the researcher's knowledge goes, a very few comprehensive and extensive research works have been undertaken on this field in the context of Bangladesh. The studies undertaken in the case of Bangladesh are not comprehensive and do not reflect the realities of the issue. Thus, the purpose of study, the talked about issue of crop diversification, is to give clear insight and to minimize knowledge gap through shedding light on this issue.

1.2 Statement of the Problem

Bangladesh is a densely populated county in the world. Every year almost two million people add to the total population of the country. However, cultivable land in the country is scarce and it has been shrinking by eighty thousand hectares, around 1% of net cultivable land, per year (GoB, 2009; Mondal, 2010; Quasem, 2011). This is definitely a matter of serious concern for a land-scarce country like Bangladesh, where per capita cultivated land is 12.5 decimal only (Quasem, 2011) and average cultivated area per farm-holding is only 1.26 acres (BBS, 2010).

Agriculture is the mainstay of Bangladesh economy and it plays a vital role in the economy of the country. More than 70% of the population in the country is directly or indirectly involved with agriculture (BBS, 2011; MoEF, 2012). Thus, the dependency of the people on this sector is still substantial. Among four subsectors of agriculture, crop subsector plays significant contribution to the gross domestic product (GDP) of Bangladesh. Again, in crop subsector, rice occupies the largest portion of cultivable land as it is the staple food of the people of Bangladesh. In addition, with the advent of high yielding varieties (HYVs)- seed, fertilizer and irrigation technology, known as *Green Revolution (GR)* technology, a significant change in land allocation towards rice is observed in Bangladesh. As a result, Bangladesh has basically become a rice producing country accounted for 78.52% of total cultivated area used to produce rice (BBS, 2010) and rest of the area is devoted to many other crops. This rice monoculture helps the country to be self-sufficient in food crop production to the some extent. However, this type of agricultural practice creates many problems like, depleting the ground water table, reducing soil fertility, eroding biodiversity, creating nutritional imbalance in food, etc. In this context, Husain *et al* (2011), Quasem and Rahman (1993) and Rahman (2010) observed that intensive rice monoculture led to displacement of land to rice production from the land under low productive non-rice crops such as pulses, oilseeds, spices and vegetables. It reduces crop diversity thereby endangering sustainability of crop-based agricultural production system.

It is assumed that rice is a more water, fertilizer and pesticide consuming crop. Cultivation of *boro* rice requires 3-5 times more water than any other field crops or vegetables (Islam, 1993). Table 1.1 shows water productivity of various crops. It is clear from the table that water productivity of tomato is the highest and rice is the lowest among different crops presented in the table. 650 millimeter (mm) water is needed to produce per hectare *boro* paddy whereas 300 mm water for wheat, 450 for winter maize and 250 mm for winter vegetables are needed.

Table 1.1: Water Productivity of Selected Crops

Crops	Water productivity (Kg/ha-mm)	Seasonal crop water requirement, mm/ha
Rice	5 – 6	650 (*boro*), 240 (T. *aus*), 120 (T. *aman*)
Wheat	12 – 15	300
Maize	15 – 18	450 (winter), 100 (summer)
Potato	35 – 40	280
Tomato	100 – 115	120 (summer vegetables)
Brinjal	55 – 65	250 (winter vegetables)
Onion	25 – 30	158(onion), 230 (garlic)

Source: Islam and Rashid (2011)

To meet water requirement for growing different crops, farmers depend on ground water mostly due to erratic rain and scarcity of surface water. So, for growing additional rice, excessive extraction of underground water is needed which is resulting in arsenic contamination and decline of the water table. The declining of water table in turn generates heavy pressure on fuel energy. Metzel and Ateng (1993) observed that rice requires higher irrigation than all non-rice crops do. Again, increased and consecutive cultivation of rice in the same land results in the decrease of nutrients for plant growth. Cultivating same crop in the same land in successive seasons/years increases crop specific pests and diseases overtime (FAO, 1984). To manage this situation external use of chemical fertilizer and pesticides is being increased every year. It demands huge import of such materials exhausting huge amount of valuable foreign currency. For example, total fertilizer production and import was 425.99 thousand tons and 350 thousand tons, respectively, in the FY1981- 82, but in 2006-07 it was 2173.86 thousand tons and 1,481 thousand tons, respectively. Import value of pesticides is Tk.202.29 million in the FY1981-82 and Tk.1,207.76 million in 2000-01(MoA, 2005). Excessive use of chemical fertilizers and pesticides has adverse effects on soil fertility, quality of surface water and fish habitat.

Moreover, emphasis on rice production has decreased the production of minor cereals like pulses, oilseeds, most of the spices crops which are also important to improve the nutritional status of the people. The area under non-cereal crops has continuously been fallen since late 1970s, mainly due to the expansion of irrigation facilities, which led to fierce competition for land between modern *boro* season rice and the non-cereals (Mahmud *et al*, 1994). Rice contains more carbohydrate, less protein and fat than many other crops. Most of the people of Bangladesh do not take balanced food because they take excessive rice, that is, 88% of the total grain consumption and take less of other nutritional valued crops in their diet. Of the total energy consumption, carbohydrate covers 82.5%, protein 10%, fat 5% and mineral 2%, whereas, according to WHO a balanced diet composition must have 55-65% carbohydrate, 10- 20% protein, 15-25% fat and 5% mineral (Mukherjee *et al*, 2011). To meet up this nutritional deficiency, government has to import those cereals expending a lot of foreign currency. It is apparent from Table 1.2 that import cost of wheat rose from US$219 million in 2001-03 to US$797 million in 2010-12, edible oil rose from US$362 million in 2001-03 to US$1,371 million in 2010 -12 and sugar cost rose from US$79 million in 2001-03 to US$854 million in 2010-12. Nevertheless, pulses, oilseed and spices are comparatively cheap sources of protein and calorie. In addition, minor cereals also have positive impacts on the nutrient balance of the soil.

Table 1.2: Food Crops Import from 2000-01 to 2012-13 (3 year's average in million US$)

Year	Wheat	Pulses	Spices	Oilseed	Ed- oil	Sugar
2001 – 03	219	118	25	70	362	79
2004 – 06	338	173	50	94	499	213
2007 – 09	647	304	84	142	974	486
2010 – 12	797	319	128	174	1,371	854

Source: Bangladesh Bank, 2012

However, it is evident from the above discussion that there is an apparent paradox as to why farmers are interested to grow rice in spite of having many adverse effects of rice monoculture. The reasons are: firstly, rice is grown in all the three seasons helping them manage their subsistence. Secondly, most of the farmers are poor and ignorant of the economic and nutritional value of non-rice crops. Thirdly, famers do not have suitable option to produce non-rice crops. Another question is why farmers continue to keep producing rice when production of many high value non-cereal crops are financially and economically more profitable. The answer lies in a combination of the technical and economic factors. There are very high price risks associated with marketing of most of the non-rice crops (Alam, 2009; Rahman & Talukdar, 2001; Shahabuddin & Dorosh, 2002). Besides, farmers are not assured of reliable access to modern inputs, technology, credit and improved commercial facilities. In addition, official polices distort markets and also create constraints and insecurities in commercial ventures (Rahman & Talukdar, 2001).

Thus, it is clear from the above discussion that rice monoculture has a number of adverse effects whereas, crop has been considered as an effective strategy to manage the reported problems by increasing cropping intensity, productivity of land and labor, and to generate income and employment which in turn will eliminate food and nutritional insecurity (Shopan *et al*, 2012). Moreover, from the studies of Chowdhury (2003), Mahmud *et al* (1994) and Mandal (1993), it is found that Bangladesh has ample opportunities for crop diversification balancing the production of major crops with that of minor crops. Likewise, crop diversification is a talked about issue in the world as well as in Bangladesh. Importance of crop diversification has been recognized since long but more recently its significance has grown manifold in agriculture dependent countries like Bangladesh. Due to dependency on producing single crop makes the agriculture as a risky business. Farmers face risk that is generated from natural and economic factors. They cannot control of the weather, market and environment. The natural risk associated with climate change and disasters are very difficult to control. Whereas, risk related to change in price commonly occurs and such risk are also inevitable. Hence, diversification of crops is the way to minimize both natural and economic uncertainties. It is apparent from the discussion that practice of crop diversification helps the farmers in different ways but yet we do not know what the level of crop diversification in Bangladesh is and how to measure the level of crop diversification. Thus, in spite of having such advantages of crop diversification, it is not clear yet about the actual situation of crop diversification in Bangladesh.

As it is evident from different literature that there are many factors that influence crop diversification in different ways, influences of some factors are common while influence of some factors differ from region to region. For example, irrigation intensity influence in the context of crop diversification is evident from the studies but some studies found it negatively and some positively. Again, there are very few studies carried out in the case of Bangladesh and the real picture regarding the factors that influence crop diversification is not properly portrayed. Thus it is needed to explore the factors that influence crop diversification in Bangladesh.

Similarly, there is a worldwide effort in favor of diversification in agriculture towards reducing various risks so as is evident in Bangladesh. Besides, practice of crop diversification reduces environmental risk; price and yield risk generated from rice monoculture are evident from different studies. Nonetheless, researcher’s knowledge goes so far, there have been found no studies on profitability of crop diversification that is whether producing different crops in different seasons in the same plot of land is profitable. Moreover, some farmers are commercializing agriculture to get more profit from their farm whereas some other produce different types of non-rice crops to make higher profit. Again, adding non-rice crops or multiple crops in the existing cropping pattern is comparatively profitable or not is unknown to all. Thus, it claims to explore whether crop diversification is economically viable alternative to rice monoculture or not.

Likewise, in every harvesting season in Bangladesh, it is heard that farmers cannot offset rice production cost due to comparatively low output price of rice. This situation makes farmers reluctant to rice but statistics say still more than three fourths of total gross crop area is devoted to rice. Moreover, rice monoculture has led to serious repercussion in the form of resource depletion, soil degradation, nutrient deficiency and fall in ground water table. In this situation, it is urgently needed to study regarding economic analysis of crop diversification in Bangladesh in the context of northern Bangladesh.

Northern Bangladesh is popularly known as the granary of Bangladesh. It is apparent from the agriculture census 2008 (BBS, 2010) that northern Bangladesh produces a lot of non-rice crops also especially vegetables and fruits which are more remunerative. More than 50% of total potato production in the country comes from this region. Irrigation facility, cheap labor force, farmers' efficiency and their devotion to agriculture make the region a food surplus area in Bangladesh. Its cropping intensity is very high comparing to that of other areas of the country. In northern Bangladesh, farmers produce different types of crop instead of producing single crop in a cropping year.

Moreover, in northern Bangladesh, 77% of total area is cultivable and this is higher than the average cultivable area (57%) of Bangladesh at national level. Similarly, cropping intensity of northern Bangladesh is 223.44% which is also higher than that of Bangladesh (191%). Only 10% of net crop area produces single crop in northern Bangladesh. The rest of the net crop area produces more than one crop in a cropping year (BBS, 2010). To carry out the study on crop diversification, it is, therefore, very much logical to choose northern Bangladesh as a study area.

Hence, the discussion made above raises several questions regarding crop diversification which are needed to answer clearly. The questions are:

1. What is the present state of crop diversification in Bangladesh?

2. How can the degree of crop diversification be measured?

3. What are the factors that influence crop diversification Bangladesh as well as in northern Bangladesh?

4. Is it profitable to practice crop diversification in a cropping pattern rather than crop monoculture? If yes, then to what extent?

However, there are few comprehensive and empirical studies in Bangladesh which are not sufficient to answer these questions. Moreover, the studies carried out in Bangladesh mostly on descriptive and theoretical basis but not empirical one. But, as far as researcher has explored, no comprehensive study has been done yet on economic analysis of crop diversification in Bangladesh let alone in northern Bangladesh. In this back drop, the study, therefore, attempts to analyze economic viability of crop diversification in northern Bangladesh.

1.3 Research Objective

Taking into account the above research questions, the main objective of the study is to analyze the economic aspects of crop diversification, especially to identify its determinants and analyze its economic viability in the context of Northern Bangladesh. The specific objectives of the study are as follows:

1. To analyze the present state of crop diversification in northern Bangladesh.

2. To identify the key factors that determines the level of crop diversification in the study area.

3. To analyze the economic viability of crop diversification in terms of measuring economic return in the case of diversified crops.

4. To forward some suggestions toward enhancing crop diversification in Bangladesh.

In order to accomplish the above objectives, the study follows the way of literature review and econometric estimation method to analyze the economic viability of crop diversification in northern Bangladesh. Specifically Herfindahl and Entropy indices have been used to measure the present state of crop diversification. Tobit regression model has been used to analyze the influence of the factors of crop diversification. Lastly, conventional profit function and benefit cost ratio have been analyzed to explore the profitability of crop diversification in northern Bangladesh. Predominantly primary data collected from the sample farmer has been used in the study and secondary data has also been used where needed to supplement the primary data.

1.4 Importance of the Study

The study of crop diversification in northern Bangladesh is very important considering the reality of food security and employment situation of the country. The outcome of the study can provide better understanding about economic viability of crop diversification in Bangladesh agriculture. From this study, firstly, interested people can know the present situation of practicing crop diversification in northern Bangladesh. Secondly, factors that influence the practice of diversification can be understood from this study. Finally, it would help understand the profitability of non-rice crops or multiple crops in existing cropping pattern. Moreover, students, researchers, planners, scholars and academicians can be benefitted from the outcome of this study. The findings may also be helpful to the agricultural extension workers to improve strategies of action for conserving farm environment that would be economically viable to the rural people.

From a subject matter perspective, this research has a contribution with an extensive review of concerning issues and methods frequently used to analyze the economic viability of crop diversification. Most of the issues and methods are complex and multidimensional and only a few studies have concentrated on all of them in a comprehensive manner. The present study focuses on economic analysis of crop diversification in a more comprehensive and meaningful way and helps to fill this literature gap. This study also has a contribution to the literature of crop diversification by analyzing economic viability of crop diversification whereas most of the previous research concentrated on nature, extent, pattern and determinant of crop diversification only. Especially, in Bangladesh, there is no significant study which has been carried out to look into this particular feature of agriculture. In this context, this issue is a new contribution in the literature of crop diversification. Therefore, this research provides a more comprehensive focus on this issue and tries to fill the literature gap.

Moreover, from the methodological perspective, the major contribution of this research is the use of Tobit regression model with marginal effects of the independent variables and the OLS regression model. Most of the previous studies used OLS, Logit or Probit models which are not exactly specified using the index of crop diversification censored to the both side. A Tobit regression model with censored values of the dependent variable is a relatively new technique to analyze crop diversification and, therefore, it would serve to make way for further research in the field of crop diversification.

Similarly, the findings of the study would definitely be helpful to the ministry of agriculture in formulating various policies. It would also help in selecting extension programs in the area of agriculture for reducing yield gap and price risk of crops as well as health and environmental hazards. The results will also be useful to the policy makers, researchers and high officials who are working in various sectors related to agriculture. Moreover, the result of the study will be an invaluable resource for those who will work in this field in the future. Last but not the least, the knowledge and skills acquired by the researcher in conducting this study will no doubt help to contribute in the field of agriculture.

1.5 Organization of the Dissertation

The dissertation has been organized in nine chapters. The review of relevant literature on crop diversification is presented in chapter Two. It covers conceptualization, extent of crop diversification, measurement indices of crop diversification, methods of analyzing the determinants and profitability of crop diversification. Chapter Three discusses production performance and crop pattern in Bangladesh agriculture. It contains land tenure system, land utilization pattern, crop sectors performance, and the intensity of crop diversification. State of crop diversification in the study area is analyzed in chapter Four which covers land characteristics, cropping patterns, cropping intensity, crop acreage and the state of diversification in sample area. Detail research methodology is placed in chapter Five. It deals with the techniques of selecting the study area, sample size selection, approaches to measure extent of crop diversification, empirical model to determine factors of crop diversification and techniques of profitability analysis. Household characteristics and crop diversification in the study area are analyzed in chapter Six. It deals with demographic and socio-economic profiles of the farmers, practices of crop diversification and comparison of the farmers' characteristics of diversified and specialized farms. Determinants of crop diversification are analyzed in chapter Seven and chapter Eight shows the analysis of economic viability of crop diversification. Finally, chapter Nine presents the major findings and conclusions of the dissertation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of past research works on various aspects of crop diversification, has been doneto enable better understanding of the conceptual and methodological issues relevant to the present study. Literature review helps understand the issues thoroughly,to identify potential areas for researchand to find out appropriate methods of analysis for a study. This chapter undertook an attempt of in-depth review of the relevant research worksand thus tried to find out the latest dimensions and updates of research in the field of crop diversification. The review is accomplished in seven sub-headings, namely,1) concepts of crop diversification, 2) measurement index of crop diversification, 3) factors influencing crop diversification, 4) empirical model used to determine factors of crop diversification, 5) crop diversification and production efficiency 6) profitability of crop diversification, and 7) opportunity of and constraints to crop diversification. All of these are presented in detail in the following sections.

2.2 Concepts of Crop Diversification

There are a number of studies carried out on different aspects of crop diversification in the context of various states of India, African countriesand Bangladesh. Different researchersdefined crop diversification in different ways and conducted empirical investigation on different aspects of crop diversification. Among them the studies of Acharya*et al*. (2011), Akanda (2010), Bhattacharyya (2008), Biswas (1993), Islam and Rabiullah (2012), Joshi (2011), Kalaiselviand Kalyani (2012) Mandal and dutta (1993), Mukherjee (2012),Rahman and Talukder (2001) and Zahir (1993) were reviewed. Most of them considered crop diversification as a strategy of reducing different types of riskand as a means of maximizing return from the farm.

Acharya*et al*. (2011) defined crop diversification as a strategy for maximizing the use of land, water and other resources relevant to agriculture and for the overall agricultural development in the country. It minimizes the adverse effects of the current system of crop specialization and rice monoculture for better resource uses, nutrient recycling, reduction of risks and uncertainty, and better soil management. While Bhattacharyya (2008) noted that crop diversification transfers resources from low value agriculture to high value agriculture,Kalaiselvi and Kalyani (2012) supported this opinion. Bhattacharyya (2008) also considered crop diversification as a means to augmenting farm income, generating employment opportunity, alleviating poverty and conserving precious soil and valuable water resources. Similarly, Abro (2012) notedthat crop diversification is advocated as one of the important strategies to stabilize and to enhance farm income, to increase employment opportunities and to conserve natural resources. However, the return from diversification depends on the availability of infrastructural facilities like irrigation, electricity, transportation, storage, markets, etc.

Mukherjee (2012) told that crop diversification reduces yield and price risk, raises yields, makes natural resources sustainable, preserves ecological balance, upholds productivity and growth, creates employment opportunities, and provides variety of foods for consumers. Joshi (2011) found that diversification towards high-value food crops yields regular, rapid and high profits to the small farmers, and offers income-security to them. The production of these crops is also labor-intensive. He also noted that it can augment income, create employment opportunities, empower women farmers and preserve natural resources. He further noted that the nature of diversification variesarea wise owing to presence of extensive heterogeneity in agro-climatic and socio-economic environment.

Mesfin*et al*.(2011) identified that crop rotation and intercropping are the two different forms of crop diversification. They find in their study that farmers intercrop for three major reasons to increase soil fertility, better use of resource and for minimizing risk due to loss from another enterprise as because crop rotation is believed to reduce disease incidence and to increase soil fertility. According to Nzie and Nonga (2012), there exist two main theoretical explanations of crop diversification. The first one holds that crop diversification derives from demographic pressure (Lightfoot & Eddy, 1995). Ruthenberg and Jahnke (1985) advocated that crop diversification comprises an exercise embedded in subsistence agriculture. Later on, they asserted that the different types of crop cultivated are dictated by taste, even if their yields are low.

Accordingly, diversification is often treated as an important means to avoid an increased dependency on a small number of agricultural productions (Wainwright, 1994). The second explanation considers crop diversification as a technique of risk minimization, in response to environmental risks (Goletti, 1999) and to economic fluctuations (Alam, 1993; Goletti, 1999). Niehof (2004) envisaged diversification as an important strategy which makes it possible to reduce vulnerability.

According to Mehta (2009), there are four dimensions of diversification,namely- number of crops, spread of cropping pattern, proportion of HVCs in the cropping pattern, and shift in cropping pattern mix. He examined the relation between different dimensions of diversification and the growth of output in India, in the last three decades. The results showed that there was great heterogeneity, in terms of typology of diversification within states, with no apparent link of one type of diversification with income and risk pattern. The temporal picture showed that the role of crop diversification in the output growth is increasing in India by the passage of time.

The extent of diversification across regions within a country depends upon agro-climatic conditions, resource endowments and infrastructure (Rao*et al.*, 2004). Mukherjee(2012) and Luenburger(1998) concluded that diversification which merely increases the return without minimizing risk is 'blind diversification'.Akanda (2010) observed that Bangladesh has an advantage of growing diversified crops in summer (April-July), monsoon (August-November) and winter (December-April) seasons. Islam and Rabiullah (2012) observed various advantages of crop diversification such as, it reduces seasonal and disguised unemployment, lessens import of non-cereals, increases soil fertility, fulfills demand for protein and calorie, increases economic growth, and expands industrialization.

In short, findings from the above literature indicate that different researchers considered crop diversification from different dimensions.Some researchers considered it as a strategy for maximizing usages of resources and overall development of agriculture. Again, some defined crop diversification as a strategy, which transfer resources from low food value crops to high food value crops. Similarly, some researchers refer it as a means of augmenting farmers' income, employment generation and elevating poverty. It is also a means of conserving natural resources, preserving bio-diversity and ecological balances. Some researchers found that it reduces yield and price risk of agricultural commodities and yield regular, rapid and high profit to small farmers.

2.3 Measurement Indices of Crop Diversification

More recent studies tend to use indices as measures of crop diversification. The simplest index is a count of the number of crops or varieties cultivated (Benin *et al.*, 2004; Ibrahim *et al*, 2009; Van Dusen& Taylor 2005). This provides a general level of overall diversity of a farm, but gives no insight as to whether the farm is growing cash or staple crops, and what percentage of resources are allocated to which. In the common example of a farm dominated by maize or another staple grain, a family often has a kitchen garden, or a small plot is used to grow vegetables or other crops for home use, the count index would fail accurately to capture the diversity of that farm.

A variety of other indices are used in the literature to address this problem. Indicesmost commonly used are (i) Index of maximum proportion, (ii) Herfindahl Index, (iii) Simpson Index, (iv) Ogive Index, (v) Entropy Index, (vi) Modified Entropy Index, (vii) Composite Entropy Index, (viii) The Shannon Index, and (ix) Margalef Index (Benin*et al.*, 2004; Chand, 1996; Kelley *et al.*, 1995;Pandey& Sharma, 1996). Different researchers have used different indicesto measure the extent of crop diversification. They used specific index according to the objectives of the study. Each method has its limitations and superiority over the others (Shiyani, 1998).

To measure the extent of crop diversification Ashfaq*et al* (2008),Ghosh (2010),Kalaiselvi and Kalyani (2012), Kumari*et al*(2010), Malik and Singh (2002), Mehta (2009) andPope and Prescott (1980) have used Theil's Entropy Index. An Entropy measure of farm diversification considers the number of enterprises a farm participates in and relative importance of each enterprise to the farm. The Entropy index spans a continuous range from zero to one. The value of index for a completely specialized farm producing one crop is zero. A completely diversified farm with equal shares of each crop has an entropy index of one.

Acharya*et al.* (2011) has used Composite Entropy Index (CEI)to analyze the nature and extent of crop diversification in the state. In this case, they used secondary data for a period of 26 years from 1982-83 to 2007-08. They calculated CEI for different crop groups and found that almost all the crop groups have higher crop diversification index during post-WTO (1995-96 to 2007-08) period than during pre-WTO (1982-83 to 1994-95) period, except for oilseeds and vegetable crops. They also found that the CEI for cereals during pre-WTO and post-WTO was 0.698 and 0.729, respectively. In general, the trend of CEI was almost the same within the pulses group with all values lying in the range between 0.704 and 0.722.Kalaiselvi and Kalyani (2012) used time series data from 1998-2008 and found Entrophy Index for Villupuram district of Tamilnadulies between 0.171 to 0.503 for food crops.

Simpson Index is used by Aneani*et al* (2011), Bhattacharyya (2008), Haque and Bhattacharya (2010), Jha*et al.* (2009), Joshi*et al.*(2004), Metzel and Ateng (1993), Ndhlovu(2010) and Roonnaphai (2006).This index accounts for both abundance and evenness of the crops. This index provides a clear dispersion of commodities in a geographical region. The index value ranges between zero and one. If there exists complete specialization the index approaches towards zero, and the index is easy to compute and interpret, which was developed initially for use in measuring biological diversity, includes both characteristics of crop diversity.Aneani*et al* (2011) found that the farmers have diversified cocoa cultivation to some extent into growing other crops such as oil palm, citrus, cassava, cocoyam, etc. to expand their sources of income. This was confirmed by Simpson Index of diversification estimated to be 0.9.

Bhattacharyya (2008) used secondary data from 1997-2005 to find out the extent of crop diversification in West Bengal and the researcher found that the Simpson Diversity index has moved up from 0.52 in 1997-98 to 0.59 in 2004-05 implying a gradual shift in cropping pattern and production of fruits and vegetables is picking up momentum in the West Bengal. The study also showed that in the same time SI of India was 0.61 in TE 1980-81 to 0.69 in TE 2004-05. The trend reflects that non-food crops are gradually replacing food crops. Haque and Bhattacharya (2010) used Simpson index of crop diversification by using 2010-11 data and found that the value of Simpson index is the highest in Orissa (0.25) followed by Bihar (0.18), West Bengal (0.16), Uttar Pradesh (0.15) and Jharkhand (0.08).

Using time series data from 1981-2000, Joshi *et al.* (2004) calculated the Simpson index of diversity (SID) for South Asia and found to be 0.59 in TE 1981-82 and 0.64 in triennium ending (TE) 1999-2000. This showed that South Asia had been gradually diversifying its crop sector in favor of high value commodities, especially fruits, vegetables. They also calculated SID for Bangladesh and found it to be 0.39 in 1981-82, 0.36 in 1991-92 and 0.35 in 1999- 2000 that indicated that Bangladesh had been making specialized its crop sector in favor of rice. Roonnaphai (2006) also used time series data from 1993-2000 and found that the values of SID of Thailand were around 0.77 to 0.80 from 1993 to 2002. This indicates that the degree of agricultural diversification in the ten major crops in Thailand is almost stable because the values have remained almost unchanged, which might be caused by commodity prices, specialization, returns from the major crop or policy. Similarly, Ndhlovu(2010) used Simpson index of crop diversification as the dependent variable in the assessment of the relationship between farm households' access to fertilizer subsidy and crop diversification level. This relationship is analyzed using the treatment effect model by using pooled panel data.The study found that farm households' access to fertilizer subsidy is associated with a decrease in the cropland allocation to maize and pulses while there is an increase in cropland allocation to ground nuts, roots-tubers and tobacco. In terms of crop diversification, the study findings suggest that farm households' access to fertilizer subsidies promote crop diversification. This has implications for household welfare in the way that crop diversification enhances stability of household incomes through the mitigation of price and crop production risks and shocks.

The Herfindahl Index, from the marketing industry index of market concentration, measures the concentration of crop type. It gives the reverse value of Simpson index. Alam (2009), Bittinger (2010), Ghosh (2010), Kalaiselvi and Kalyani (2012), Malik and Singh (2002), Mehta (2009), Mukherjee (2012),Rahman (2010, 2009a, 2009b) and Turner (2014) used Herfindahl Index to measure the extent of Crop diversification. It should be noted that the Herfindahl index is the index of concentration and thus, the higher value is an indication of specialization of crop activities. Therefore, to obtain the index of diversification, it is subtracted from one, which is the simplified form of Simpson Index of diversification. Like Simpsonindex, Herfindahl index accounts for both abundance and evenness of the crops in a specific region. By using time series data from 1980–99 Alam (2009) found that growth trend of crop diversification is positive and satisfactory in the country, however, a few districts have been seen in negative trend.

Benin *et al* (2004), Rahman (2010), Rahman (2009a, 2009b) used Shannon Index. This index was adapted from the ecological indices of spatial diversity in species, measure evenness which combines both richness (number of crops) and relative abundance. Its value ranges between zero and one. Higher value denotes higher diversification. Benin used this index to measure the degree of crop diversification of household farms in the highlands of northern Ethiopia whereas Rahman used this index in Bangladesh.

Margalef Index, characterized by richness or the number of crops observed, was used by Rahman (2008) and Rehima*et al* (2013). Extent of crop diversification can also be measured as proportion of non-rice area in the total cropped area (Rahman&Talukdar, 2001).Metzel and Ateng (1993) have used Rice share index (RSI) to calculate the level of crop diversification in Bangladesh. The RSI says that the higher is the rice share area of total crop areathe loweris the extent of crop diversificationof a farm.

From numerous empirical research reviewed above, it is found that there are different measurement indices of crop diversification and those indices yield different value at different context. Interestingly, most of the study used time series secondary data to calculate the indices of crop diversification and very few studies used primary data in this regard. However, among these indices, Herfindahl Index, Simpson Index and the Entropy Index are widely used in the literature of crop diversification as these indices are easy to compute and to provide appropriate measure of crop diversification. All these indices are computed on the basis of proportion of gross cropped area under different crops cultivated in a particular geographical area.

2.4 Factors Influencing Crop Diversification

Most of the recent studies carried out on different aspect of crop diversification, for example,Acharya*et al* (2011), Badiuzzaman*et al*(1995), Bhattacharyya (2008), Kalaiselvi and Kalyani (2012), Malik and Singh (2002), Mesfin*et al* (2011), Metzel and

Ateng (1993), Pingali*et al* (1997),Rahman (2009a), Turner (2014)andZahir (1993) tried to find out determinants of crop diversification and to estimate their impacts on crop diversification. Determinants of crop diversification from their findings are farm size, family pressure, age of the farmers, farming experience, infrastructure, family income, farm income off-farm income, irrigation intensity and what not. However, factors used by the researcher are almost similar but their influences on crop diversification yield mixed influence.

Acharya*et al* (2011) found that crop diversification is influenced by a number of infrastructural and technological factors. They suggested that basic infrastructural facilities like sustained supply of irrigation water, markets, fertilizer availability, proper roads and transportation is an essential pre-requisite for creating enabling conditions for fostering the process of agricultural development and crop diversification. Most of these parameters were found to influence the nature and extent of crop diversification.

Ashok and Balsubramania (2006) found the importance of infrastructure in explaining the extent of diversification. They observed that access to road for mechanized transport, market and irrigation determines the extent, success and profitability of diversification through high paying crops. The role of farm size according to their study was insignificant. Using data from the South Asian countries, Joshi *et al* (2007) reported results similar to those observed by Pingali*et al* (1997). They found that with the gradually shrinking of land holding size and with the growth in total, factor of productivity and profitability stagnating or slowing down the viability of small holders should not depend only on rice.

Walker*et al*(1983) found that the type of diversification and its consequences and implications are strongly conditioned by different regional agro-climatic and soil environment. Rahman (2009b) showed the determinants of crop diversification are farmers' land ownership, education, experience of cultivation, family size, extension contact, non-agricultural income of the household,infrastructureand soil fertility. Abro (2012) found land tenures, off-farm activities, education and environmental dissimilarity as an important determinant of crop diversification at the farm level.Chowdhury (2003)used cross sectional data with twelve selected characteristics to observe the attitude towards the crop diversification. Seven of them namely education level, family's annual income, cosmopoliteness, knowledge on crop diversification, risk orientation and awareness on adverse effect of rice monoculture were positively correlated with their attitude towards crop diversification. On the other hand, age, family size, training exposure, extension media contact and innovativeness had no significant relationships with attitude towards crop diversification. He also used stepwise regression and Path analysis to observe the effect on farmers' attitude towards crop diversification.

Sharma (2011) observed that farm size, family labor, non-farm income, irrigation facility, farm asset, etc. which influence the farmers' decision in selecting crops. Kar*et al*(2004) concluded that crop diversification in upland areas served as a good measure to mitigate drought as well as to increase water use efficiency. Ashfaq*et al*(2008) evaluated that the main factors affecting diversification were farm size, age, education, farming experience and off-farm income of the family of the farmers, distance of farm from main road and distance of farm from main market and farm machinery. Among the factors farm size, education of the farmers and farm machinery influence crop diversification positively whereas distance of farm from main road influences negatively. Gupta and Tewari(1985) found that irrigation intensity, farm value, price risk, and farm size were strong variables affecting the level of crop diversification.

Rahman (2008) identified that in Bangladesh, crop diversification is positively influenced by farm size, livestock ownership, farming experience, education, membership in NGOs, region with developed infrastructure and unavailability of irrigation. Also, diversification is significantly higher among the owner operators. Inverse findings are available from Mesfin*et al* (2011). The findings like livestock ownership and the number of extension contact are negatively related to crop diversification whereas the number of farm, access to market information, ownership of farm machinery and access to irrigation are positively related to crop diversification.

Metzel and Ateng (1993) also observed that distance of farm from market and alternative sources of income are negatively related and access to electricity, extension contact and ownership of farm asset positively related to crop diversification.Nagarajan, *et al* (2007) found that education, livestock, number of plot, road density, off-farm employment, distance to seed sources, seed replacement rate, seed to grain price ratio, seed trader and farm location were significant determinants of the Indian household and community level millet variety diversification.

Turner (2014) studied the determinants of crop diversification among Mozambican smallholders. By using household panel data collected in 2008 and 2011, he employed Fixed Effect Model and found that expected crop prices, access to roads and mobile networks, household and farm size are all significant determinants of household level diversity. He also employed a two-stage decision model using correlated random effects to explore the recent upsurge in pigeon pea cultivation, finding market prices to be significant predictors of a farmer's decision to plant pigeon peas, while the presence of communication infrastructure in a village increases the amount of land allocated to pigeon peas.

Zahir (1993) found that regions receiving greater rainfall and characterized by medium land are found to be more suitable for cereal production. In contrast, cultivation of minor crop is more suitable on high land in regions with low rainfall. He also observed that expansion of irrigation is negatively related to the crop diversification. Badiuzzaman*et al* (1995) found that the farmers' decision in selecting crop and cropping pattern is based on climatic factors, family needs, labor availability, capital, market demand, irrigation suitability and above all the farmers' preference. Farmers usually make their crop plans based upon tradition, i.e., through their own and inherited experience and from the discussions with neighboring farmers.

Benin *et al* (2004) found that socio-economic and demographic characteristics of the household such as the age and sex of the household head, the education of its members and its size bear no significant relationship to the diversity of cereal crops they grow.By using secondary data from the Central Statistical Office of Zambia,Sichoongwe*et al* (2014) studied the determinants of crop diversification of smallholder farmers in Southern province. They used double-hurdle model and found landholding size, fertilizer quantity, distance to market, and the type of tillage mechanism adopted have a strong influence on whether a farmer practices crop diversification.

The findings from abovereviewed studies,with regard to the factors that influence crop diversification, are mixed and ambiguous.The study found some variables, whose influences on crop diversification are positive for some areas whereas the same variables influenceon crop diversification negative for other areas.

2.5 Empirical Models Used to Determine Factors of Crop Diversification

It is observed in the recent studies that to find out the causal relation and intensity of the factors of crop diversification, different researchers have used different regression models. Some of them have used Multiple Regression Model with using Ordinary Least Square (OLS) estimation technique while some other have used Logit, Probit and Tobit Regression Modelswith using Maximum Likelihood estimation technique on the basis of the nature of dependent variable. The values of crop diversification indices computed for measuring horizontal diversification were taken as dependent variable and different factors affecting the intensity of crop diversification were taken as independent variables.

Aneani*et al* (2011), De and Chattopadhyay (2010),Kumari*et al* (2010) and Ojo*et al* (2013) usedMultinomial Logistic Regression analysis for the investigation of the determinants of a phenomenon or relationship between categorical dependent variable and a set of explanatory variables. Using Logistic Regression Model, Pitipunya (1995) identified the land/man ratio, education and trade experience as most important factors that influenced the cropping pattern, in Thailand. The Multinomial Logistic Regression Model results indicated that age, access to credit and regional location affected the crop diversification in Ghana (Aneani*et al*, 2011).

Ojo*et al* (2013) found from the results ofMultinomial Logistic Regression model that income, farm size and output from the chosen enterprise had positive and significant effect on farmer's choice of an enterprise. This implies that the probability of choosing yam or cassava enterprise increased with income earned from the enterprise, farm size and output from chosen enterprise. De and Chattopadhyay (2010) found that marginal and small farmers play a positive role in crop diversification and that has been supported by the growth of various infrastructure networks during the period under consideration.

From the Logistic analysis,Kumari*et al* (2010) found that farmers in responding to crop diversification opportunities are constrained by the inactive farmer organization, markets, and poor irrigation infrastructure. This analysis also showed that the probability of the diversification was determined by family labor, farmer organizations' collective action including irrigation management and market arrangement. They also checked Heteroskedasticity and Multicollinearity in the model. Heteroskedasticity arises due to cross-sectional data and it was corrected by using Goldfeld and Quant test. Multicollinearity was tested using the correlation matrix of the independent variables and he found that farm size was highly correlated with farming category. Thus, farm size was dropped from the model in order to avoid Multicollinearity. Chi-square (χ^2) statistics indicated that the models were significant at 10% level.

Abro (2012) and Joshi *et al* (2004) applied Generalized Least Square (GLS) technique with fixed-effect model to examine how different forces have influenced crop diversification in India. The analysis is based on pooling of cross section and time series data. The GLS eliminates the effect of Heteroskedasticity arising due to cross section data, and Autocorrelation as a result of time series data. Moreover, using Generalized Least Square (GLS) technique Joshi *et al* (2004) found that relative profitability, irrigation, road, markets, rural literacy, the proportion of small holders, income from crop, urbanization, rainfall and production year affected crop diversification in South Asia.

By applying GLS technique with Fixed Effect Model Abro (2012) found that infrastructural development, length of roads has positive and significant impact on crop diversification. Similarly, the demand-side factors such as per-capita income have also positive and significant impact whereas the regression coefficient of population showed a negative and significant impact on crop diversification towards HVC. Ndhlovu(2010) examined crop choice and cropland allocation patterns by using GLS model.Empirical results indicate that farm households' cropland allocation patterns and the subsequent crop diversification levels are sensitive to fertilizer subsidy program. In particular, the results showed that farm households' access to fertilizer subsidy is associated with a decrease in the cropland allocation to maize and pulses while there is an increase in cropland allocation to ground nuts, roots-tubers and tobacco. In terms of crop diversification, the study findings suggest that farm households' access to fertilizer subsidies promote crop diversification. The results illustrate that fertilizer subsidies to maize positively contribute to promoting farm households' crop diversification level through intensified maize production. This has implications for household welfare as crop diversification enhances stability of household incomes through the mitigation of price and crop production risks and shocks.

Ashfaq*et al* (2008), Bhattacharyya (2008) and Ibrahim*et al*(2009) used Multiple Linear Regression model with cross section data to determine the effect of different factors on crop diversification. To explores the determinants of crop diversification in Pakistan, Ashfaq*et al* (2008) applied Multiple Regression model and discovered that farming experience, education, land size, farm distance from main road and farm machinery are the significant factors.

Using Multiple Linear Regression model Ibrahim *et al*, (2009) identified that age and education of the household head, extension visits, availability of tractor hiring, income from crops and road access to be the significant determinants of crop diversification in Nigeria. Olujenyo (2012) studied determinant of agricultural production with special reference to maize production. Production function was analyzed by employing the Ordinary Least Square (OLS) estimation techniques. Result found from the study that showed that majority of the farmers were age old and quite experienced in maize farming. Also there was high level of illiteracy as about 65% of total respondents had no formal education while 25%, 6% and 4% had primary, secondary and technical education respectively. Farming was majorly on subsistence level as the mean farm size was 0.39 hectares. In addition, results showed that farm operation was in stage II of the production function with RTS estimated as 0.62 and factors of production were efficiently allocated with elasticity which waspositive but less than one. Results further showed that age, education, labor and cost of non-labor inputs were positively related to output while farm size and years of experience carried negative signs. However, only labor input has significant influence on output.

Bhattacharyya (2008) found from the regression results that of the two technology variables, fertilizer use has a positive and significant effect on the degree of crop diversification. The coefficient of irrigation is, however, negative implication that crop diversification decreases with the increase of irrigated area. Urbanization also has a positive impact on crop diversification. Improved technology however reduces diversification.

On the other side, Rahman (2004, 2008) used Bivariate Probit analysis and found that Bangladesh's crop diversification was significantly affected by farm asset, irrigation access, rented land, education, farming experience, infrastructure and non-agricultural income. He also used Multiple Regression Model using OLS estimation technique and Tobit Regression model using Maximum Likelihood Estimation technique.

Abay*et al* (2009),Gauchan*et al* (2005), Husain*et al*(2001) and Mesfin*et al* (2011) used Standard Tobit model to estimate adoption function for hybrid rice. Using Tobit model, Abay*et al* (2009) revealed that barley variety diversity was affected by age, age square, male headed household, numbers of children, livestock, fragmentation index, farm size, altitude, rainfall, extension and temperature in Tigray, Ethiopia. Similarly, Mesfin*et al* (2011) estimated that extension contact, livestock rearing, market information, access to irrigation, number of farm plots and ownership of farm machinery significantly influenced crop diversification in eastern Ethiopia. By using Poission and Tobit models, Gauchan*et al* (2005) discovered that growing rice varieties was significantly influenced by the age and education of the household heads, adult labor, livestock, subsistence ratio, irrigation, land type, plot dispersion, modern variety sold and market access in Nepal. Similarly, Kankwamba, *et al* (2012) conducted a study on the determinants of crop diversification in Malawi. Taking Herfindahl Index as the dependent variable the researchers used Tobit Regression Model. They found that, although crop diversification had decreased nationally and regionally, beneficiaries of the subsidy program had become more diversified in their cropping practices. Their study concluded that while various policies in Malawi encourage agricultural diversification in broad terms, there was a lack of strategic thinking around how exactly it was to be achieved, and more importantly, how crop diversification could be promoted among different types of farmers with the aim of contributing to economic growth, risk mitigation, and nutrition security.

Rehima*et al* (2013) used the Heckman two-stage model to estimate separately the farmers' decisions and level of diversification. The factors that affected crop diversification were gender, education and trade experience, membership in cooperatives, resource ownership, features of the land owned, access to extension services and transaction costs.Kimhi and Chiwele (2000) used same model and detected that household demographics, rural road construction, market access and maize yield rate influenced Zambian maize diversification. Weiss and Briglauer (2000) applied instrumental-variable regression model and found out that farm size, part-time farming, education, family size and the location of the district are significant determinants of the farm diversification in Australia.

Other researchers used Generalized Linear Model (GLM) and NLRM and observed that proximity to town, access to road, education, liquid wealth, and irrigation access are significant factors that affected crop choices in Northern Ethiopia (Seid&Seebens, 2008). To find the determinants of agricultural diversification in Central Queensland of Australia, Windle and Rolfe (2005) employed the Nested Multinomial Logit model and observed that debt, age, education, number of children, off-farm income, farm size, start-up cost, net income, other crops grown and risk time are the most determinant factors.

It is evident from the above reviewed literature that different researchers used different empirical,models to capture the causal relation and intensity of factors that influence crop diversification. Different studies found mixed and inconclusive results in the causal relation and intensity of the factors although used almost the same factors in their regression model.

2.6 Crop Diversification and Production Efficiency

A review of the study suggests that the impact of crop diversification on production efficiency is quite mixed. While Guvele (2001) and Van den Berg *et al* (2007) found that crop diversification minimizes income variability in Sudan and sustains a reasonable income level for Chinese farmers, respectively, and Kar*et al* (2004) conclude that crop diversification increased agricultural production in Bangladesh.

According to Johston*et al* (1995), crop diversification has three dimensional benefits which the author described as economic, social and agronomic. The economic benefits include: seasonal stabilization of farm income to meet other basic needs of life like education of the children; coverage of their subsistence need; most especially meeting family food security; and a reduction of risk of the overall farm return by selecting a mixture of activities whose net return has a low or negative correlation while lessening price fluctuations. Social benefit includes seasonal employment for farm workers while the agronomic benefits include: conserving precious soil and water resources, reducing diseases, weed and insect build up, reducing erosion, increasing soil fertility, and increasing yields (Ali &Beyeler 2002; Caviglia-Harris & Sills, 2005;Gunasena, 2000).

Paul and Nehring (2005) observed that diversification is a significant factor explaining differences in the level and variability of farm income between higher and lower performing small farms. Several other micro-level studies supported the above proposition (Braun, 1995; Ramesh, 1996; Ryan & Spencer, 2001). In addition, many developing countries have incorporated crop diversification strategy in several development programmes (Gunasena, 2000). A significant example of this is the well documented Asian experience in the successful use of diversification strategy in the commercialization of agriculture in the 1990s (Hoque, 2000;Mariyono, 2007).

Ogundari (2013) found the evidence of decreasing returns-to-scale and technical progress in the food crop production in the region. Education, extension, and crop diversification are identified as efficiency increasing policy variables while an average technical efficiency level of about 81% was obtained from the analysis. Haji (2007) and Lleweln and Williams (1996) revealed that diversification significantly decreases the efficiency of farmers in Indonesia and Ethiopia, respectively.While

Coelli and Fleming (2004) and Rahman (2009) reported that diversification improves efficiency of the farmers in Papua New Guinea and Bangladesh, respectively. The mixed findings from these studies indicate that the effect of crop diversification on agricultural productivity might vary from region to region or case to case.

The findings from the empirical studies highlighted above appear mixed with regard to the impact of crop diversification on production efficiency in the developing agriculture. However, considering the fact that the studies have shown that crop diversification is a recognized phenomenon of interest among the dominated peasant farmers in the agricultural production systems (Ajibefun, 2006; Fawole&Oladele, 2005).

2.7 Profitability of Crop Diversification

Several recent studies have attempted to estimate profitability of crop production. They used various methods to analyze profitability. Mostly used methods are total cost and gross return (Π = TR- TC) analysis, benefit cost ratio (BCR), Gross Margin (GM) and Net Margin (NM) etc. There are host of studies where researchers have used cost benefit analysis (CBA) to measure the profitability of the crops. For example, Ahmed *et al*(2013), Haque*et al* (2013), Haque*et al* (2012), Haque*et al*(2011), Hoq*et al* (2012), Kabir and Islam (2012), Karim*et al*(2009), Moniruzzaman*et al* (2009) and Mukul and Rahman (2013) have used benefit cost ratio (BCR) over total cost and total variable cost to analyze profitability of respective crops in their study.

Haque*et al* (2011) estimated profitability of onion cultivation by using farm level primary data. To estimate the profitability, they used benefit cost ratio and found that the cost of onion cultivation was found to be Tk.93,517.00 per hectare on total cost basis. Seed cost (41%) was the major cost item followed by human labor cost (24%). The yield of onion was found 9,869 tons per hectare. The gross margin and net return were found to be Tk.85,308 and Tk.79,487 per hectare, respectively. The benefit cost ratio was found 1.85 for onion.

Kabir and Islam (2012) did a comparative study on Rabi crops by using farm level primary data. They did cost benefit analysis by using net margin and gross margin approaches. They found that wheat is a more profitable Rabi crop than other crops like grass pea, mustard, lentil. Farmers earned the highest per hectare gross return (Tk.98646) and gross margin (Tk.22870) from the Wheat + *Aus*rice + T. *Aman* rice pattern whereas *Boro* rice + Fallow + T. *Aman* pattern produced the lowest gross return (Tk.65918) and gross margin (Tk.10134). Higher benefit was achieved from the pattern Wheat + *Aus*rice + T. *Aman* rice because of less production cost and high price of wheat grain, though three cereals crops could exhaust soil nutrient so that Mung-bean + *Aus* rice + T. *Aman* pattern may be alternate option to sustain soil health as well as productivity of the selected area.

Afroz and Islam (2012) estimated the relative profitability of growing *aus*rice and jute and to determine the resource use efficiency in the production of these crops by using primary data. They used benefit cost ratio and found that total costs for producingjute and *aus*rice were Tk.50,254 and Tk.44,970 per hectare, respectively. The equivalent gross returns were Tk.83,717 and Tk.55,762, respectively. Accordingly, net return for jute was Tk.33,463, which was about three times higher than that for *aus*rice (Tk.10,792/hectare). Moreover, BCR of producing jute was about 30% higher (1.7) than that of *aus*rice (1.3). Cobb-Douglas production function was used to estimate specific effects of individual inputs on production of jute and *aus*rice. Resource use efficiency analysis showed thatneither in jute nor in*aus*rice production farmers were found efficient enough to use various inputs. Therefore, it seems that efficient and judicious use of various resources would enable both jute and *aus*rice farmers to earn more profit.

Haque*et al* (2012) analyzed profitability of hybrid maize seed by using primary data collected from hybrid maize seed contract growers and 120 maize (non-seed) growers were selected randomly for the study.In this case, they used cost benefit ratio and found that the cost of production was higher forNGO (Tk.66,472/ha) than the public agency (Tk.64,836/ha) and private company(Tk.59,352/ha). The yield of hybrid seed was higher under NGO (3,780 kg/ha)than that of public agency and private company. Net return of hybrid seedproduction for contract growers was higher under public agency (Tk.78,204/ha)compared to private company (Tk.39,088/ha) and NGO (Tk.33,246/ha). Benefitcost ratio (BCR) was higher for the contract growers of public agency (2.21). Netreturn of hybrid maize seed production was 50% higher than that of non-seedproduction. High price of seed and lack of technical knowledge were majorconstraints of hybrid maize seed production in the study area.

Karim*et al* (2009) assessed the profitability, contribution of factors to production of BARI hybrid tomato. In this case, they used cost benefit ratio and Cobb-Douglas production function to estimate functional form of tomato production by using multiple regressions. They found from the study that about 42% and 21% of total variable cost was incurred for tunnel preparation and using human labor, respectively. The average return per hectare over variable cost is observed to be Tk.11,44,387 on full cost basis and Tk.12,07,481 on cash cost basis. On an average benefit cost ratio was found to be 4.19 on full cost basis and 5.09 on cash cost basis. The cost of per kilogram hybrid tomato cultivation was Tk.10.94 and return from one kilogram of tomato production was Tk.45.83. The functional analysis shows that MP and TSP had positive significant contribution to yield while human labor, hormone, irrigation and seed had negative significant impact on yield of hybrid tomato.

Mukul and Rahman (2013) estimated profitability of banana production by using primary data. In the study, they investigated total cost, profit and benefit cost ratio for different marketing channel like banana producers, wholesalers and retailers. They found that profit for producer wasTk.55,002.8 per hectare. Similarly, benefit cost ratio for producers was 1.40.

Haque*et al* (2013) studied the profitability of crop diversification by using data collected from randomly selected farmers. They used benefit cost ratio over variable cost as well as total cost. They found that the costsof rose cultivation were Tk.3,87,569 and Tk.2,75,214 per hectare on full costand variable cost basis, respectively. The major share of full cost was incurredfor human labor (30%), followed by land use (23%), fertilizer (17%), andirrigation (12%). The netreturn from rose cultivation was Tk.23,31,196per hectare. The benefit costratios were 2.29 and 1.63 on variable cost and full cost basis, respectively. Thehighest profit was obtained from rose cultivation compared to its competitivecrops like potato+jute, lentil+*teel* and mustard+*mung* +bean for Rose.

Moniruzzaman*et al* (2009) analyzed profitability level of maize production in Bangladesh. They collected data from 200 randomly selected maize growers using pre-designed interview schedule. To analyze profitability, they used net margin, gross margin and benefit cost ratio and found thatthe average cost of maize production were Tk.44,197, Tk.33,195 and Tk.24,441 per hectare on total cost, variable cost and cash cost basis, respectively and gross return was Tk.69,773 per hectare. The gross margin was Tk.36,578/ha on total variable cost (TVC) and Tk.45,332/ha on cash cost basis. The net return was observed to be Tk.25,575 per hectare. Benefit cost ratios were calculated as 1.58, 2.10 and 2.85 on total cost, variable cost and cash cost basis, respectively.

Olujenyo (2012) studied profitability of maize production in Akoko North East and South West Local Government areas of Ondo state. Data collection was through well structured questionnaire. The methods of analysis used were gross margin analysis and found Maize farming was profitable in the study area with gross margin and net returns N2,637.80 and N2,141.00, respectively.

Although there are several research works onprofitability of various issues, very few of them were focused on crop diversification. To analyze the profitability most of them use conventional profit determining model, i.e. total costs and total returns analysis. To find out profit, total costs are deducted from total returns. Zahir (1993) observed that vegetables, spices and modern variety of potatoes are much more profitable than modern variety of *boro* rice. He also found that vegetables-based cropping pattern on irrigated high land was much more remunerative than *boro*-based cropping pattern. The results of financial and economic analyses had shown that a number of crops such as potato, vegetables, onion and cotton have high financial and economic return which were significantly higher than those of rice.On the other hand, wheat, sugarcane and oilseeds had a very low economic return although private return from sugarcane was quite high (Mahamud*et al*,1994).Alam (2009) studied on the comparative cost and return of the various crops and found diversified crops were more profitable than rice and it had a positive impact on reducing poverty through consuming nutritional food. Alam also concluded diversified agriculture might be a leader of uplifting socio economic condition through effective and pragmatic planning on income and nutrition.

2.8 Opportunities and Constraints of Crop Diversification

Crop diversification has been considered as a strategy to augment yield, production and income of the farmers. It also reduces risk of yield and price volatility of the farmers. Hence, it is very much common that there may have some constraints. Very few comprehensive studies have been carried out on opportunity and constraint of crop diversification. Metzel and Ateng (1993) observed that various problems like infestation of weeds, vulnerability to pest and diseases, declining yield over time, requirement of excessive labor, high fertilizer and plant protection chemical cost, lack of credit facilities, erratic rain, sensitivity to dry spell, output price fluctuation and low profits are faced by non-rice producers in Bangladesh. Pingali*et al* (1997) concluded that small and marginal farmers need diversification of crops for meeting their living-cost, but the farmers, in most cases, constrained by the size of market, price risk, soil suitability, irrigation- infrastructure quality, availability and cost of labor.

Rahman and Talukder (2001) found that one important constraint of diversification, in existing soil quality and heterogeneous topography, is the irrigation and existing water arrangement system. Most of the present irrigation systems in Bangladesh are planned, designed, constructed and managed mainly to water rice field and are inappropriate to produce non-rice crop.Alam (2009) found that over supply on non-rice crop, price deprivation, and inadequate marketing infrastructure were the major problems of diversified crops.

Biswas (1993) identified important constraints like scarcity of land, appropriate soil fertility, chronic food deficit, lack of suitable water management practice with present rice-based irrigation approach and poor tillage practice. Rapid economic growth with decelerating demand for cereals due to accelerating demand for high value commodity, increasing availability of modern technology, falling agricultural output price, changing role of government, expanding role of private sector, improving supply chain management, improving food safety and better quality, emerging trade liberalization and liberalization of capital flow are nurturing the process of crop diversification.

In a similar vein, the market availability and size, price risk, land suitability and land right, irrigation infrastructure and labor supply are identified to be the major constraints in accelerating the process of crop diversification (Braun 1995; Dorjee*et al*,2003; Joshi *et al*, 2007; Pingali, 2006;Pingali&Rosegrant, 1995; Pingali*et al*, 2005;Sharma, 2011).

Bangladesh is endowed with favorable climate and soil to produce a variety of crops all the year round. So, there are ample opportunities for diversification in crop agriculture. In Fourth Five Years Plan (1990-95), introduction of appropriate cash and commercial crops and policy support for flood and drought resistant crop are considered as the guiding force to promote national crop diversification effort. Zahir (1993) observed that in Bangladesh there are narrow scopes for crop diversification for high and medium high land; and also long-established irrigation. Expansion of minor irrigation will generally make high and medium-high land more cereal based crop economy and here crop diversification is made possible due to production of vegetables, potatoes and spices. Potatoes as well as other shorter duration vegetables crops can be grown during the turn-around period between the harvest of transplanted *aman* and planting of HYV *boro* rice without affecting *boro* rice yield (Mandal&dutta, 1993).

Rahman and Talukder (2001) observed that although many high value crops are more profitable, farmers produce rice because most of the non-rice crops face high price volatility, lack of access to modern input, technology, credit and improved commercial facilities. However, some researchers believe that a lesser degree of crop diversification is prevailing in Bangladesh andBiswas (1993) concluded that crops are by and large diversified in Bangladesh as more than a hundred crops are grown depending on farmers’ choice and preferences with respect to soil, climate, and other taste and economic gains.

Biswas (1993) noted that the major opportunities of crop diversification are thought to be lying in the dry months which have both brighter days and longer active day lengths compared to wet months. A low level incidence of pests and diseases prevail in dry month due to both low temperature and low humidity. The real prospects for crop diversification, however, would still depend on how far technological innovations could make non-cerea1 crops competitive under the conditions of modern irrigation (Mahmud *et al*,1994).

Haqueand Bhattacharya (2010) concluded that major constraints reported by small and marginal farmers for crop diversification towards high value crops were lack of proper irrigation facilities, lack of knowledge and information, and non-availability of timely credit. Chowdhury (2003) found that lack of agricultural credit, lack on extension contact, lack of necessary training and marketing problems of different crops are the major problem faced by the farmers to adopt crop diversification.

2.9Major Findings and Gaps in the Literature

In this chapter, the researcher tried to review comprehensively the previous literature and empirical studies, on crop diversification, carried out in home and abroad. The prime objective of this chapter was to find out research gaps in the literature. The above review shows that, there are several studies regarding crop diversification in India, Pakistan, Philippines and many African countries. But, a very few studies have been carried out in the context of Bangladesh and these studies have been concentrated on measurement and drivers of crop diversification. It is also observed that although determinants of crop diversification are almost same in all the studies, their influences are found different. Hence, the majority of the existing literature, reviewed in the chapter, does not shed much light on economic viability of crop diversification. However, it is certain from the above literature that natural and socio-economic factors among the important determinants of crop diversification would be the focus of this study.

In addition, majority of the studies regarding this issue have been carried out based on secondary data from various government and non-government sources. The sources provide national level average data. As there are many Agro Ecological Zones (AEZs) in Bangladesh and each zone is special for specific crops, so national level of data hardly represents a particular area. Besides, the studies carried out in Bangladesh were not empirically tested, which is momentous to find out significance of the result. As far as researcher’s knowledge goes, there are a very few empirical studies regarding this issue which can help the government in making policy. In short, there is no comprehensive research on economic analysis of crop diversification in Bangladesh, let alone, in northern Bangladesh. In this study, the researcher will try to explore the effectiveness of crop diversification strategy in northern part of Bangladesh along with the judgmentwhether it is profitable or not.

2.10 Conclusion

From the brief review of the literature on crop diversification and its different dimensions, it is found from the literature that there are some indices of crop diversification like Simpson index, Entropy index, Herfindahl index, Shannon index, Margalef index, etc. to calculate the level of crop diversification. The literature review also reveals that there are some socio-economic and demographic factors of farmers and farm like farm size, household size, age, education and experience of the farmers, cropping intensity, infrastructures, etc. which influence crop diversification directly. To estimate the influence of these factors on crop diversification, some empirical models like Logit, Probit, Tobit and Ordinary regression model have been used. It is also found that crop diversification enhances production efficiency and profitability of farms from crop production. Finally,this literature review successfully exposes the scope of further research study on crop diversification issue in the context of northern Bangladesh. Specifically, the findings and major gaps of the earlier studies show the way to move on. Therefore, this study will fill up the earlier literature gaps in the above aspects and pave the way for further research in this field.

CHAPTER THREE

PRODUCTION PERFORMANCE AND CROP PATTERN IN BANGLADESH AGRICULTURE

3.1 Introduction

Agriculture is the main source of income and employment of majority of the rural populace in Bangladesh. It is also a significant contributor to theeconomy of Bangladesh. After the independence in 1971, the agricultural sector has developed gradually and at the same time has undergone many changes as a result of availability of modern technologies and government policy changes. Despite the case that total area of cultivable land has shrunk over the years as a result of construction of roads, homesteads and other setups due to increase in population, growth of agricultural production has continued due to technological advancement and government policies. As a result, volume of food production increased by threeanda half folds compared to that was immediately after the independence. Moreover, a lot of changes in the patterns and performance of agriculture have also taken place. These features of Bangladesh agriculture are analyzed in this chapter.

This chapter is presentedin nine sections.Section 3.2 provides some facts and figures of agriculture in Bangladesh,its contribution to the GDP, trend of cultivable land, demand for food crop, production of different crops, etc. Land and land use pattern of Bangladesh are discussed in Section 3.3. Pattern of farm size in Bangladesh is presented in Section 3.4. Cropping intensity and production performance of different crops in Bangladeshis discussed in Section3.5. Crop diversification in Bangladesh and government policies regarding crop diversification arediscussed in Section 3.6 and Section 3.7, respectively. Constraints and potentials of crop diversification in Bangladesharediscussed in section3.8. Finally, this chapter ends with making aconclusion in Section 3.9.

3.2 Agriculture Sector in Bangladesh Economy

The significance of agriculture sector in Bangladesh economy is enormous.Livelihood of the two-thirds of total population of the country depends on agriculture and on its allied sectors. Agriculture helps provide the basic needs of the people of the country. The most salient contribution agriculture makes is that it produces food crops to feed the ever increasing population of the country. To feed the rapidly increasing population, it is necessary to increase productivity of crops and is a great challenge for the agricultural sector in Bangladesh. Before the independence, during the decades of 1950s and 1960s farmers used to produce almost all crops necessary to manage the subsistence of their family. However, at national level, there was prevailing food deficit in the country. Therefore, government had to import food grains to meet the food demand of the people. Immediately after the independence, government has taken initiatives to increase cereal crop production with the introduction of high yielding varieties of rice and wheat, and by launching the programs such as‘Green Revolution’and ‘Grow More Food’ in order to attain self-sufficiency in food production and to feed the growing population of the country. As a result of these initiatives, cereal crop production has increased tremendously, but land allocation and yields for minor crops, such as pulses, oilseeds, vegetables, fruits and spices have decreased.

Despite the policy emphasis on cereals, demand for minor crops increased and government had to spend valuable foreign exchange to import them. To ensure the success of the policy, large quantities of fertilizers were imported to improve the nutrient status of soil. However, realizing the importance of growing minor crops, government has launched Crop Diversification Program (CDP) for the whole country in1980s and Northwest Crop Diversification Program (NCDP) for Northwest Bangladesh in 2001. Recently, Second Crop Diversification Program (SCDP) is being implemented in Western Bangladesh. However, a trend of commercialization in agriculture, nowadays, is being observed among the farmers in Bangladesh. Farmers are producing more vegetables and fruits on commercial basis. It indicates that agriculture of Bangladesh moves away to non-cereal crops to a significant extent.

In Bangladesh, net cultivable land area is 8.52 million hectares (57% of total area) of which around two-third is engaged with rice production. Of the total contribution of agriculture to the GDP which is 16.77%, the contribution of crop sectoraloneis 13.09% (GoB, 2014).According to the latest report, total food crop demand in our country is 37.7 million tons whiletotal food production (rice and wheat) is 35.09 million tons and it is taken that the country is at the stage of attaining self sufficiency in food production. But this self-sufficiency in food crop production is limited within rice productiononly. Except for food and some vegetables the country needs to import other food crops and items such as wheat, pulses, edible oil, spices, fruits,etc. to meet up the demand of the people. In this context, Table 3.1 presents some facts and figure of agriculture in Bangladesh.

Table 3.1: Some Facts and Figures of Bangladesh Agriculture

Attributes	Facts
Total Households	28,695,763
Total farm households	15,183,183
Total land area (mil. hec.)	14.86
Cultivable land area (mil. hec.)	8.52
Gross cropped area (mil. hec.)	14.94
Net cropped area (mil. hec.)	7.84
Irrigated area (% of crop area)	62.96%
Contribution of agriculture to GDP (2012-13)	16.77%
Contribution of crop sector to GDP (2012-13)	13.09%
Total food crop demand (mil. tons)	34.7
Total food crop production (mil. tons)	35.09
Surplus (mil. tons)	3.88

Source: AIS (2013), BBS (2012), GoB (2014), Ambia (2014)

The economy of Bangladesh consists of three main sectors like agriculture- called as primary sector, industry- known as secondary sector and service- named as tertiary sector. Although the contribution of agriculture to GDP was as high as more than two thirds of GDP, nowadays its contribution declined to 17% (GoB, 2014). It is evident from Table 3.2 that in 1950, contribution of agriculture was 70% of total GDP and it declined to 55% in 1970 and 20% in 2010. In contrast, contribution of service sector was 26% in 1950 and it rose to 50% in 2010. Thus, at present, contribution of service sector is leadingin Bangladesh economy and it is more than half of the total GDP.

Table 3.2: Contribution to GDP by Sectors (%)

Year	Agriculture	Industry	Service
1950	70	4	26
1960	62	5	33
1970	55	10	35
1980	33	17	50
1990	29	21	50
2000	25	26	49
2010	20	30	50

Sources: Various issues of BBS, GoB

Agriculture sector is composed of different subsectors of which crop sector dominates agriculture directly. Farmers of Bangladesh produce a large number of crops around the year. Major crops grows in Bangladesh are cereals, sugarcane, fruits, vegetables, oilseeds etc. Major industrial crops are jute, tea, tobacco etc. Crop subsector absorbes most of the agricultural labor in the country. Similarly, it is a major source of industrial raw materials and contributor of food security in Bangladesh. Presently, crop sector contribution to GDP and agriculture is 9.49% and 56.59, respectively (GoB, 2014).Table 3.3 depicts that crop sector contribution to GDP and in agriculture is high but it is decreasing over the years. In agriculture sector, though crop sub-sector's contribution is being declined yet it is more than 50% of total agriculture. Table shows that in 1975 crop sector contribution to GDP was 38.50 and it declined to 11.32% in 2010. Similarly its contrbution to Agriculture was 78.09% in 1975 and 56.32% in 2010.

Table 3.3: Contribution of Crop Sectors to GDP and Agriculture (%)

Year	Contribution to GDP	Contribution to Agriculture
1975	38.50	78.09
1980	35.10	79.41
1985	32.90	79.66
1990	19.34	65.51
1995	14.42	58.52
2000	14.70	58.73
2005	12.28	56.23
2010	11.32	56.32

Sources: Various issues of BBS, GoB

3.3 Land and Land Use Pattern in Bangladesh

Bangladesh is endowed with a favorable agro-climatic condition and land for agriculture. In rural Bangladesh, majority of the people in rural area are landless and unemployed. In this context, landis considered to be the highly scarce resource in Bangladesh.Cultivable land is that portion of the soil which is used to produce crops. Thus, in agriculture, cultivable land is considered to be an important factor. It is apparent from the Table 3.4 that there is a decreasing trend in available net cultivable land in Bangladesh, which is declining very alarmingly by up to 1% in every year (Alam& Islam, 2013). The reasons behind the decreasing trend of net cultivable land are rapid urbanization and industrialization in Bangladesh with houses, roads, bridges, culverts, schools, colleges, markets and other infrastructure being built for the ever increasing population of the country. The continuation of such decline in cultivable land will, of course, pose serious risk in terms of domestic production and supply of food crops in Bangladesh.

Table 3.4: Net Cultivable Land in Bangladesh(5 year's average in mill. hec.)

Year	Net Cultivable Land	% of total Area
1980 – 85	9.40	63%
1985 – 90	9.68	65%
1990 – 95	8.84	59%
1995 – 00	8.44	57%
2000 – 05	8.43	57%
2005 – 10	8.77	59%

Source: Various issues of BBS

In rural areas of Bangladesh, land is cultivated in three systems. It can be observed from Table 3.5 that there are three typical types of cultivation system found in Bangladesh. These are: farming operated by the owners, owner cum tenant farming and tenant farming. The land distribution pattern by types of tenure remains more or less stable with a somewhat relative decrease in owner-cum-tenant farmers as well as the area on which they operate. An insignificant percentage of tenant farms (1.39% in 1983/84, 3.48% in 1996 and 2.1% in 2008) are observed to operate on an insignificant percentage of land (0.55% in 1983/84 and 1.90% in 1996 and 0.13acres). Furthermore, the table shows that the average size of farms is getting smaller for all types of tenure. Average size of owner-cum-tenant holdings was higher than that of owner holdings in both the 1983 and 2008 censuses. The number of owners and owner-cum-tenant farms has also gone up considerably between 1983 and 2008.

Table 3.5: Distribution of Farm Holdings and Area by Type of Tenure

Type of Tenure	1983			1996			2008		
	Farm Holdings %	% of Area	Average Size(Acres)	% ofFarm Holdings	% of Area	Average Size (Acres)	Farm Holdings %	% of Area	Average Size (Acres)
Owner	62.78	58.76	2.13	61.66	58.51	1.61	65.29	56.53	0.71
Owner cum tents	35.83	40.69	2.58	34.86	39.59	1.9	21.88	41.37	1.54
Tenants	1.39	0.55	0.89	3.48	1.9	0.88	12.83	2.1	0.13
ALL	100	100	2.27	100	100	1.71	100	100	0.82

Source: Various issues of BBS, Author'scalculation

3.4Pattern of Farm Sizein Bangladesh

Fragmentation of the farm size is a common picture in Bangladesh. It happens due to population pressure, inheritance lawof the country, urbanization and industrialization etc. Low per capita land and employment opportunities in the non-farm sector have made the land distribution system uneven though there are only a small number of large landholdings.Table 3.6 presents the changes in rural farm holdings in Bangladesh from 1983 to 2008. It is found from the table that small and marginal farm holdings are increasing over the years whereas large and medium farm holdings are decreasing rapidly. In 1983, 70.34% of the total farm holdings were small and marginal and it rose to 84.39% in 2008. However, in the same period, medium and large farm holdings have declined from 24.72% and 4.94% to 14.07% and 1.54%, respectively. However total number of farm holdings has increased from 10,045 thousand acres in 1983 to 14,870 thousand acres in 2008. Table 3.6 also presents that average cultivable land per farm was 2.00 acres in 1983and in 2008 it declined to 1.26 acres. Thus, it is a clear signal from the table that the continuous process of fragmentation of farm size is a serious concern for Bangladesh agriculture. If this process continues, Bangladesh economy will no longer depend on agriculture in near future.

Table 3.6: Changes in Rural Farm Holdings (1983-2008)

Farm Type	1983	1996	2008
Small and marginal farm holdings (%)	70.34	79.87	84.39
Medium farm holdings (%)	24.72	17.61	14.07
Large farm holdings (%)	4.94	2.52	1.54
Total number of farm holdings (‘000’)	10,045	11,798	14,870
Average cultivated land per farm (acre)	2.00	1.50	1.26

Source: Various issues of BBS

Similarly,Table 3.7 presents the distribution of farms by landsize. It is evident from the table that in the year 1983, 8.7%household had no cultivable land and it rose to 12.83% in 2008. Similarly, in 1983, 18.6% holdings had only 0.01 to 0.049 acres of land and it also rose to 28.51% in 2008. Likewise, in 1983, 19% holdings had only 0.05 to 0.49 acres of land and it increased to 24.7% in 2008whereas, holdings having 0.5 to 2.49 acres was 33.6% in 1983 and in 2008 it decreased to 25.5%. Holdings having 2.50 to 4.99 and 5.00 to 7.49 acres of land were 11.6% and 4.7%, respectively, in 1983and it declined to 5.53% and 1.81%, respectively, in 2008. In a similar fashion, holdings owning 7.5 to 24.9 acres, and 25 acres and more than 25 acres of land were 3.6% and 0.2%, respectively, in 1983 which declined to 1.06% and 0.06%, respectively, in 2008. It is also apparent from the table that there is an increasing trend of landless and marginal farms while the trends of small, mediumand large farmsare decreasing alarmingly.

Table 3.7: Distributions of Farms by Land Size (1983 - 2008)

Size of holding (acre)	1983	1996	2008
	% of Household	% of Household	% of Household
No land	8.7	10.2	12.83
0.01 to 0.049	18.6	23.62	28.51
0.05 to 0.49	19	22.18	24.7
0.50 to 2.49	33.6	30.7	25.50
2.50 to 4.99	11.6	8.2	5.53
5.00 to 7.49	4.7	3.0	1.81
7.50 to 24.99	3.6	2.0	1.06
25.0 and above	0.2	0.1	0.06
Total	100.0	100.0	100.0

Source: Various issues of BBS

3.5 Cropping Intensity and Production Performance in Bangladesh

In Bangladesh, land is used for cultivating one or more crops in the year depending on the suitability and fertility of the land. Sometimes, same crop is cultivated more than once in a year. Due to scarcity, land is cultivated more than once in most cases indicating a high intensity of crops cultivation in Bangladesh. It is found from various reports and census that production performance measured in terms of volume of production per unit of land area differs from crop to crop, although there is a clear increasing trend of production for all crops taken under consideration. The situations of crop intensity and production performance of different crops are described in the following sub-sections.

3.5.1Crop Acreage and Cropping Intensity

Crop acreage is directly related to the level of crop diversification. In Bangladesh, allocation of land for various crops production is very much skewed and it is traditionally found that almost more than three fourths of gross crop area of the country is devoted to rice production. As most of the farmers in Bangladesh are poor and securing food is the main concern to them, they generally tend to produce rice in their land instead of other crops. It is found from various reports that in 1972, 80% of gross crop area was used in growing rice and in 2013 it declined to 76%, which is presented in Table 3.8. Proportion of rice crop area to gross crop area almost remainedthe same in last three decades although availability of improved rice technologies led to a little bit increase in rice harvest area in some districts. Due to dominance of rice area, cultivation of other crops is generally taken on in fewer areas and thus the magnitude of crop diversification is comparatively low in Bangladesh. It is also found from the table that the trend acreage of wheat, vegetables and spices is increasing gradually with a slow pace whereas that of pulses and oilseed remained stagnant with little fluctuation and crop acreage of jute has declined from 6% in 1972 to 3% in 2013.

Table 3.8: Crop Acreage in Bangladesh (%)

Year	Rice	Wheat	Pulse	Oilseed	Potato	Vegetables	Spices	Jute	Others
1972	80.5	1.1	3.1	2.6	1.2	0.9	1.4	5.9	3.2
1975	82.0	1.1	2.6	2.6	1.5	1.0	1.3	4.8	3.2
1980	79.2	3.4	2.6	2.4	1.3	1.0	1.2	5.9	3.0
1985	74.5	4.9	5.7	3.5	1.3	1.0	1.1	4.9	3.1
1990	75.5	4.3	5.4	4.1	1.2	1.2	1.1	3.9	3.4
1995	74.1	4.8	5.3	4.2	1.3	1.4	1.1	4.2	3.7
2000	76.6	4.9	3.5	3.1	2.0	1.7	1.8	2.9	3.5
2005	77.5	4.2	2.9	2.4	2.7	1.8	2.3	2.9	3.4
2010	77.1	2.6	3.1	2.5	3.1	2.5	2.0	2.9	4.3
2013	76.0	2.9	3.5	2.7	3.0	2.7	1.8	2.9	4.5

Source: Various Issuesof BBS

Generally, there are three crop seasons in Bangladesh. Due to continuous decline in agricultural land and some other problems, all the cultivable land cannot grow crops in all seasons. It is apparent that some pieces of land grow crops once in a cropping year, again some grow crops twice or thrice in a cropping year. Previously up to the early 1970s, most of the cultivable land is used for single crop in a cropping year and rest of the time the land remained fallow. It happened due to lack of appropriate technology, inefficiency of farmers and minimum demand of the farmers. Now the time has changed and at present, 29% of net cultivated land is single cropped area whereas 52% and 19% area is used for double and triple cropped area, respectively (AIS, 2013). Improved technology and updated knowledge and efficiency of the farmers have made this possible to reduce single cropped area in the country. It is found from Table 3.9 that in the year 1977, 56.5% of net cultivable land was used to produce crops once in a cropping year. Most of the time in a cropping year, major portion of cultivable land were remained fallow. Over the time, single cropped area has been declined gradually. In 2012,it came down to only 29%. With the declining of the single cropped area, cropping intensity of Bangladesh is increasing over the years.

Table 3.9: Distribution of Land by Single, Double and MultipleCropped Area

Year	Single Cropped Area (% of Goss Cropped Area)	Double Cropped Area (% of Gross Cropped Area)	Multiple Cropped Area (% of Gross Cropped Area)
1977	56.5	36.3	7.2
1985	53.5	38.5	7.5
2001	36.0	51.0	12.5
2012	29.0	52.0	19.0

Sources: Hossain (1988), GoB (2005), AIS (2013)

In Bangladesh, cropping intensity, which refers to the ratio of gross cropped area to net cropped area, is comparatively moderate. However, cropping intensity has been increasing in Bangladesh and further getting boost up from increased technological development in agriculture. At present, cropping intensity of Bangladesh is 181% (Ambia, 2014). It is evident from Table 3.10 that the trend of cropping intensity is increasing gradually. In the year 1980 cropping intensity was 153% and in 2010 it rose to 179%. Despite the continuous declining out of the net cultivable land, this ratio proves the proper use of our existing land. As a result, production of crops has increased continuously.

Table 3.10: Cropping Intensity in Bangladesh (five year's average)

Year	Cropping Intensity (%)
1980	153
1985	162
1990	167
1995	174
2000	175
2005	177
2010	179
2014	181

Source: Various issues of BBS

There are regional variations in performing agricultural activities. As different regions locate in different Agro Ecological Zones (AEZs), all the regions cannot perform agricultural activities equally. Moreover, efficiency of the farmers is not the same in different regions. Therefore, there may have variation in cropping intensity of different divisions. Table 3.11 shows the trend of cropping intensity of different divisions. It is evident from the table that in 2008, cropping intensity of Rajshahi division was the highest among the divisions. At that time, cropping intensity of Rajshahiwas 201.25% and it was 165.22% in 1977. Reason for such an increase in cropping intensity of Rajshahi division is the installation of deep tube wells (DTWs) by BMDA which brings large number of areas under irrigation. Similarly, irrigation facility attributes to the increment of cropping intensity in the other divisions of Bangladesh.

Table 3.11: Cropping Intensity by Divisions

Division	Cropping Intensity (%)		
	1977	1996	2008
Dhaka	177.82	181.39	184.16
Rajshahi	165.22	180.05	201.25
Chittagong	157.00	163.79	169.33
Khulna	157.26	177.29	190.33

Source: Various issues of BBS

3.5.2 Production Performance of Crops in Bangladesh

Crop agriculture plays a vital role in Bangladesh economy and gets the utmost importance from the government. It is the biggest subsector of agriculture, whose contribution to GDP and labor absorption capacity is the highest among other sectors. Land quality of Bangladesh is deteriorating owing to degradation of soil fertility (nutrient imbalance), soil erosion and soil salinity. In addition, water resources are also shrinking continuously due to high exploration of ground water for irrigation. In order to produce more food for the increasing population of the country and to meet up high demand for raw materials of agro-industries, agricultural productivity needs to be increased. However, increase in the productivity of agriculture is possible by increasing yield rate through intensification and diversification of agriculture. But unfortunately, due to frequent natural calamities like floods, drought, cyclone, etc. progress of agriculture sectors have become slow.

Rice is the main food in Bangladesh and major food items are rice, wheat, pulses, potato, vegetables and fish. It acquired fourth place in the world for the production of huge rice in the middle of the 1980s, which was possible by the use of high yielding varieties of seeds, fertilizer and modern irrigation However, in the 1980s, Bangladesh had to import 'an average of 2 million tons of food grains each year' to feed the people of the country. In the late 1980s, there was a progress in industrialization and from 1990 industrial establishments and foreign investments increased to a great extent. As a result, agriculture sector was being neglected and its improvement was hampered and fell down sharply.

Therefor, major technological changes have been occured in agriculture during last couple of decades. As a result, use of fertilizer, irrigation equipment and high yielding varieties (HYVs) of seed have increased.Simulteniously, rice production has also increased significantly. Though majority of farm holdings are small and marginal in the country, farmers are increasingly using modern machinery, with the help of cooperatives. Domestic production of other agricultural products such as pulses, sugar, milk, meat, fish, vegetables and oil never fulfilled the requirements of the country, rather remained short.

Table 3.12 shows the production performence of crop sub sectorsof agriculture. It is evident from the table that production and yield of rice in the first decade after the independence were 11,620 thousand tons and 1.17 tons, respectively, whereas, after 40 years of independence production of rice reached to 27,199 thousand tons and yield reached to 2.53 tons. Production of other crops have also increased but comparativelyat a slower rate. Similarly, wheat production was 284 thousand tons in the year1971-80 while in 2001-10 it was 1,119 thousand tons and per hectare average yield of wheat was 1.34 tons in 1971-80 and 2.05 tons in 2001-10. Again, it is evident from the table that there is a tremendous increase in maize production as well as its yield rate. In 1991-2000 its average production was 40 thousand tons while in 2001-10 it reached to 542 thousand tons. In those times, its average yieldswere 2.51 tons and 4.83 tons per hectare, respectively.

Table 3.12: Crop Production and Yield (per hectare) in Bangladesh from 1971 to2010 (10 year's average)

Crops	1971-80		1981-90		1991-2000		2001-10	
	Production (000' tons)	Yield(tons)	Production (000' tons)	Yield (tons)	Production (000' tons)	Yield(tons)	Production (000' tons)	Yield (tons)
Rice	11,620	1.17	14,980	1.40	18,766	1.84	27,199	2.53
Wheat	284	1.34	1,098	1.90	1,400	1.93	1,119	2.05
Maize	2	0.81	2	0.80	40	2.51	542	4.83
Pulse	219	0.63	424	0.70	507	0.75	285	0.83
Oilseed	240	0.78	391	0.90	466	0.85	584	1.29
Vegetables	2,277	8.00	2,645	8.00	3,405	9.00	7,417	11.0
Spices	300	1.97	293	2.00	328	2.13	925	3.20
Fruits	1,315	11.53	1,378	9.70	1,395	7.24	1,411	6.66
Jute (bale)	5,188	7.14	5,400	8.20	4,790	9.32	4,597	10.86
Sugarcane	6,234	43.09	6,980	42.0	7,312	40.13	5,898	39.44

Sources: Various issues of BBS

Average production of pulse was 219 thousand tons in 1971-80 and 285 thousand tons in 2001-210, whereas its average yield was 0.63 tons per hectare and 0.83 tons per hectare, respectively. It is observed that productivity of pulse is very low comparing to other crops. Farmers are paying less attention to these crops as their yield ratesare very low comparedto other crops.Likewise, average production of oilseeds was 240 thousand tons in 1971-80 and 584 thousand tons in 2001-10 whereas per hectare average yield was 0.78 tons and 1.29 tons, respectively. Although, edible-oil is an important food-stuff of the people of Bangladesh, oil crops have been neglected equally by farmers, researchers, extension workers and policy planners in Bangladesh.

Average production of vegetables has increased from 2,277 thousand tons in 1971-80 to 7,417 thousand tons in 2001-10. Average yield rate has also increasedfrom 8.00 tonsto 11.00 tons in the same period. Vegetables of Bangladesh are divided into two categories such as winter vegetables and summer vegetables. A major portion of the vegetables are grown during the winter season. Winter season vegetables are cabbage, broccoli, tomato, brinjal, beans, radish, carrots, cauliflower etc. While summer vegetables are sweet gourd, bitter gourd, ribbed gourd etc.

In 1971-80, the average production of jute was 5,188 thousand bells while in 2001-10 it was 4,597 thousand bells. During this time,per hectare yield has increased from 7.14 bells to 10.86 bells. Conversely, average yield rate of sugercane has been decreased continuously but in case of production, it has increased up to 1990s then decreased in the last decades. In 1971-80 average production of sugarcane was 6,234 thousand tons while in 1991-2000 it was 7,312 thousand tons but in 2001-10 it has decresed to 5,898 thousand tons.

3.6Crop Diversification in Bangladesh

From the above discussion, it is found that Bangladesh agriculture is dominated by rice. More than three fourths of gross crop area is used for rice production that indicates low practice of crop diversification. The production system dominated by a single crop, rice, is neither scientific nor acceptable from the economic point of view. It is, therefore, necessary to increase the cultivation and production of other crops.

In addition to using the number of crops, crop acreage in measuring the extent of crop diversification, other techniques such asHerfindahl Index (HI) and Entropy Index (EI) are widely used to measure the extent of crop diversification. Higher value of HI gives lower level of crop diversification and vice-versa whereas higher value of EI provides higher value of crop diversification. Table 3.13 shows that HI value of crop diversification in 1972 was 0.67 and in 2013 it declined to 0.57 that indicate that magnitude of crop diversification has been increased a little bit. Similar result is found from the value of EI of crop diversification that was 0.38 in 1972 and rose 0.45 in 2013. It is clear from the values of indices that the growth rate of crop diversification index is lowin comparison toother countries in south Asia. Thus, present state of crop diversification of the country is not at expected level.

Table 3.13: Extent of Crop Diversification in Bangladesh

Year1a	HI	EI
1972	0.65	0.38
1975	0.66	0.37
1980	0.64	0.39
1985	0.58	0.45
1990	0.57	0.46
1995	0.58	0.46
2000	0.59	0.45
2005	0.58	0.46
2010	0.58	0.46
2013	0.57	0.45

Source: Various issues of BBS and GoB

In Bangladesh, different areas are specialized in producing different crops due to climatic advantages and soil quality. Table 3.14 shows the intensity of crop diversification in different divisions in Bangladesh. It is apparent from the table that the highest magnitude of crop diversification (EI = 0.53) is found in Rajshahi division and the lowest value (EI = 0.44) is found in Chittagong division. It is found that crop diversification varies by type of farms. Because, farmers of different types and farm sizeshave different objectives for cultivation. Some farmers produce crop for their subsistence whereas some produce only for profitearning and some others cultivate land for subsistence as well as in need of cash.It was assumed that farmers of small farms practice crop diversification more than the farmers of large farms.

Table 3.14: Crop diversification in Bangladeshby Divisions

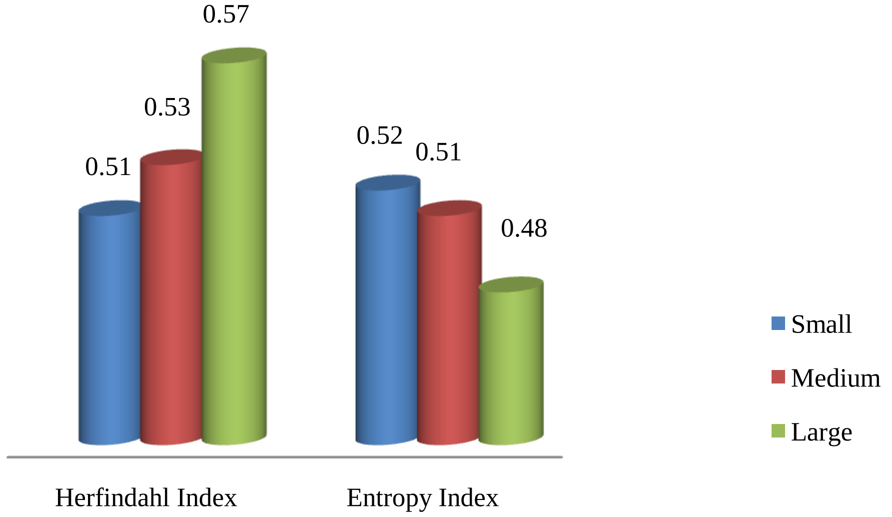
Division	HI*		EI	
	1983	2008	1983	2008
Dhaka	0.56	0.52	0.48	0.51
Rajshahi	0.58	0.50	0.47	0.53
Chittagong	0.64	0.60	0.38	0.44
Khulna	0.60	0.56	0.43	0.48

Source: BBS, 2010

*Higher value of HI shows the lower diversification.

Figure3.1has provided such information. The figure shows the level of crop diversification with respect to different size of farms in Bangladesh. From the figure, it is apparent that farmers of small farmspractice crop diversification more than the farmers of large farms.

Figure 3.1: Crop Diversification by Farm Size



Source: BBS (2010)

3.7Government Policy on Crop Diversification

Bangladesh government has been giving emphasis on Crop Diversification. In accordance with that government has taken various programs like CDP, NCDP, SCDP, etc. to enhance the practice of crop diversification. Much emphasis was given in the different Five Year Plans (FYPs) to attain self-sufficiency in food grain production along with increased production of other nutritional crops, as well as to encourage the export of vegetables and fruits keeping in view of domestic production and need.

Such an emphasis at the policy level enhanced the practices of crop diversification in Bangladesh. Besides, national policy documents including NFPPA (2008), NAP (2013)and CIP (2011) recognize the need for crop diversification to attain nutritional deficiency in calorie intake of the people.

Bangladesh government has taken six FYPs so far. Almost in every FYP, government took various steps to enhance the practices of crop diversification to eliminate the nutritional deficiency of the people of Bangladesh and to enhance the fertility of cultivable land. Measures taken by the government are discussed below.

The Second Five Year Plan (1980-1985) puts emphasis on the production of minor crops other than rice. It quoted that production of minor crops like pulses, oilseeds and vegetables would be increased through utilization of irrigation facilities. It has also paid attention to multiple cropping with a view to taking care of protein deficiency of farmers of small and landless farms and also to stabilize farmers' earnings through the process of crop diversification.

The Third Five Year Plan (1985-90) especially gives more attention on crop diversification program with the strategy of replacing the existing variety of crops with the more profitable ones. The plan pointed out that the major crops under crop diversification would be potato, sweet potato, oilseed, mustard, maize, pulses and all kind of vegetables.

The Fourth Five Year Plan (1990-95) mentioned that although crop diversification was a goal of the Third Five Year Plan, the crop base did not expand to improve dietary quality and food security. The plan also mentioned that the contribution of domestic production to calorie availability has declined to some extent than that of the early seventies. This plan also indicated that the essential task of crop diversification was to select appropriate crops and to assist farmers to adopt them through adequate incentives in terms of cost effectiveness and relative cost advantages. Emphasis was put on promoting gradual diversification of agriculture through changes of cropping system to move away from present monoculture in rice to diversified agriculture through enhancing production of horticultural crops, vegetables, pulses and oilseeds.

The Fifth Five Year Plan (1997-2002) also gives emphasis on due importance of crop diversification. The plan noted that Bangladesh has a favorable climate and there exists ample of opportunities for crop diversification balancing major crops with minor crop production. The diversification of cropping pattern will encourage crop rotation in crop production, especially towards production of high value crops that would contribute to enhance farmers' income and also to maintain better soil structure for long term sustainability in agricultural production.

The Sixth Five Year Plan (2011-15) gives emphasis on crop diversification by taking various steps.It gives emphasis on the growth of non-cereal food production to address the issue of unbalanced diet of the poor. It also noted that it would emphasize for import substitution of non-cereal crops looking at their comparative edge through promoting crop diversification. Setting up growth center and cooperative to ensure stable market price of high value non-cereal crops, to reduce the middlemen from market channel is also a priority of Sixth FYP.

National Agriculture Policy

In Bangladesh, only a very small portion of net cultivable land remains as current fallow which means that there is hardly any scope for increasing cultivable land. Currently, cropping intensity is around 181percent. Thus, the only possible option for increasing agricultural production is to increase both the cropping intensity and yields simultaneously. In this respect, policies adopted by the government are:

1. To take supportive programs for inter-cropping in a field instead of single cropping; and
2. To take appropriate measures in reducing the gap between potential yield and farmers' realized yield of different crops to raise the present level of production significantly.

Crop diversification is one of the major components of crop production policy. For the overall development of crop sector, special emphasis has been given to crop diversification program under the crop production policy. The government policies in this respect are as follows:

1. Area under wheat has meanwhile reached at a significant level. By giving the potential for expanding wheat acreage, governmental efforts will continue to encourage farmers to grow more wheat.
2. The production of maize has shown prospective results in last two years. Maize has also gained popularity as human food side by side with the poultry feed. Public sector procurement of maize has been introduced like rice and wheat in order to encourage farmers in maize cultivation. The efforts for increasing area and production of maize will be strengthened.
3. The program for increasing area and production of other crops, e.g., potato, pulses, oilseeds, vegetables, fruits and spices will gradually be extended under the crop diversification program.
4. Production of different cash crops including jute, cotton will be increased and efforts will be made to expand their multiple uses.
5. Special development programs will be taken with a view to increasing production of potential crops suitable for the coastal areas and the hill tracts.

3.8Constraints and Potentials of Crop Diversification

It is evident from the above discussion that practice of crop diversification is comparatively low in Bangladesh. Agriculture of a very few countries of the world depends on a single crop as high as the case of Bangladesh. From different studies, it is found that practicing crop diversification has a numbers of limitations. Rao et al (2006) observed that lack of access to markets; transport facilities and post-harvest infrastructure inflate the transaction costs of marketing, which discouragefarmers to diversify towards high value agriculture. Similarly,Zohir (1993) noted that the constraints on the way of crop diversification are: established soil condition; flood depth levels;lower rainfall; lack of proper training on non- rice crops, inappropriate water management, and inadequate supply of water weresome major constraints in Bangladesh. Similarly, poor road condition and under developed road connectivity, and transportation problems stood on the way to crop diversification (Haque& Bhattacharya, 2010).

One important constraint for crop diversification is the irrigation and water management system. Existing irrigation and water management system in Bangladesh is not conducive to crop diversification.Irrigation system in Bangladesh are planned, designed, constructed and managed primarily to irrigate rice fields and are not suitable for growing non-rice crops (Alam, 2005; Rahman&Talukdar, 2001). Farmers cannot grow non-rice crops especially high value crops(HVCs) due to inflexible existing irrigation system. Under same irrigation scheme most of the farms produce rice.In addition, perishable nature of many HVCs, lack of cold storage and weak market management system are also great hindrances on the way to crop diversification.

Bangladesh is endowed with favorable climate and soil to produce a variety of crops all the year round. So, there are ample opportunities for diversification in crop agriculture. In Fourth Five Year Plan (1990-95), introduction of appropriate cash and commercial crops and policy support for flood and drought resistant crop are considered as the guiding force to promote crop diversification practice in Bangladesh.

As high value crops are more labor intensive, it helps employment generation for the farmers. HVCs especially vegetables need more labor than non-rice crops. Diversification along the line of production of non-rice crops also has implications for labor employment. Some crops like oilseeds and pulses are less labor intensive and hence will have negative impact on employment generation. Since potatoes, vegetables and spices are highly labor-intensive, expansion of area for the production of these crops will have positive impact on labor employment. However, with fluctuation of price and lack of storage, transportation and processing facilities may constrain any large scale expansion of area under these crops. Substantial employment opportunities are generated in seed and seedling production, land preparation, irrigation, harvesting, cleaning, grading, and packaging of HVCs. It was estimated that a one-hectare of land shifts from cereal to vegetables in one season generated more than one year round full-time employment, that is, the difference between cereals and vegetables was more than 220 working days per hectare (Ali &Abedullah, 2002;Rahman&Talukdar, 2001). Joshi et al (2004) also reported similar results. Therefore, cultivation of vegetables, unlike food grains, is labor intensive on the one hand and requires more skilled labor and continuous attention to individual plants at various stages of growth, on the other hand (Bhattacharyya, 2008).

Globalization and market liberalization have opened up the new opportunities to export agricultural crops and crops product from Bangladesh. According to BSS (2013), the country's fresh fruit exports increased twelve times in the past five years, with earning of Tk.4,631.2 million alone in FY 2011-2012. Saha (2013) noted that the demand for fresh fruits and vegetable has gradually increased globally as many people have switched to a vegetarian diet. He also noted that in peak season Bangladesh exports 450 metric tons of fruits and vegetables a week against the off-season shipments of about 180 metric tons. Braun (1995) quantifies that as a result of diversification to export vegetable production in Guatemala, employment is increased by 45% on participants' farms. So, this export potentiality offers a great scope for crop diversification in Bangladesh.

3.9 Conclusion

It is found from above discussion that agriculture's contribution to GDP is decreasing over the years and still now its contribution is significant in Bangladesh economy. It is also found that in Bangladesh net cultivable land is decreasingover the years howevercropping intensity,yield and production performance of nearly all crops, especially cereal crops, has increased to a large extent. It has become possible due to technological advancement and government policies to agriculture.

Similarly, it is found thatlevel of crop diversification in Bangladesh is low. However, it is increasing gradually with a little fluctuation due to increment of per capita income, increasing demand of non-rice food, rural development and different policies of the government. Northern Bangladesh made a remarkable progress in practicing crop diversification. Similarly, the level of crop diversification in small farms is higher thanother farms in Bangladesh. It is also found that there are positive relation between crop diversification and cropping intensity. Weak infrastructure, bad road connectivity, high transaction cost and existing irrigation system are some constrains in the way of crop diversification.

CHAPTER FOUR

STATE OF CROP DIVERSIFICATION IN THE STUDY AREA

4.1 Introduction

This chapter discusses the present situation of crop diversification in the study area. In this purpose, four districts from northern Bangladesh have been taken as sample area for the study. The districts areRajshahi and Naogaon from Rajshahi division and Kurigram and Thakurgaon from Rangpur division. Selected districts are located in different agro-ecological zones. Because of variabilityin soil fertility,rainfall, temperature, humidity and some other agro-ecological features, farming practices, techniques and irrigation facilities differ among the districts and the farmers also havedifferent attitudes. Consequently, cropping pattern, yield and productivityalso differ in the study districts.

To know the present situation of crop diversification in the study area, farm characteristics, cropping pattern, cropping intensity, crop acreage, etc. are discussed in this chapter. Crop diversification indices are calculated alongside. These are discussed in two stages-for sample districts and then for sample villages. The analyses presented in this chapter are based on both primary and secondary data. Secondary information were collected from District and Upazila Agriculture Extension offices for the cropping year 2011/12.

This chapter is presented in seven subsections. Section 4.2 portrays the size of farms in the study area. Cropping pattern in the study areais presented in Section 4.3. Cropping intensity and crop acreage arediscussed in Section 4.4. Extent of diversification in the study area is discussed in Section 4.5. Advantages of crop diversification are discussed in Section 4.6 and finally, this chapter ends with making a conclusion in Section 4.7.

4.2 Farm Sizein the Study Area

According to holding size, farms are categorized into four types, namely,marginal, small, medium and large farms. Landless farmers who cultivate land on tenancy basis are considered asmarginal farms,and these households own less than 0.5 acres of land. Small farmshave land size from 0.5 acres to less than 2.5 acres, medium farms own land between 2.5 acres and 7.5 acres, and large farms have landsize 7.5 acres and more (BBS, 2010).Table 4.1 presentsthe distribution of different farms in the sample districts.It is evident from the table that marginal farms in the sample districts comprise of59.3%, followed by small farms 26.4%, medium farms11.9% and large farms 2.4%. At national level, only 1.54% farms are large, 14.07% are medium and the rest of the farms fall under small, marginal categories (BBS, 2010).

In the disaggregated analysis, it is found thatin Rajshahi district, the percentage of marginal farms is much higher than that in the other sample districts.Thakurgaon district shows the lowest percentage of marginal farms among the sample districts. It is seen from the table that percentage of marginal farms is almost 73.6% in Rajshahi district and 40.6% in Thakurgaon district. The highest percentage of large farms is found in Naogaon district (4.7%) and the lowest is in Kurigram district (0.4%).

In Rajshahi, 73.6% farms are marginal, 14.1% are small, 10.4% are medium and 1.9% arelarge. In Naogaon, percentage of marginal farm is 59.5%. It is 21.1% for small, 14.7% for medium and 4.7% for large farms. In the same way, in Kurigram, 49.6% farms are found to be marginal, 43.2% are small, 6.8% are medium and 0.4%are large. In case of Thakurgaon, 40.6% farms are marginal, 36.5% are small, 19.7% are medium and 3.1% are large farms.

Table 4.1: Distribution of Farmsby Sample Districts

Attributes	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Large	8,394 (1.9)	23,049 (4.7)	1,901 (0.4)	7,881 (3.1)	49,619 (2.4)
Medium	44,977 (10.4)	72,510 (14.7)	32,874 (6.8)	49,667 (19.7)	245,005 (11.9)
Small	60,966 (14.1)	104,076 (21.1)	208,211 (43.2)	91,842 (36.5)	526,061 (26.4)
Marginal	318,965 (73.6)	293,409 (59.5)	238,959 (49.60)	102,252 (40.6)	1,272,550 (59.3)

Sources: DAE, regional data (2011/12)
(.) indicates percentage

Distribution of farms according to the sample villages are presented in Table 4.2. It is seen from the table thatthe highest number of marginalhouseholds is found atAlidewanavillage (64.8%) in Mohadebpurupazila and the lowest is found at Bajemujrai (37.5%) in Rajarhatupazila. Similarly, the highest number of large farms is 2.8% in Alidewana village of Mohadebpurupazilaand the lowest is 0.7% in Mallikpur of Pabaupazila. The table reveals that in the sample villages on the average 1.9% farms are large, 9.8% are medium, 35.1% are small and 53.2% are marginal.

Table 4.2: Distribution of Farms by Sample Villages

Villages	Large	Medium	Small	Marginal
Gholharia	9 (2.1)	75 (17.8)	124 (29.5)	213 (50.6)
Mallikpur	3 (0.7)	39 (9.4)	133 (31.9)	242 (58.0)
Fazilpur	12 (2.1)	28 (5.0)	300 (53.1)	225 (39.8)
Alidewana	10 (2.8)	15 (4.2)	100 (28.2)	230 (64.8)
Chhinaihat	3 (1.2)	25 (10.1)	70 (28.2)	150 (60.5)
Bajemujrai	5 (1.3)	45 (11.3)	200 (50.0)	150 (37.5)
Hatpara	7 (1.8)	28 (7.1)	105 (26.6)	255 (64.6)
Chapor	10 (2.7)	55 (15.0)	81 (22.1)	220 (60.1)
All	59 (1.9)	310 (9.8)	1113 (35.1)	1685 (53.2)

Sources: DAE regional data (2011/12)
(.) indicates percentage

It is evident from Table 4.1and 4.2that,in the sample area, most of the farms are marginal. Household members associated with these farms have to depend mostly on others' farms to work wage laborer. Sometimes, they have to depend on different non-farm activities to manage their livelihood. Marginal farmers are often found to cultivate others' land through share cropping or lease taking arrangements. As farmers associated with marginal farms are very poor, they cannot invest on use of modern technology in agriculture. Hence, both the yield rate and the productivity are low although the cropping intensity is high.

4.3Cropping Pattern in the Study Area

Cropping pattern of an area is generally determined by physical, biological and socio-economic factors. In Bangladesh, the physical determinants of cropping pattern include topography, soil type, climate, length of the cropping season, availability of moisture, etc. Biological factors influencing cropping pattern are the food habit of the people, types or varieties of seed available, incidence of pests and diseases etc. Among the socioeconomic factors, size of farm, availability of labor, financial resources, tastes and preference of the farmers are the important ones. Nevertheless, at the farm level, potential productivity and monetary benefits also act as guiding principles while choosing a particular crop and cropping system.

The decision with respect to the choice of crops and cropping patterns is further narrowed down under the influence of several other forces related to infrastructural facilities, socio-economic factors and technological developments, all operating interactively at micro-level. The cropping pattern plays a vital role in determining the level of agricultural production and reflects the agricultural economy of an area.

In the study area, cropping pattern is generally designed in terms of *Kharip*1 + *Kharip*2 + *Rabi crops*. *Kharip*1 starts from 16th March and ends on 30t^{h} June; *Kharip*2 is from 1st July to 15th October and from 16th October to 15th March is for *Rabi* season. By the cropping pattern, we can perceive the intensity of crop diversification. If a single crop dominates the cropping patterns then the level of diversification will be less and vice-versa.

It is seen from the Table 4.3 that major portion of agricultural land in all sample districts is devoted to rice production. The table also shows that T. *Aus* + T. *Aman*+ *Boro;* fallow + T. *Aman* +*Boro;* and fallow + fallow + *Boro* are the most usable patterns among the farmers in all the sample districts, although there are other cropping patterns exist in the areas. These types of cropping patterns prove that major portion of the agricultural land in the sample districts is devoted to rice production.Interestingly, all the cropping pattern of the sample district roughly have includedT.*aman* rice as it needs no or minimum irrigation. It is found from the cropping patternsinRajshahi district as shown in Table 4.3 that theyincluded different types of crops. In the cropping patterns of Rajshahi, dominance of rice is comparatively low. Similarly, different crops are included in the cropping pattern of Thakurgaon district. Farmers in Thakurgaon grow a little bit smaller acreage of rice than that of Naogaon and Kurigram districts.

Table 4.3: Cropping Pattern in Sample Districts

Cropping Pattern	Area (Hectares)	% of total land
Rajshahi		
T. *Aus* + T. *Aman* + *Boro*	29,760	17
T. *Aus* + T. *Aman* + Potatoes	24,200	13
Fallow + Fallow + *Boro*	15,000	8
Fallow + T. *Aman* + *Boro*	9,500	5
Aus + T. *Aman* + *Mustard*/*Boro*	15,000	9
Fallow + T. *Aman* + *Musur*	12,000	6
Jute + Vegetables + Wheat	8,000	4
Aus + *Maskalai* + *Boro*	8,500	4
Maize + T. *Aman* + Potatoes	5,600	3
Sugarcane	12,000	6
Others	27,866	17
Naogaon		
Fallow + T. *Aman* + *Boro*	129,763	48
Fallow + Fallow + *Boro*	25,272	9
T. *Aus* + T. *Aman* + *Boro*	16,786	6
Fallow + T. *Aman* + Wheat	9,168	3
T. *Aus* + Fallow + *Boro*	7,085	3
Others	81,076	30
Kurigram		
Fallow + T. *Aman* + *Boro*	105,314	64
Jute + T. *Aman* + Wheat	13,164	8
Jute + T. *Aman* + Potatoes	13,164	8
Fallow + T. *Aman* + Mustard/*Boro*	9,873	6
Fallow + T. *Aman* + Potatoes/Boro	6,582	4
Others	2,956	2
Thakurgaon		
Fallow + T. *Aman* + *Boro*	56,500	37
Fallow + T. *Aman* + Wheat	26,000	17
Mung/Maskalai + T *Aman* + Wheat	12,500	8
Maize + T. *Aman* + Potatoes	6,000	4
Jute + T. *Aman* + Wheat	6,500	4
Others	43,311	29

Sources: DAE regional data (2011/12)

Kurigram and Naogaon districts show comparatively high rice dominancy in the cropping patterns. However, there are a few portions of cultivable land that produce single crop in a cropping year and it is only rice in most of the cases. In other seasons, these portions of land remain fallow. Other than rice, various types of vegetables like potatoes, papayas, tomatoes, various pulses and some oilseeds are produced in farms of Rajshahi and Thakurgaon districts. From the above discussion, it can be said that Rajshahi and Thakurgaon districts are comparatively more diversified in crop production compared to other two districts.

Table 4.4: Cropping Pattern in Sample Villages

Gholharia	Mallikpur
Fallow + T. *Aman*+ *Boro*	Jute + T. *Aman*+ Wheat
Jute+ T. *Aman* + Potatoes	Fallow + T. *Aman*+ *Boro*
Vegetables + Fallow + Vegetables	Jute + T. *Aman*+Potatoes
Fallow + T. *Aman*+ Potatoes/*Boro*	Maize + T. *Aman*+ Potatoes
Fallow + T. *Aman*+ Wheat	Vegetables + Fallow + Vegetables
Fazilpur	Alidewana
T. *Aus* + T. *Aman*+ *Boro*	T. *Aus* + T. *Aman*+ *Boro*
Fallow + T. *Aman*+ Mustard/*Boro*	Fallow + T. *Aman*+ *Boro*
Wheat+ T. *Aman*+ Vegetables	Fallow + T. *Aman*+ Mustard
Chhinaihat	Bajemujrai
Fallow + T. *Aman*+ *Boro*	Fallow + T. *Aman*+ *Boro*
Fallow + T. *Aman*+ Wheat	Jute + T. *Aman*+ *Boro*
T. *Aus* + T. *Aman*+ Wheat	Vegetables+ T. *Aman*+ Potatoes
Mung + T. *Aman*+ Wheat	Fallow + T. *Aman*+ Mustard/ *Boro*
Hatpara	Chapor
Fallow + T. *Aman*+ Boro	Fallow + T. *Aman*+ *Boro*
Fallow + T. *Aman*+ Wheat	Fallow + T. *Aman*+ Wheat
T. *Aus* + T. *Aman*+ Wheat	T. *Aus* + T. *Aman*+ Wheat
Fallow+ T.*Aman*+Mustard/ Potato/*Boro*	*Mung* + T. *Aman*+ Wheat

Sources: DAE regional data (2011/12)

Table 4.4 presents the cropping patternspracticed in the sample villages. It is seen that cropping patterns in the sample villages resembled with their respective districts. All the sample villages have rice centered cropping patterns. However, Gholharia and Mallikpur village of Rajshahi district show a little bit different picture. Chhinaihat village of Kurigram and Chapor of Thakurgaon grow a little bit more wheat than theother sample villages. Other than the above mentioned cropping patterns, farms cultivate various spice crops such as turmeric, ginger and coriander during the first two or three years of mango and litchi orchards preparation and also during the first six months of sugarcane growth. *Musur, khesari* and chili are also intercropped with sugarcane. *Mustard* and pulse categories are grown as mixed crops.

Thus, it can be concluded that there is similarity in the cropping patterns among the villages and the respective districts. The major cropping patternsin the study area are rice based,andRajshahi and Thakurgaon districts are more diversified than other sample districts. It is also to be noted here that almost all the farms in the study area produce T. *aman* rice in *kharip*2 season as it is basically a tropical rain dependent crop and it does not require extra irrigation while giving high yield.

4.4Cropping Intensityand Crop Acreage in the Study Area

The extent of cropping intensity is determined by several factors. The most important factor is the availability of water from natural sources, that is, rainfall and/or man-made resources, viz., irrigation. However, the scope for year round cropping activities in most areas of Bangladesh is severely constrained by the seasonal distribution of rainfall. Till now this natural constraint is being eased by developing irrigation facilities. The flexibility in selecting appropriate cropping pattern is also enhanced when irrigation facilities make water available in a controllable manner to the farmers throughout the year.

In general, the extent of cropping intensity is higher in the regions with higher percentage of net sown area irrigated and with higher intensity of land use by irrigation (Mandal&Dutta, 1993). However, it is not always correct to expect a one-to-one correspondence between irrigation and cropping intensity. The other crucial variable that determines the level of cropping intensity is the availability of labor. The characteristics of the farm according to holding size in Bangladesh suggest that labor availability is an important determinant of cropping intensity.

Therefore, it is said that cropping intensity of an area or region depends firstly, on the supply of energy in the form of human labor, animal labor and mechanical device; secondly, on the supply of water in the form of rainfall or irrigation and its distribution over the cropping year; and thirdly,on the physical limits imposed by the adopted cropping pattern on the duration of cropping activities during a particular cropping year. Cropping intensity puts more pressure on energy demand in the form of human, bullock, machine, fertilizer and pesticides.

It appears from Table 4.5 that cropping intensity among the sample districts is more than two hundred per cent. Highest cropping intensity is 241% and the lowest is 212% which have been found in Thakurgaon and Naogaon districts, respectively. Table 4.5 also shows that few places of the sample districts are found to produce crops four times in a cropping year that increases cropping intensity of the study area. In Thakurgaon district, volume of single cropped area is very low compared to other sample districts. This is why Thakurgaon occupies the highest position in terms of cropping intensity. One of the most important reasons behind high cropping intensity in Thakurgaon is that farmers of this district have a tendency to diversify their agricultural production. Among the sample districts, cropping intensity of Rajshahi and Thakurgaon is higher than that of northern region of Bangladesh. Cropping intensity of sample district is much higher than national level cropping intensity. Cropping intensity of Bangladesh is 181% (Ambia, 2014). Reasons behind the higher cropping intensity in the sample districts may be higher soil fertility, comparatively a large amount of high and medium land, favorable agro-ecological conditionetc.

Table 4.5: Cropping Intensity in Sample Districts (areas in hectares)

Districts	Net cropped area	Gross cropped area	Cropping intensity (%)
Rajshahi	167,426	390,069	233
Naogaon	269,150	570,772	212
Kurigram	151,053	334,741	222
Thakurgaon	150,811	363,468	241
All	738,440	1,659,050	225

Sources: DAE regional data (2011/12)

Table 4.6 shows the cropping intensity of sample villages. It is found from the table that cropping intensity in the sample villages is quite high.Mallikpurvillage of Pabaupazila has the highest cropping intensity andGholharia village of the same upazila has the lowest one as Gholharia villages is comparatively low land area. The highest cropping intensity is 265% and lowest one is 217%, rest of the sample villages show more or less the same picture in terms of cropping intensity. On an average, cropping intensity in the sample villages is 233%.

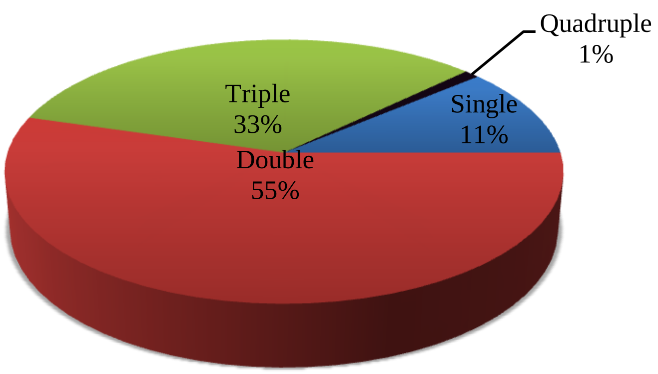
Table 4.6: Cropping Intensity in Sample Villages (areas in hectares)

Villages	Net cropped area	Gross cropped area	Cropping intensity (%)
Gholharia	224	486	217
Mallikpur	130	344	265
Fazilpur	190	445	234
Alidewana	208	476	229
Chhinaihat	115	275	239
Bajemujrai	106	235	222
Hatpara	232	532	229
Chapor	193	458	237
All	1398	3251	233

Sources: DAE regional data (2011/12)

Generally, there are three crop seasons in Bangladesh namely *Kharip*1, *Kharip*2 and *Rabi*. Land cultivation depends upon agro-climatic condition, elevation of land, irrigation, soil fertility and other agro-ecological features of the area. As a result,all the cultivable land cannot be cultivated three times in a cropping year.

Figure 4.1: Distribution of Land in the Study Districts by
Single, Double and Multiple cropped Area

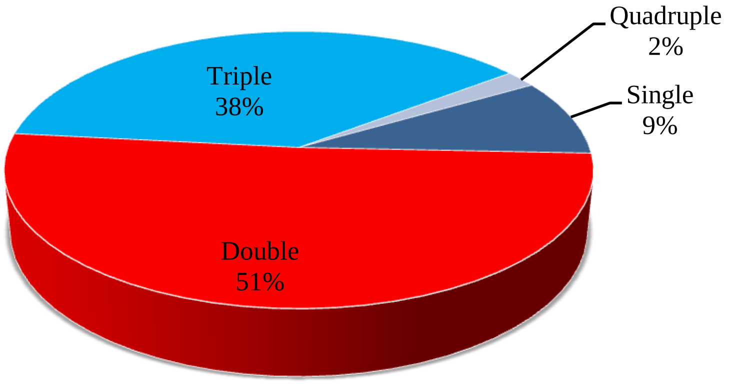


Sources: Author's calculation

Figure 4.1 presents the distribution of land in the study districts by single, double and multiple cropped area. It is apparent from the figure that a little bit more than half of the net cultivated area have been used as double cropped area and about one third area have been used for triple crop in a year and only 11% land have been used for single crop whereas at national level 29% of net cultivable land is used to produce single crop, 52% land have been used for double crop and only 19% land are used three times in cropping year. Therefore, it is clear from the graph that sample districts are more diversified in case of crop diversification comparing with the national level of diversification.

Figure 4.2 presents types of crop area in the sample villages. It is evident from the table that there are 9% of net cultivable area generally cultivated once in a cropping year whereas 51% land has been used two times, 38% three times and 2% four times in a cropping year in the sample villages.

Figure 4.2 Distribution of Land in the Study Villages by Single, Double and Multiple cropped Area



Sources: Author’s calculation

Thus, it is evident from Figure 4.1 and 4.2 that in the sample area a little bit more than half of the net cultivable area have been used two times and more than one third area have been cultivated three times in a cropping year whereas roughly one tenth of cultivable land have been used once in a year.

Again, crop acreage is one of the methods of measuring crop diversity. The higher the acreage of a single crop the lower is the level of crop diversification. Therefore, to see the present state of crop acreage in the sample area, this study has categorized the crops into ten groups. These are: (a) rice, which includes local, HYV and hybrid rice of three seasons (*aus*, *aman*, and *boro*), (b) local and HYV wheat, (c) local and HYV maize (d) pulses that include lentil, gram, black gram, checkling vetch (*khesari*), *mung* and pulse like crops etc. (e) oilseeds that include rapeseed, mustard and groundnut, *till*, *tisi*, soybean etc. (f) vegetables that include potatoes, sweet potatoes, brinjal, cauliflower, *seem*, radish, yam, green papaya and leafy vegetables etc. (g) cash crops that include sugarcane, jute, cotton, tobacco etc. (h) spices that include onion, garlic, turmeric, ginger, coriander and chili, (i) fruits that include banana, melon, water melon, pineapple and other temporary fruits, and (j) other crops include rest of the crops produced in temporary agricultural land. However, Table 4.7 shows the crop acreage of the sample districts. It is evident from the table that the highest rice share area is 79% of total crop area found in Naogaondistrict followed by Kurigram 74%, Thakurgaon 57% and Rajshahigets the lowest proportion (46%) of rice area to the total cropped area. Therefore,it can be said that practice ofcrop diversification is highest in Rajshahi and lowest in Naogaonthan that of other districts in the sample area.

Table 4.7: Crop Acreage in Sample Districts(%)

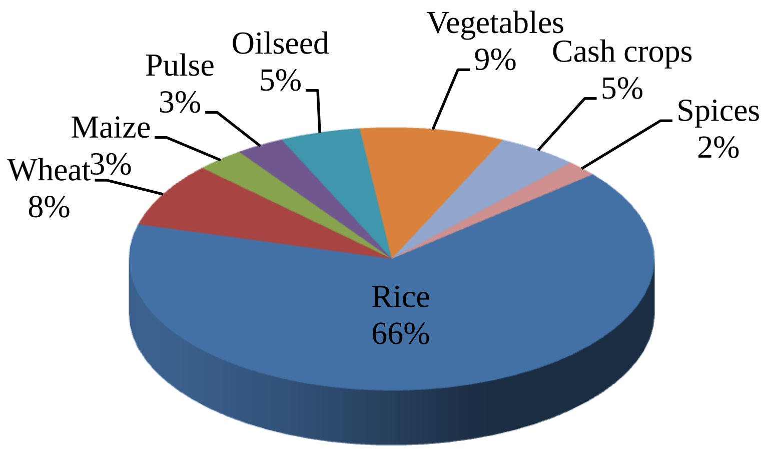
Attributes	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Rice	46.1	79.5	74.1	56.6	65.6
Wheat	8.4	3.4	5.1	15.7	7.6
Maize	3.3	0.6	1.1	7.5	2.8
Pulses	7.1	0.2	1.2	2.4	2.5
Oilseeds	6.3	6.0	4.1	2.6	5.0
Vegetables	14.3	6.4	5.0	8.8	8.5
Cash crops	7.6	1.7	7.3	4.4	4.8
Spices	5.6	1.8	1.6	0.8	2.4
Fruits	0.6	0.1	0.1	0.1	0.2
Others	0.5	0.3	0.3	0.7	0.4

Sources: Author’s calculation

Furthermore,an apparent look at the table also shows that numbers of non-rice crops grown in Rajshahi and Thakurgaon districts are more than those in Naogaon and Kurigram districts. The table also givesan idea that the farms inRajshahi district grow more vegetables, pulses, oilseeds and cash crops than those of other sample districts in the study area. It can also be noted that the proportion of rice area compared to the total cropped area varies across the districts. Based on these indications, it may be said that there is enough variation in crop diversity across the districts of the study area.

Similarly, Figure 4.3 shows the average crop acreage in the sample districts. It is evident from the figure that 66% gross cultivable area is devoted to rice production, which is somewhat less than that of national level rice crop area (78%). Again 9% gross crop area is used for vegetable cultivation, 8% for wheat and 5% for oilseeds in the sample districts.

Figure 4.3: Crop Acreage in Sample Districts



Sources: Author's calculation

Table 4.8 presents crop acreage in the sample villages. It is evident from the table that Gholharia village of Rajshahi district is the lowest rice growing village among all sample villages while Alidewana grows more rice than other sample villages. The highest rice crop acreage is 91% found in Alidewana followed by Bajemujrai (87%), Chapor (73%), Fazilpur (73%), Hatpara (57%), Chhinaihat (47%), Mallikpur (37%) and Gholharia (35%). Crop acreage of vegetables in Gholharia village is the highest and Alidewana is the lowest. Gholharia uses 37% of gross crop area to produce vegetable followed by Chhinaihat 33%, Mallikpur 25%, Fazilpur 11% and Bajemujrai 7%. In case of wheat acreage Hatpara uses, 18% of gross crop area followed by Chapor 12%, Fazilpur 6% and Mallikpur 6%. The table presents that among the sample villages Gholharia and Mallikpur grow almost all types of crops in a cropping pattern. Similarly, Fazilpur of Naogaon grows almost all types of crops except maize but 73% of total crop area is devoted to rice. Further, Hatpara and Chapor of Thakurgaon district grow several numbers of crops. Therefore, considering everything, it can be said that Gholharia and Mallikpur are highly diversified villages, while Chhinaihat and Hatpara are mediocre diversified villages across the sample villages.

Table 4.8: Crop Acreage in Sample Villages

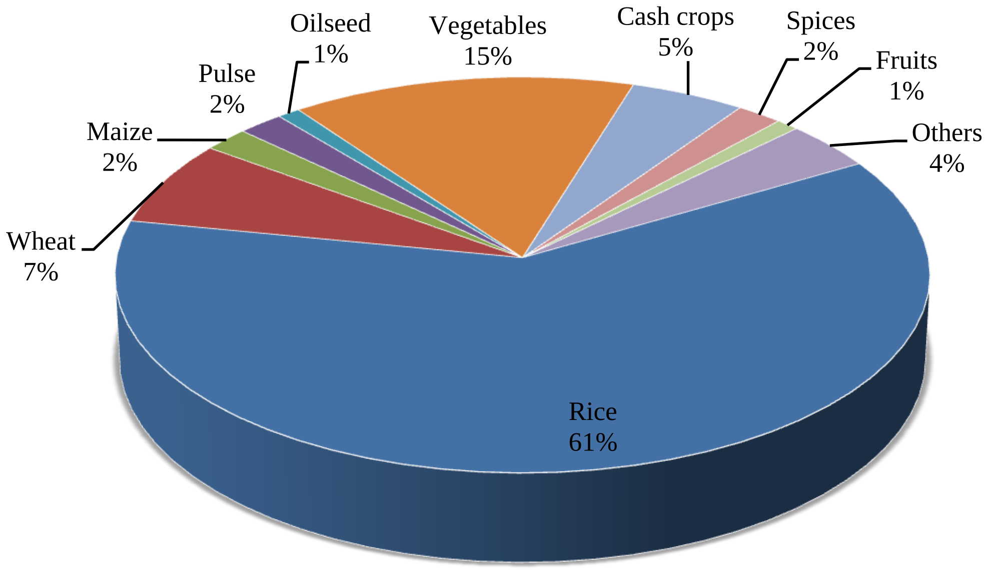
Crops	Gholharia	Mallikpur	Fazilpur	Alidewana	Chhinaihat	Bajemujrai	Hatpara	Chapor	All
Rice	34.9	37.2	73.0	90.9	46.5	86.8	56.6	73.4	61.6
Wheat	4.1	6.1	5.6	0.4	3.6	0.8	18.2	12.4	6.8
Maize	1.0	5.8	-	-	9.1	0.4	2.8	0.4	2.2
Pulses	3.3	3.5	0.7	-	-	2.1	1.3	2.2	1.9
Oilseeds	1.2	0.9	3.8	0.2	-	0.9	2.1	-	1.1
Vegetables	37.0	25.3	11.2	1.1	32.7	7.2	5.1	4.1	15.0
Cash crops	6.7	14.2	1.1	2.5	3.6	1.3	4.9	2.4	4.5
Spices	7.4	6.7	1.1	0.6	-	-	-0.4	0.4	1.9
Fruits	1.0	0.3	0.4	-	-	0.4	1.5	0.4	1.4
Others	3.1	0	2.9	4.2	4.3	-	7.1	4.1	3.6

Sources: Author’s calculation

Figure 4.4 presents average crop acreages of sample villages.It is found from the figure that 65% of gross crop area belongs to rice production, 8% area produces wheat, 9% area grows vegetables and 5% area is devoted to cash crops in the total sample districts. Likewise, 61% for rice, 7% for wheat, 15% for vegetables and 5% area was used for crops production according to village level data.

Thus, it is evident from Figure 4.4 and 4.5 that data from all the levels give roughly the same result regarding crop acreage. This result strongly proves that the study area is a high crop diversified area in Bangladesh as rice acreage of the study area is roughly 65% (collected data) which is smaller than that of national rice acreage (more than 75%).

Figure 4.4: Crop Acreage in Sample Villages

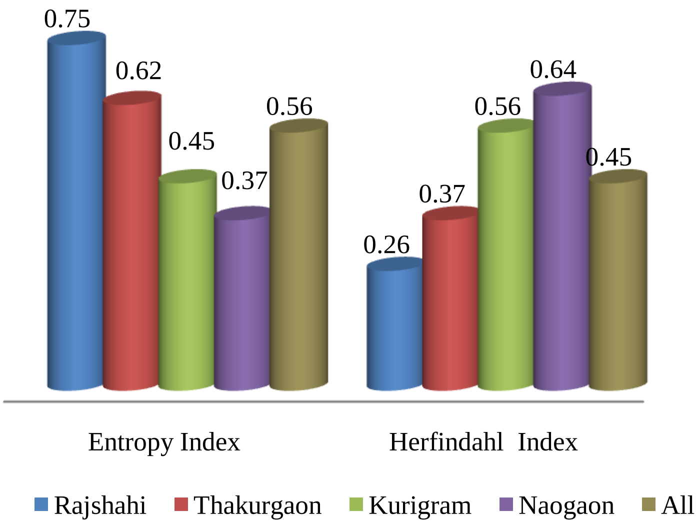


Sources: Author’s calculation

4.5Extentof Crop Diversificationin the Study Area

It is found from crop acreage, cropping pattern and cropping intensity that the sample districts are diversified by different crops although exact level of diversification is different. To measure the extent of crop diversification in the study area, the widely used Herfindahl and Entropy indices are used. Figure 4.7 shows the value of EI and HI of crop diversification. Entropy index of crop diversification confers direct relation to crop diversification and Herfindahlindex entails inverse relation to crop diversification. It is found in the table from the indices that Rajshahi district is the most diversified area in growing crops and Naogaon is the least one among sample districts. In Rajshahi, farms grow almost all categories of crops such as rice, pulses, oilseeds, cash crops and vegetables. Value of EI in Rajshahi is 0.75 followed by Thakurgaon (0.62), Kurigram (0.45) and Naogaon (0.37). Exactly same result is found from the value of HI.

Figure 4.5: Crop Diversification in Sample Districts



Sources: Author’s calculation

Table 4.9 shows the extent of crop diversification in sample villages. It is found from the table that Mallikpur village of Rajshahi district shows the highest diversified villages among the sample villages considering the value of the Herfindahl index. It is 0.73 followed by Gholharia of same district 0.70, Hatpara of Thakurgaon 0.62, Chhinaihat of Kurigram 0.57 etc and Alidewana (0.19) of Naogaon has the lowest position among the sample villages.The same result is found from Herfindahl index of crop diversification.

Table 4.9: Crop Diversification in Sample Villages

Villages	Entropy Index	Herfindahl Index
Gholharia	0.70	0.27
Mallikpur	0.73	0.24
Fazilpur	0.44	0.55
Alidewana	0.19	0.83
Chhinaihat	0.57	0.34
Bajemujrai	0.25	0.76
Hatpara	0.62	0.36
Chapor	0.43	0.56
All	0.58	0.42

Sources: Author’s calculation

4.6Advantage of Crop Diversification

There are several advantages of crop diversification as is found from various studies that crop diversification increases income of rural households, generates rural employment and alleviates poverty etc. (Chand, 1996; Delgado &Siamwalla, 1999; Jha, 1996; Ryan& Spencer, 2001;Vyas, 1996). Therefore, in this section, from the farmers' point of view, advantages of crop diversification have been explored. In this case, farmers were askedabout the advantages of growing different crops in their land and farmers' opinions are reported in Table 4.14. Again, they were asked to mention the advantages of growing different crops in different plots in the same season and their answers are presented in Table 4.10.

Table 4.10: Advantages of Crop Diversification

Advantages	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Soil fertility increased	51	99	76	99	81
Fertilizer cost reduced	8	58	53	54	46
Pesticidecostdecreased	4	19	26	43	25
Humanhealth not harmed	4	35	16	77	25
Provide nutritious food	69	90	89	75	79
Crop disease reduced	39	83	49	74	65
Insectattack minimized	65	63	43	69	62
Beneficial insects remain alive	44	30	43	80	46
Yieldrate increased	59	44	74	66	61
Waterlevel not declined	76	68	14	23	62
Employmentgeneration increased	84	85	93	81	83
Farm income increased	97	81	94	43	88
Womenparticipation increased in agriculture	52	24	83	6	48

Source : Field Survey, 2013

It is found that 88% farmers opined that growing different crops increase farmers' income followed by increase employment generation (83%). Similarly, 81% noted that it increases soil fertility; 79% reported that it provides nutritious food and 65 quoted that growing different crops in the land reduces crop diseases.

4.7 Conclusion

This study found that most of the farms are marginal in the study area. The highest number of marginal farms belongs to Rajshahi district and the lowest one to Kurigram.Rice dominance cropping pattern has been found in the study area. However, among the sample districts, Rajshahi and Thakurgaon produce, apart from rice, various types of vegetables such as, potatoes, papayas, tomatoes, etc. different types of pulses and few oilseeds. Generally, most of the cultivated land is used two times in a cropping year although one third of the land is found to produce three crops in a year. The cropping intensity of the study area is very high in comparisonto the national level and other area in the country.

Across the sample districts, Rajshahi and Thakurgaon grow almost all types of crops. In terms of crop diversification index, the study area is a more diversified area compared to many other areas of Bangladesh. The commonadvantages of crop diversification are: increased income to the farmer,higher employment opportunities, increased soil fertility and nutritious food.

CHAPTER FIVE

RESEARCH METHODOLOGY

5.1 Introduction

This chapter discusses the methodology of the study. The methodology includes the empirical approach, quantitative techniques to measure the level of crop diversification and econometric model to estimate the effects of different socio-economic and farm characteristics on the intensity of crop diversification in northern Bangladesh.The methodology also includes data collection and data analysis techniques and empirical design of the model.

This Chapter is divided into eleven sections. The second section of this chapter deals with the research approach, third section discusses the measurement indices ofcrop diversification. Thefourth section describes the Tobit regression model. Techniques of economic viability analysis are discussed in the fifth section and estimation issuesare discussed in section six. Section sevendiscussesvariability and association tests of the data and variables. Area and sample selection techniques are discussed in section eight. Techniquesof data collection and data analysis and presentation are discussed in section nine and ten. Finally,eleventhsection draws the conclusion.

5.2 The Research Approach

There are two basic approaches in conducting any research, viz, quantitative approach and qualitative approach. Quantitative research is basically a data led-approach which provides a measure of what people thinks from a statistical and numerical point of view.In the present study, quantitative approach is used based on primary data collected from farm household. This approach usually involves collecting and converting data into numerical form so that calculation can be made to draw conclusion.It also refers to the systematic empirical investigation of the phenomena using mathematical, statistical or computational techniques.

There are several earlier studies which concentrated on measuring the level of crop diversification and there are many dimensions found in those studies. These dimensions include calculation of the level of crop diversification, identification of factors which influence crop diversification and the factors that induce farmers to go for crop diversification. There are different methods for measuring the level of crop diversification and several indices are also used for measuring the level of crop diversification. Whether farms are diversified or specialized can be identified by the numbers of crops grown in the farms (Benin *et al*, 2004; Ibrahim *et al*, 2009; Van Dusen& Taylor, 2005). However, it cannot identify the level of diversification. Majority of earlier studies on crop diversification measured the level of crop diversification in terms of the proportion of gross cultivated land distributed to each crop(Benin *et al*, 2004; Chand, 1996; Kelley *et al*, 1995; Pandey& Sharma, 1996). When the distribution is equal for each crop, it indicates perfect diversification and when the land is allocated to a particular crop, it indicates perfect specialization or monoculture. Metzel and Ateng (1993) have used Rice Share Index (RSI) to calculate the level of crop diversification in Bangladesh. RSI holds that the higher is the rice share area of total crop area the lower is the extent of crop diversification of a farm.

In studying crop diversification in agriculture, it is important to identify the key determinantsof crop diversification. To identify the factors that influence the level of crop diversification,some studies used Multiple Regression Model (Ashfaq*et al*, 2008;Bhattacharyya, 2008; Ibrahim *et al*, 2009). Aneani*et al*(2011) De &Chattopadhyay(2010) and Kumari*et al* (2010) used the Logit model to identify the factors of crop diversification, while Ojo*et al*(2013),Pitipunya (1995) and Rahman (2008) used the Probit Model. Apart from these modelsAbay*et al* (2009),Gauchan*et al* (2005), Husain *et al* (2001) and Mesfin*et al* (2011) used the Tobit Model on the basis of the nature of dependent variable.

Similarly, it is also equally important to analyze economic viability of crop diversification in conducting research on crop diversification. Several recent studies have attempted to analyze profitability of producing different crops.In this respect, they used various methods to analyze profitability of different crops. Most common methods used by the researchers are total cost and total revenue ($\Pi = GR - TC$)

analysis, benefit cost ratio (BCR), Gross Margin (GM) and Net Return (NR) analysis etc. There are several studies where researchers have used BCR and net return analysis to measure the profitability of different crops. Ahmed *et al* (2013), Haque*et al* (2013, 2012, 2011), Hoq*et al* (2012), Kabir and Islam (2012), Karim*et al* (2009), Moniruzzaman*et al* (2009) and Mukul and Rahman (2013) have used net return analysis and benefit cost ratio (BCR) to analyze economic viability of respective crops in their study.

Thus, to achieve the objectives, the present study tries to measure the level of crop diversification by calculating the Herfindahl Index (HI) and Entropy Index (EI) following Ghosh (2010),Kalaiselvi and Kalyani (2012), Malik and Singh (2002) and Mehta (2009). The advantage of the HI andEI is that they account for both abundance and evenness of the crops in a specific region and they arewidely used by the researchers as they provide appropriate measure of crop diversification. The studyused regression modelfor identifying the factors affecting the level of crop diversification in the study area.The Tobit model is employed following Abay*et al* (2009)and Mesfin*et al* (2011) in this purpose. Since dependent variable in the model is index value of crop diversification which is bounded by zero to one, in this casethe Tobit model gives more reliable result compared to other models. Finally, cost-return and cost-benefit ratio analyses are performed to analyze the economic viability of crop diversification in northern Bangladesh.

5.3 Measurement Index of Crop Diversification

To measure the state of crop diversification, there are different measurement approaches. Each approach has some limitation as well as superiority over the others (Shiyani, 1998). This study has used two different measures of crop diversification, namely,Herfindahl Index (HI), and Entropy Index (EI) which have been used extensively in various studies.

5.3.1 Herfindahl Index

Herfindahl Index (HI) is defined as the sum of squares of all the proportion of farm acreage involved in a particular enterprise. The index is represented as:

$$HI = \sum_{i=1}^{n} p_i^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where, $p = \sum_{i=1}^{n} \frac{a_i}{A}$, $a_i =$ area devoted to a particular crop in a given year, and A is annual gross cultivated area (equal to the sum of all crop areas in all seasons). The value of the HI ranges between zero to one, denoting zero for perfect diversification and one for perfect specialization. This indicates that the value of HI has inversely related to crop diversification.

5.3.2 Entropy Index

Entropy Index is regarded as an inverse measure of crop concentration having logarithmic character. This measure is applied on acreage proportion to measure the crop diversification. The index is

$$EI = \sum_{i=1}^{n} p_i \log {}^{1}\!/_{p_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where, p_i= Proportion of i^{th} crop stated in HI. The value of EI varies from zero to one. Zero value of EI indicates perfect specialization whereas value of one shows perfect diversification i.e. it has direct relationship with diversification.

To measure the present state of crop diversification, cross section data were used. During the arrangement of data, crops were categorized into different groups, like rice, wheat, maize, pulses, oilseeds, spices and condiments, cash crops, fruits and vegetables. Rice included local, hybrid, HYV *aus*, *aman* and*boro* varieties. Cash crops included sugarcane, tea, jute, tobacco, cotton etc.

5.4Model for Determinants of Crop Diversification

There are many factors that determine the level of crop diversification.To estimate the key determinants of crop diversification following modelis used:

$$CD = F (X_i, D_i, Z_i,) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where, *CD* = crop diversification index, X_i = set of socio economic variables; D_i = set of demographic variables, and Z_i= set of infrastructure related variables.

As crop diversification is measured by the HI and EI, the values of these indices were used as the dependent variable. The value of the indicesis censored because some of the values cluster at the limit. This censoring may occur from an underlying unobserved (latent) variable that determines the level of diversity at the farm level. An appropriate econometric model for such variable is a censored regression (Tobit) model. It accounts for censoring of the dependent variables, which occurs at both the lower and upper limit of each of the indices.

In the case of limited values of the dependent variable, standard Ordinary Least Squares (OLS) produces biased and inconsistent estimates. In addition, OLS model is only used to estimate linear model. So, for estimation, other type of suitable econometric model is required. One of such models is Censored Regression model. As the value of dependent variable in this study is limited, Tobit Regression model can be a very useful one. The Tobit approach has been applied in previous studies of crop diversification (Abay*et al*, 2009;Bittinger, 2010; Gauchan*et al*, 2005;Husain *et al*, 2001;Mesfin*et al*, 2011). This model is appropriate since the dependent variable is an index which takes a value between zero and one.

5.4.1The Tobit Model

The Tobit model is a statistical model proposed by James Tobin (1958).It describes the relationship between a non-negative dependent variable and the independent variables.It is an extension of the Probit model(Gujarati, 1995). The classic example of censoring is Tobin's (1958) study of household expenditures. The Tobit model can be described in term of latent variable Y^*. The general formulation for Tobit specification is usually given in terms of index function (Greene, 2000). The model is as follows:

$$Y_i^* = \beta' X_i + \varepsilon_i \qquad (4)$$

where Y^*_i is a latent variable (unobserved for values smaller than lower limit and greater than upper limit) representing crop diversification index, X_i is a vector of explanatory variables, β' is a vector of unknown parameters to be estimated, and ε_i represents the disturbance term which are independently and identically normally distributed with zero mean and constant variance σ^2, that is, $\varepsilon_i \sim NID\ (0,\ \sigma^2)$ (Mesfin*et al*, 2011). Denoting Y_i(CD Index) as the observed dependent variable, the observed Y_i is defined by the following measurement equation:

$$Y_i = \begin{cases} 0 & if \quad Y^*_i \leq Y_l \\ Y^* & if \quad Y_l < Y^*_i < Y_u \\ 1 & if \quad Y^*_i > Y_u \end{cases} \quad \text{...} (5)$$

5.4.2 Specification of the Model

The above model needs to be specified properly for empirical investigation. This helps to find out the relation of the determinantswith crop diversification. Thus, the specified model is:

$$Y_i = \beta_0 + \sum_{i=1}^{11} \beta_i X_i + \sum_{i=1}^{2} \delta_i D_i + \varepsilon_i \quad \text{..} (6)$$

Here Y_i is dependent variable that represents the value of crop diversification index. In case of the value of entropy index, researcher has taken 0.2 as lower limit and 1 as upper limit of the dependent variable. Similarly, in case of Herfindahl index, lower limit is zero and upper limits is 0.8. X_1 *to* X_{11}represent continuous explanatory variables whereas D_1 and $D_2$are dummy explanatory variables, $\varepsilon_i$is the error term, β_0 represents intercept of the model, $\beta_1 to \beta_{11}$ represent coefficients of continuous explanatory variables and, δ_1 and δ_2 represent coefficients of dummy explanatory variables to be estimated.

5.4.3 Estimation of the Tobit Model

The Tobit model is non-linear in nature. Thus, this non-linear model employs the Maximum Likelihood (ML) estimation technique to estimate the likelihood of the function. In principle, the ML approach may be employed to address the censoring and to account for correlations in error terms across equations by specifying a multivariate density function for the error terms. Censored regression models (including the standard Tobit Model) are usually estimated by the ML method. Estimating Tobit regression model using ML approach requires a formula for the probability of the observed value of the dependent variable based on the coefficient of the latent variable and transformation of the latent variable to observed variable. The standard Tobit model assumes a normal distribution for the difference between the fitted value and the latent value which leads the following equation for the probability of the observed values.

$$P_{(censord)} = P(Y^* \le 0) = 1 - \Phi\left(\frac{X_i\beta}{\sigma}\right) \quad \text{.............................} \quad (7)$$

$$P_{(uncensored)} = P(Y^* > 0) = \Phi\left(\frac{X_i\beta}{\sigma}\right) \quad \text{..........................} \quad (8)$$

Thus the likelihood function can be written as

$$L = \coprod_i^N \left[\frac{1}{\sigma}\phi\left(\frac{Y_i - X_i\beta}{\sigma}\right)\right]^{d_i}\left[1 - \Phi\left(\frac{X_i\beta}{\sigma}\right)\right]^{1-d_i} \quad \text{.....................} \quad (9)$$

Where d is the indicator variable that equals 1 if Y>0, i.e., the observation is uncensored and is equal to 0 if Y = 0, i.e., the observation is censored.

There are three expected values of the Tobit model (Sigelman&Zeng, 1999) which are: expected value of the latent variable Y^*, expected value of the positive observation [Y|Y>0] and expected value of the actual observation Y. However, in this research the researcher is interested on the expected value of the actual observation Y.

Thus, mathematical expressions of the expected values of Tobit are:

1. Expected value of the latent variable Y*:

$$E\left(Y^{*}\right) = X_i \beta \quad \text{...(10)}$$

2. Expected value of the positive observation [Y|Y>0]:

$$E[Y \mid Y > 0] = X_i \beta + \sigma\lambda(\alpha) \quad \text{...(11)}$$

3. Expected value of the actual observation Y:

$$E(Y) = \Phi\left(\frac{X_i \beta}{\sigma}\right)\left[X_i \beta + \sigma\lambda(\alpha)\right] \quad \text{..(12)}$$

Where, $\lambda(\alpha) = \dfrac{\phi\left(\dfrac{X_i \beta}{\sigma}\right)}{\Phi\left(\dfrac{X_i \beta}{\sigma}\right)}$ is the inverse 'Mills' Ratio'.

This is the probability of being uncensored multiplied by the expected value of outcome variable Y given Y is uncensored.

5.4.4 Marginal Effect of Tobit Model

The Tobit coefficients, unlike the traditional multiple regression coefficients, cannot be interpreted directly as estimates of the magnitude of marginal effects of changes in the independent variables on the expected value of the dependent variable (Mesfin*et al*, 2011). In a Tobit equation, a marginal effect includes both the influence of the explanatory variable on the probability of crop diversification as well as its intensity. More explicitly, the marginal effect takes into consideration that a change in an explanatory variable will affect simultaneously the number of sample farmers diversifying their crops and the extent of diversification. That is,

1. Marginal effect on the latent dependent variable Y*:

$$\frac{\delta E[Y^*]}{\delta X_k} = \beta_k \text{ ………………………………………………………… (13)}$$

Thus, the reported Tobit coefficient indicates how a one unit change in an independent variable $X_k$changes the latent dependent variable.

2. Marginal effect on the expected value for Y for uncensored observation

$$\frac{\delta E[Y \mid Y > 0]}{\delta X_k} = \beta_k \left\{1 - \lambda(\alpha)\left[\frac{X_i \beta}{\sigma} + \lambda(\alpha)\right]\right\} \text{..(14)}$$

3. Marginal effect of actual observation:

$$\frac{\delta E[Y]}{\delta X_k} = P(Y > 0)\frac{\delta E[Y \mid Y > 0]}{\delta X_k} + (E[Y \mid Y > 0])\frac{\delta P(Y > 0)}{\delta X_k} \text{ ……………… (15)}$$

It can be written as:

$$\frac{\delta E[Y]}{\delta X_k} = \Phi\left(\frac{X_i \beta}{\sigma}\right)\beta_k \text{ …………………………………………….. (16)}$$

Where, $\Phi\left(\frac{X_i \beta}{\sigma}\right)$is simply the estimated probability of observing an uncensored observation at these values of Xs.

5.4.5 Description of the Variables

In this study intensity of crop diversification was treated as the dependent variable. It is measured by Herfindahl Indexor Entropy Index. The values of these indices lie between zero and one. Independent variables have been selected from the previous studies which have been extensively used in different studies. The selected independent variables are farm size (FS), household size (HS), number of plots (NP), age of the farmers (AGE), education of the farmers (EDU), annual total income of the family (TFI) non-farm income (NFI), distance of farm from road (DFR), distance of market from farm (DMF), number of extension contacts (EXC), irrigation intensity (IRR),credit facilities (CF) and training exposure (TE). Those variables are identified from the review of the existing literatures. The justification for including these variables in the model is discussed below:

Land is the scarcest resource in Bangladesh, and farm size largely determines the level and extent of income to be derived from farming. Land also serves as a surrogate for a large number of factors as it is a major source of wealth and influences decision to choose crops. There are hosts of studies that used farm size as a determinant of crop diversification. For example,Abay*et al* (2009), Mesfin*et al* (2011) and Rehima*et al* (2013) have used farm size as a determinant of crop diversification. Farm size of a farmer refers to the total area of land on which his family carried out farming operations, the area being estimated in terms of full benefit of his family at the time of interview. It was expressed in acres following Chowdhury (2003). Similarly, household size was measured on the basis of total number of individuals including the respondent, his wife (if any), parents, children and other dependents living and eating together and sharing their earnings. The household size was expressed in number. If a respondent had four members in his family, the family size score was taken as 4. Chowdhury (2003), Mesfin*et al* (2011), Rahman (2008, 2009a) and Sharma (2011) have used household size as a determinant of crop diversification. Household size has a great influence on chosen growing crops. In the same fashion, number of plots is the most important variables in chosen growing crops. The higher is the number of plots, the higher are the options of growing different types of crops. It is used as an influential variable in many studies such as Benin *et al* (2004), Gauchan*et al* (2005), Gebremedhin and Jaleta (2010), Nagarajan*et al* (2007) and Rehima*et al* (2013) have used this variable in their studies.

Age of the respondents was measured in terms of his actual years at the time of data collection. It was measured in complete years as reported by the respondent. A score of one (1) was assigned to each year of age. Ashfaq*et al* (2008), Benin *et al* (2004), Ibrahim *et al* (2009), Mishra and El-Osta (2002), Rahman (2008) and Sharma (2011) have used age in their studies. Similarly, the level of education was measured in terms of grade (class) passed by a respondent. If a respondent received education in a school, his level of education was measured in terms of educational standard of the school. For example, if a respondent passed the final examination of class V, his education score was taken as five (5). If a respondent had education outside school and the level of his education was equivalent to that of class II then his education score was taken as two (2). If a respondent did not know how to read or write, his education score was taken as zero (0) but if he could read or write but no formal education he was given score of one (1). Chowdhury (2003), Gauchan*et al* (2005), Rehima*et al* (2013) and Sharma (2011) have used education level as the variable of crop production.

Annual income of a farm was measuredon the basis of the responses of the farmers. Annual farm income is the summation of total agricultural income and non agricultural income which has been earned by the members of the farms. Annual income of a respondents' family was expressed in 'thousand taka'. Joshi *et al* (2004) and Chowdhury (2003) used the same procedure in measuring annual income of the farms in their study.Off-farm income is defined for this particular study as all income except farm income earned by the family members of the sample farms. Off-farm income is a great support to the farmers to manage their farm and family. High value crops are labor intensive and comparatively high cost oriented. Thus, off-farm income can help the farmers to take decision which crop to grow. It is also expressed in 'thousandtaka'.Mesfin*et al* (2011), Mishra and El-Osta (2002) and Sharma (2011) used off-farm income as independent variable in their studies.

Ashfaq*et al* (2008), Joshi *et al* (2004) and Rehima*et al* (2013) used distance of farm from road as an independent variable in their studies. Similarly, carrying cost of agricultural products is considered before taking decision as to which crop is to be produced. If carrying cost is high then net profit will be low. It is apparent that farmers live in periphery of a town area produce high value crops because their carrying cost is lower than that of the farmers who lives outside of town area. Previous works on farm diversification highlighted the importance of market distance. It is measured in kilometers. Ibrahim *et al* (2009), Joshi *et al* (2004) and Rehima*et al* (2013) used distance of farm from main road as an independent variable in their studies.

Agricultural extension contact can be treated as one of the important sources of information dissemination directly relevant to agricultural production practices, particularly to the farmers like Bangladesh where farmers have very limited access to information. Therefore, this variable was incorporated to account for its influence on adoption decisions. Abay*et al* (2009), Ibrahim *et al* (2009) andRahman (2008, 2009a, 2009_b) used number of extension visits as an explanatory variable in their studies. Access to modern irrigation facilities is an important pre-requisite for growing modern rice, particularly the modern *boro*rice grown in the dry winter season. Lack of access to modern irrigation facilities has been identified as one of the principal reason for stagnation in the expansion of modern rice area, which currently accounts for a little over 50% of total rice area (Mahmud *et al*, 1994). Irrigation may also decrease diversity through uniform moisture conditions (Benin *et al*, 2004). Benin *et al* (2004),Jha*et al* (2009), Rahman (2008, 2009a, 2009_b) and Rehima*et al* (2013) used irrigation intensity as an independent variable in their studies.

Credit facility to a farmer was determined by dummy variable. If he received any credit the value will be one otherwise zero. Credit can influence crop diversification indices in a different way. Credit is believed to increase the risk bearing ability of farmers. Therefore, one can expect a positive effect of credit on agricultural diversification provided increase in diversification fulfills the objective of rational farmers (Jha*et al*, 2009). Rahman (2008, 2009a, 2009b) has also used credit facility as a variable in his study. In the same manner, training exposure of a farmer was expressed by dummy variable. If he received training, the value takes one, otherwise zero. Chowdhury (2003) has used training exposure as a determinant of crop diversification in his study.

5.5Analysis of Economic Viability of Crop Diversification

One of the objectives of this study is to investigate whether diversified cropping practice is economically viable to the farmers. Economic viability basically refers to profitability and this study employed net return analysis and benefit cost ratio (BCR) analysis to investigate the economic viability of crop diversification. Computation procedures under these techniques are provided below:

5.5.1 Net Return Analysis

Net return analysis is the most common approach for determining and comparing profitability of different crops. Profit is defined as the difference between the gross return and total cost. Thus, to analyze profitability, gross return and total cost of the crops were considered. Total cost includes all types of costs which are paid from farmers' pocket and imputed cost of family labor and other factors of production. All types of imputed costs were converted according to the market price. Even land and other agricultural implements of the owner farmers were treated as rented one. Total return includes return from main product and by-products. Farmers' actual cost and returns of production have been calculated in this research. Where farmers buy inputs of production at retail price and sell their product atwholesale price.The following conventional profit determining model, which is the simplest procedure to determine profitability and commonly used, were employed to analyze farmers' profitability in producing crops.

$$GM = (GR - TVC) \quad \ldots\ldots (17)$$

$$NR = (GR - TC) \quad \ldots\ldots (18)$$

Where,

$$GR = \sum_{i=1}^{n} P_{q_i} Q_i \quad \ldots\ldots (19)$$

$$TC = TFC + TVC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

GM = Gross Margin (profit) from i^{th} crop per *bigha* (33 decimal) of land

NR = Net Return (profit) from i^{th} crop

GR = Gross return from i^{th} crop

TC = Total cost of i^{th} crop

TVC = Total cost except land cost(summation of labor cost, tillage cost, seed cost, fertilizer cost, pesticide cost and irrigation cost)

TFC = Total fixed cost (land rent)

P_{qi} = Unit price of i^{th}main crop and related by-products (if any)

Q_i = Quantity of i^{th}main crop and related by-products (if any)

Rahman (1998) noted that land is an important fixed asset and a source of wealth in rural settings. Therefore, the opportunity cost of land for the owner operator is imputed at the net rental cost of land incurred by the tenant farmers. The family supplied inputs of human labor and animal power services, seeds, and manures are imputed at their market rates. Cost and returns were analyzed for rice monoculture and crop diversification due to find out more profitable one.

Gross returnis computed on the basis of actual prices at which farmers sold their products and by-products. Where only a fraction of the output was sold, the unsold output was valued at the rate at which a fraction of the output was sold.For estimating the cost of cultivation, following costs were considered in the present study. The details included under each of the concepts were as follows:

1) Cost of labor (hired or imputed)
2) Cost of plough (hired or imputed)
3) cost of using machineries (hired or imputed)
4) cost of seeds (imputedor purchased)
5) cost of fertilizers, pesticides and manures (imputed or purchased)
6) rental value of land (real or imputed)

5.5.2 Benefit Cost Ratio (BCR) Analysis

Undiscounted BCR is another technique of profitability analysis. BCR analysis is an important tool to assesseconomic viability of farming. It is the ratio of total cost to total return (gross return). If BCR is greater than one, the farm is considered as profitable. This study has used undiscounted BCR to compare profitability of monoculture and diversification.The formula is stated as:

$$BCR = \frac{TR}{TC} \quad \text{(21)}$$

The farm is treated as a profitable farm if the value of BCR is greater than one (BCR>1).

5.6Estimation Issues

In analyzing the collected data, both statistical and econometric techniques are used. Statistical analysis such as two-way ANOVA test and two-sample t-test are used in accordance with the descriptive statistics to summarize the data on household demographic and socio-economic characteristics that are generated by the survey. Moreover, econometric regression model is applied to determine the key factors of crop diversification in the study area. The Tobit regression model is applied to find out the factors that affect the decision of practicing crop diversification.Estimation software STATA(version 11) is used to estimate the empirical model.

As a case of regression with limited dependent variable,the estimation of Tobitmodel includes the some special issues. The estimated coefficients of the Tobitmodel show the change in the probability of dependent variable for a one unit change in the predictor variable.The likelihood ratio (LR) shows the model's overall level of significance. One of the measures goodness of fit for Tobit model is pseudo R-squared, higher value of which shows better fitting of the model.

Since the study is entirely based on primary cross sectional data,the problem of multicollinearity and heteroskedasticity may arise. Multicollinearity was checked using variance inflation factors (VIF) for the continuous variables and contingency coefficient for the dummy variables. The calculated VIF values are less than 5 (the cut-off point is 10) and contingency coefficient was less than .01 but cut-off point is 0.75. Again Pearson Correlation Analysis (Appendix B) also carried out for checking multicollinearity in the model. Both the test confirmed that multicollinearity is not a serious problem.

5.7 Variability and Association Tests

The differences between the mean values of socioeconomic and demographic characteristics offarmers of different farm size (marginal, small, medium and large), different types (diversified and specialized), belong to different districts have been testes using the conventional t test, Chi-squared test and ANOVA test.Moreover, differences with respect to mean age, experience and education of the farmers are also tested.

In the rural areas,socio-economic and demographic characteristics of the farmers differ significantly. There are several statistical tests to see whether these differences are statistically significant or not. In case of quantitative data, t test is used to compare the mean value of variables when test variable is taken from two independent groups. On the other hand, ANOVA is used when the test variable are taken from more than two groups. Again, in case of categorical data, chi-square (χ^2) test is used to see the association of the variable taken from different categories. These test statistics are discussed below:

Independent Sample *t* Test

Usually *t* and z tests are commonly used when making comparison between the means of two samples or between some standard value and the mean of single sample (Gaur & Gaur, 2009). In this study independent sample t test is used to compare the meansof two independent variables. In this study, it has been executed to compare the mean value of some characteristics of diversified and specialized farms in the study area. The formula of independent sample t test is:

$$t = \frac{\overline{X}_1 + \overline{X}_2}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad \text{……………………………………………..} (22)$$

Where, t= student t statistic, $\overline{X}_1$ = mean value from first sample, $\overline{X}_2$ = mean value from second sample, S= combined standard deviation of the sample, n_1 = first sample size and n_2 = second sample size.

Analysis of Variance

Analysis of Variance (ANOVA) is generally used to compare the mean values of more than two populations (Gaur & Gaur, 2009). ANOVA uses F statistic which tests if the mean value of the groups formed by one independent variable or a combination of independent variables are significantly different. The F statistic calculates the ratio between the variance due to difference between groups and error variance. In this study, it has been carried out to test the variation of the farmers and farm level characteristics of sample districts and sizes of farm. The F statistics is:

$$F_{stat} = \frac{MS_B}{MS_W} = \frac{ESS/K-1}{RSS/N-K} = \frac{SS_B/K-1}{SS_W/N-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (23)$$

Where, MS_B = mean square between group, MS_w = mean square within group, ESS = explained sum of square, RSS = residual sum of square, SS_B = sum of square between group, SS_w = sum of square within group, K= number of parameter and N = total number of observation.

Chi–Square (χ^2)

Chi–Square (χ^2) is one of the simplest and very popular methods for testing hypothesis on discrete data. A chi-square (χ^2) statistic is used to investigate whether distributions of categorical variables differ from one another. A small χ^2 statistic indicates that there is no association between the two variables, i.e., two variables are independent to each other and vice-versa. It is also a non parametric test and makes no assumption about the population being sampled. In this study, the researcher uses χ^2 statistic to test the association between credit access and types of farm; training exposure and types of farm; sizes of farm and types of farms and so on. The formula for computing χ^2 is:

$$\chi^2 = \sum\left[\frac{(O-E)^2}{E}\right] \qquad (24)$$

Where, χ^2 = Chi square statistic, O = observed frequency and E = expected or theoretical frequency. In this study χ^2 was executed to confirm whether there is any relation between the types of farmers' and sample districts.

5.8 Study Area and Sample Selection

The present study is mainly based on primary data collected from sample households.In this purpose, eight villages from four districts under northern Bangladesh, which is comprised of Rajshahi and Rangpur divisions, have been selected. The sample farmers are chosen randomly using multi-stage random sampling method. To fulfill the objectives of the present study, the sample has been selected in such a way that it covers all necessary data required for analysis. For conducting the present study, the researcher selected the study area with great care so that the estimated results become representative. The rationale behind selecting northern Bangladesh for the present study is that this area is an agriculture-based area. Although rice is the dominant crop in northern Bangladesh, it also producesseveral other minor crops such as wheat, potato, vegetables, jute, maize, oilseeds, pulse, onion, garlic etc. In northern Bangladesh,farming is the principal occupation of most of the population and their livelihood mostly depend on agricultural activities. In this area, farming is characterized by low level of production technology and small size of farm holding. Production is primarily subsistence with little surplus for marketing. Around 80% people of the study villages are farmers. Moreover in northern Bangladesh, there is sufficient scope to enhance crop diversification using improved technology. Thusnorthern Bangladesh has been chosenfor conducting the research.

The selection of sample for this study involves the selection of districts, upazila and villages. The first step was to select four districts out of sixteen districts from northern Bangladesh. Four districts that are chosen purposivelyare Thakurgaon and Kurigram from Rangpur division and Rajshahi and Naogaon from Rajshahi division.The districtshave been selected purposively on the basis of consultation with regional office of DAE. In the next step, one upazila from each district has been selected randomly. Thus, Pirgonjupazila of Thakurgaon district, Rajarhatupazila of Kurigram district, Pabaupazila of Rajshahi district and Mohadebpurupazila of Naogaon district have been selected for the survey. From each of the selected upazila, two villages have been selected randomly. After that farm households have been listed from the records available to the Sub Assistant Agriculture Officer (SAAO) of the respective villages and then sample households are chosen by using random sampling method. A total number of 343 farm households, using statistical formula proposed by Arkinand Colton (1963), are selected for this study. Finally, these data have been collected from head of the each sample household. The total sampling information is presented in the following table:

Table 5.1: Distribution of Sample farms

District	Upazila	Name of Village	Number of farm households	Number of Sample
Rajshahi	Paba	Gholharia	421	46
		Mallikpur	417	45
Naogaon	Mohadebpur	Alidewana	565	61
		Fazilpur	355	38
Kurigram	Rajarhat	Chhinaihat	248	27
		Bajemujrai	400	43
Thakurgaon	Pirgonj	Hatpara	395	43
		Chapor	366	40
	Total		3167	343

After collecting the data, farms were then classified into four groups on the basis of landholding, such as marginal farms owning more than 0.05 but less than 0.5 acres of land, small farms owning from 0.5 acres but less than 2.5 acres of land, medium farms with land between 2.5 and 7.5 acres and large farms having land 7.5 acres and more (BBS, 2011a) for analysis.

5.9Techniques of Data Collection

The study is based on primary data along with secondary data and extensive literature review. As most of the aggregated data for this study is not readily available in the form required, extensive field works, for collection, coordination and screening of data from secondary sources were done. Primary data were collected from the sample households through whichwelldesignedstructured questionnaire(Appendix A) isprepared with great attention and care on the basis of research questions inherent in the research objectives. To test the accuracy of the questionnaire the researcher made pilot surveys. The questionnaire is modified according to the suggestions of the expert (supervisor) and finalized after necessary corrections. After that data have been collected using a well structured questionnaire. The technique of data collection involves both quantitative and qualitative aspects. Both close ended and open ended questions are used in the questionnaire. The study focuses on the 2012/13 crop year and therefore relied on recalled information.These data have been collected from May toJuly, 2013. Through the questionnaire survey, socio-economic data such as household size, age, sex, education, experience, training, extension contact etc. of the respondents; production information such as farm size, number of plots, yield and total production of the farm, production cost, etc. and other related information such as amount of credit, annual income, non-farm income etc. are collected. The data are collected in such a way that they can easily be fitted for estimation of the specified model.

In addition to collecting primary data, some secondary data have also been collected through review of different related published and unpublished issues. The main sources of secondary data are: various issues of Yearbook of Agricultural Statistics in Bangladesh, Statistical Yearbook of Bangladesh, Bangladesh Economic Survey, Bangladesh Census of Agriculture and Livestock, Bangladesh Population Census, Bangladesh Labor Force Survey, Five Year Plan Documents and Agricultural Databases of Bangladesh. In addition, studies conducted by Bangladesh Institute of Development Studies (BIDS), International Food Policy Research Institute (IFPRI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural University Research System (BAURES), and other unpublished M. Phil and Ph.D. dissertations served as useful secondary sources for this study.

5.10 Data Analysis and Presentation

Collected data were compiled, tabulated, coded and analyzed according to the objectives of the study. In this process, all the responses in the interview schedule were given numerical code value and were entered into the Statistical Package for Social Sciences (SPSS; version 17) and later converted to STATA file for Tobitregression analysis. Once the data entry was completed, the data were then cleaned by producing frequency figures for each question and examining the outliers. Consequently, a large number of completed questionnaires were rechecked to avoid inconsistencies. At this stage, the data file was ready for final analysis.

Finally, processed data were analyzed statistically and empirically. Statistical analysis includes descriptive analysis and inferential analysis. Descriptive analysis includescalculation of frequency, mean,percentage, standard deviation etc. related to socio-economic and demographic characteristics of farmers and others farm level data. Similarly, empirical analyses,level of crop diversification, determinants of crop diversification and economic viability of crop diversification, were carried out in the study.At last, by accomplishing the analyses of collected data, the findings of the study were presented through tabulation and graphically in the dissertation.

5.11 Conclusion

This chapter highlights the research methodology and data collection techniquesused in the study. In the methodology, the ways through which the sample respondents are selected are described. It is found from the discussion that Entropy index and Herfindahl index are suitable to measure the level of crop diversification and the Tobitmodel is appropriate to identify the key factors of crop diversification. Similarly, it is found that cost return and cost benefit ratio are widely used method to analyze the profitability of different crops production. This chapter has also provided necessary estimation process, econometric methods of estimation and brief description of variable that are usedin the model.

CHAPTER SIX

HOUSEHOLD CHARACTERISTICS AND CROP DIVERSIFICATION

6.1 Introduction

The main objective of this chapter is to discuss the characteristics of the respondent households in the study area and the association of those characteristics with crop diversification. In this respect, this chapter discusses the demographic and socio-economic characteristics of the farms and farmers. Furthermore, to analyze farmers' characteristics in crop diversification perspective, two way analysis of variance (ANOVA), independent sample t test and chi-square (χ^2) test have been used. The study has used ANOVA analysis to see whether there are any differences in mean value of socio-economic characteristics across the farmers of different size of farms and sample districts. Similarly, the independent sample *t* test is used to see the differences in the mean values of selected characteristics of the farmers of specialized farms and diversified farms. Likewise, chi-square (χ^2) test is used to examine the association between categorical variables related to the study.

This chapter consists of four sections. Section 6.2 discusses demographic and socio economic profiles of the farmers that contain age, education, farming experience of the farmers. It also discusses household size, farm size, own cultivated land, number of plots and extension contacts of a farm in the sample area. Similarly, it discusses annual income from crops, annual income from non-agriculture activities and annual gross income and livestock asset of the farm. Section 6.3 presents rice and non-rice producing farms, number of crops grown by the sample farms, crop acreage in the sample area and level of crop diversification of the sample farms in the sample districts. Section 6.4 presents comparison of some selected characteristics of diversified and specialized farms in the sample area. Finally, this chapter ends with making a conclusion in Section 6.5

6.2 Demographic and Socioeconomic Characteristics of Farmers

Demographic and socio-economic features of a farmer have substantial role in agricultural activities. They influence agricultural activities extensively in taking decision about which crops to be produced, when and how much. For example, higher aged and experienced farmers have indigenous knowledge of farming and usually they follow traditional subsistence farming whereas educated and young farmers have knowledge of modern and commercial farming which influences them to diversify their crops. The discussion of socio-economic and demographic characteristics and crop diversification practices of the farmers help to provide a better understanding of the planners, researchers and concerned others to make better agriculture related policy for Bangladesh. The objective of this section is whether there exists any variability in different socio-economic and demographic characteristics of the farmers in the study area.

6.2.1 Age of the Farmers

Age of the farmers is considered as an important factor influence agricultural activities. It is assumed that higher aged farmers can contribute more in raising crop frequency than those of lower aged farmers. Table 6.1 presents the mean age of the farmers in the study area.

Table 6.1: Age of the Farmers in the Study Area

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	35.26	37.38	40.13	43.13	38.59
Small	42.38	45.22	46.12	45.00	44.55
Medium	43.56	43.71	47.97	48.17	46.58
Large	31.00	50.00	47.67	45.80	45.60
All	39.93	42.42	46.37	45.06	43.21

ANOVA Table

Sources	DF	F Stat	
		Value	Sig.
Districts	3, 327	3.69	0.01
Size of Farm	3, 327	6.72	0.00

Source: Author's calculation

It is apparent from the table that aggregated mean age of the farmers in the study area is 43.21 years. However, if we go for disaggregated analysis, we find that mean age of the farmers in Rajshahi district is 39.93 years and for Kurigram district it is 46.37 years. Going over farm size, it is found that mean age of the farmers of medium farms is 46.58 years, which is the highest mean age among farmers of all farm sizes and mean age of the farmers of small farms is 38.59 years which is the lowest. Mean age of the farmers of Kurigram district is 46.37 years followed by mean age of the farmers of Thakurgaon (45.06), Naogaon (42.42) and Rajshahi (39.93). There is significant difference in the mean ages of the farmers among different size of farms which is found from F value in the ANOVA analysis ($F_{3, 327} = 6.72$, $p = 0.00$). Similarly, there are also significant differences in the mean age of the farmers of different districts ($F_{3, 327} = 3.69$, $p = 0.01$).

6.2.2 Education Level

Education is considered as an important indicator of human capital which provides knowledge, skills and experience for performing economic activities. It also provides adequate knowledge and experience of agricultural farming. Thus, education is also an important factor for agricultural activities. Table 6.2 reveals the education level of

Table 6.2: Education Level of the Farmers

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	5.35	4.92	4.13	5.43	5.13
Small	4.70	4.58	4.58	4.80	4.66
Medium	5.11	7.57	5.61	4.67	5.45
Large	7.00	2.80	5.00	5.40	4.67
All	5.05	4.83	5.03	5.04	4.98

ANOVA Table

Sources	DF	F Stat	
		Value	Sig.
Districts	3, 327	0.25	0.86
Size of Farm	3, 327	1.42	0.24

Source: Author's calculation

the farmers in the study area. It is found average education level of the farmers of the study area is 4.98 years whereas slight differences in education level of the farmers in different districts and farmers of different sizes of farms. It is apparent from the table that there is no significant difference in average education level of the farmers across the sample districts according to the F value of ANOVA ($F_{3, 327}$ = 0.25, P = 0.86). Similarly, no significant difference was also found in education level of farmers with different size of farms also ($F_{3, 327}$ = 1.42, P =0.24).

6.2.3 Farming Experience

Experienced farmers can contribute more to agricultural activities as farming experience of a farmer can help to take proper decision about producing suitable crops. Table 6.3 gives an idea about farming experience of the farmers in the study area. Average experience of the farmers in the study area is 23.24 years. In details, the table shows that experience of the farmers of medium farm in the study area is 26.11years which is the highest farming experience amongst all sizes of farms followed by experience of the farmers of large farms (25.00), small farms (24.83) and marginal farms (18.76 years). In district wise analysis, it is found that average experience of the farmers of the sample districts is almost the same as is apparent from the table. Lower panel of the table confirms that different sizes of farms have highly significant effect on the experience of the farmers of the study area ($F_{3, 327}$ = 7.20, P = 0.00). However, district variability does not affect the experience of the farmers significantly ($F_{3, 327}$ = 0.18, P = 0.91).

Table 6.3: Farming Experience of the Respondent

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	17.65	18.38	17.88	20.63	18.76
Small	26.55	24.56	24.31	23.43	24.83
Medium	29.72	22.29	24.70	26.56	26.11
Large	16.50	31.00	23.33	23.40	25.00
All	23.92	22.41	23.71	23.10	23.24

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	0.18	0.91
Size of Farm	3, 327	7.20	0.00

Source: Author’s calculation

6.2.4 Household Size in the Study Area

Household size refers to the number of persons living and eating together in the same arrangement, and sharing their earning. Number of active persons in the household is one of the important demographic indicators of the farms. It also indicates about the economic condition as well as economic pressure of the household. As most of the farms in the country are subsistence in nature, active household member is treated as an asset to the household whereas dependent members are considered as a burden of the same. Table 6.4 demonstrates household size in the study area. Average size of household in the study area is 5.29. In details, average size of household of a large farm is 5.87 which are the highest among all farms in the study area followed by household size of medium farms (5.59), small farms (5.21) and marginal farms (4.75). However, average size of households in different districts is almost same as is clear from the table. It is clear from the F value that different size of farms have highly significant effect on the size of households in the study area ($F_{3, 327}$ = 9.78, P = 0.00).

Table 6.4: Household Size in the Study Area

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	4.68	4.70	4.13	5.03	4.75
Small	5.30	5.22	5.23	5.03	5.21
Medium	6.56	5.14	6.03	5.28	5.59
Large	7.00	6.00	5.33	5.80	5.87
All	5.32	5.16	5.39	5.13	5.29

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	1.20	0.09
Size of Farm	3, 327	3.78	0.00

Source: Author's calculation

Not only household size but also earning members in the households is an important factor of agricultural activities. Usually, the higher the earning members in a household, the better is the economic condition of the household. Because of higher number of earning members in the household, it can remain pressure-free from subsistence agriculture. In addition, they can produce high value crops which give them further economic solvency. Average earning members of a household is 1.57

persons in the study area whereas average earning members of a large farm is 2.20 which is the highest mean earning members among all size of farms and average earning members of a small farm is 1.33 which is the lowest in the study area. Average number of earning members in a household of Kurigram district belongs to the highest number of earning members (1.71) whereas, the lowest numbers of earning members (1.41) have been found in Thakurgaon district (Appendix C).

6.2.5 Farm Size in the Study Area

Farm size is an important determinant of production in agriculture. Apparently, the bigger the farm size is, the larger the number of crops it produces. Table 6.5 presents average farm size of the farmers in the study region. It is found that average farm size in the study area is 214.95 decimal whereas, average size of a large farm is 841.27 decimal, medium farm is 383.67 decimal, small farm is 191.71 decimal and marginal farm is 43.88 decimal in the study area. Similarly, average farm size in Thakurgaon district is 234.47 decimal which is the highest farm size across the study districts followed by 208.14 decimal in Kurigram, 186.97 decimal in Naogaon and 181.51 decimal in Rajshahi district. Based on the ANOVA analysis, it is evident that there is significant difference in farm size across the districts in the study area ($F_{3, 327} = 24.15$, $P = 0.00$).

Table 6.5: Farm Size in the Study Area

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	45.87	42.32	43.25	43.90	43.88
Small	174.95	193.08	156.73	219.03	186.97
Medium	359.83	506.71	363.61	396.44	383.67
Large	810.00	842.40	783.33	887.40	841.27
All	181.51	191.71	208.14	234.47	214.95

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	11.31	0.00

Source: Author’s calculation

6.2.6 Own Cultivated Land of a Farm

Ownership of the farm has influence on the decision of producing crops. Owner farmers can take production decision independently whereas tenant or owner cum tenant farms cannot take decision independently. Usually, higher the own cultivated area, higher is the contribution to agriculture. Optimal size of the cultivated land helps to increase productivity of the farms. As most of the farmers are subsistence in nature, size of own cultivated land is an important factor to them in managing their subsistence pressure. Table 6.6 displays average size of own cultivated land of farms

Table 6.6: Own Cultivated Land of a Farm in the Study Area (decimal)

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	20.74	26.00	14.38	23.90	22.99
Small	125.18	156.10	108.23	165.77	141.09
Medium	218.44	527.71	272.88	398.50	313.21
Large	638.00	767.00	305.00	672.80	626.00
All	119.32	164.61	183.56	195.51	163.94

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	44.27	0.00

Source: Author's calculation

in the study region. Average size of own cultivated land of the farmers in the study area is 163.94 decimal whereas, average size of the own cultivated land of a large farms is 626 decimal. It is 313.21 decimal for medium farms, 141.09 decimal for small farms and 22.99 decimal for a marginal farm in the study area. Similarly, average size of own cultivated land in Thakurgaon district is 195.51decimal which is the highest size of own cultivated land across the study districts followed by 183.56 decimal in Kurigram, 164.61 decimal in Naogaon and 129.32 decimal in Rajshahi district. Therefore, it is evident from the F value that different districts have significant effects to the size of own cultivated land of the farms ($F_{3, 327}$ = 29.37, P = 0.00).

6.2.7 Number of Plots of a Farm

The more is the number of plots of a farm, the higher is the degree of crop diversification (Benin et al, 2004). There remain ample opportunities to produce different types of crops especially high value crops if there are more numbers of plots of a farm. Table 6.7 gives a picture of average number of plots of a farm in the study area. Average number of plots of a farm is 6.84 in the study area.

Table 6.7: Number of Plots of a Farm

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	5.42	6.00	3.63	4.20	5.14
Small	6.90	6.20	5.88	5.77	6.25
Medium	10.06	10.29	9.48	7.61	9.25
Large	18.50	14.00	10.67	9.60	12.47
All	7.27	6.81	5.53	5.83	6.84

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	10.82	0.00
Size of Farm	3, 327	52.04	0.00

Source: Author's calculation

In disaggregated analysis, it is found that average number of plots of a large farm is 12.47 followed by 9.25 plots for medium farms, 6.25 for small farms and 5.14 for marginal farm in the study area. Similarly, at district level analysis, average number of plots of a farm in Rajshahi district is 7.27 plots which are the highest in number of plots in the study districts. It is 6.81in Naogaon, 5.83 in Thakurgaon and 5.53 in Kurigram as found from the study. Thus, it is clear from the F value of ANOVA that size of farms have highly significant effects on the number of plots in the study area ($F_{3, 327}$ = 52.04, P = 0.00). Similarly, district variability also have significant effect to the numbers of plots of the farms ($F_{3, 327}$ = 10.82, P = 0.00).

6.2.8 Extension Contacts of a Farm

Extension contact provides opportunity to the farmers to receive cutting-edge knowledge regarding agricultural activities and by this way, farmers can enhance their agricultural knowledge, skills and ability to handle the farm properly. Table 6.8 presents number of extension contacts by the farmers in the sample area. Average number of extension contacts of a farm in the study area is 2.68 times during the survey year whereas extension contacts by a large farm is 5.47 times, which is the highest among all size of farms followed by medium farms 3.72 times, small farms 2.23 times and marginal farms 2.15 times a cropping year.

Table 6.8: Number of Extension Contacts in a Cropping Year

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	1.68	2.95	.00	2.23	2.15
Small	1.53	2.82	1.65	2.67	2.23
Medium	4.11	4.29	3.52	3.50	3.72
Large	8.50	5.80	3.67	5.00	5.47
All	2.24	3.12	2.43	2.83	2.68

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	6.74	0.00
Size of Farm	3, 327	31.43	0.00

Source: Author's calculation

Similarly, when analysis is done at district level, it is found that average extension contacts of a farmer in Naogaon district is 3.12 times which is the highest extension contact in the study district and it is 2.83 times in Thakurgaon, 2.43 times in Kurigram and 2.24 times in Rajshahi district. ANOVA results presented in the lower part of the table verify that there are highly significant differences in the number of extension contact among different size of farms ($F_{3,\ 327}$ = 31.43, p = 0.00). Similarly, there are also significant differences in the average number of extension contacts of the farmers in different districts ($F_{3,\ 327}$ = 6.74, p = 0.00).

6.2.9 Number of Crops Produced by a Farm in a Cropping Year

There are several crops produced in northern Bangladesh apart from rice. In a cropping year, farms can produce more than one crop. Which crops are to be produced and how much actually depends on soil quality and subsistence pressure of the farms. Generally, the farms with high subsistence pressure produce food crops more to ensure food security of their family. Conversely, farms with less family pressure produce more number of HVCs for making profit and cash. Table 6.10 presents a picture about number of crops produced by a farm in the study area. On an average, a farm produces 4.57 crops in the study area. In detail analysis, it is found that a large farm produces 6.00 crops in a cropping year which are the highest in numbers while it is 4.7 crops for medium farms, 4.18 for small farms and 4.03 crops for marginal farms in the study area.

At district level analysis, the highest number of crops produced by the farmers of Rajshahi and the number of crops are 6.31 followed by Thakurgaon 4.55 crops, Naogaon 3.99 crops and Kurigram 3.10 crops in a cropping year. The lower panel of the table clearly exhibits that there are highly significant differences in average number of crops produced by different sizes of farms ($F_{3,\ 327}$ = 8.08, p = 0.00). Similarly, there are also significant differences in average number of crops produced by the farmers of different districts ($F_{3,\ 327}$ = 21.53, p = 0.00).

Table 6.9: Numbers of crops produced by farms in a Cropping Year

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	5.52	4.08	2.13	3.37	4.03
Small	6.25	3.32	2.77	4.90	4.18
Medium	7.50	4.86	3.52	4.44	4.70
Large	9.00	3.40	4.00	8.60	6.00
All	6.31	3.99	3.13	4.55	4.57

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	21.53	0.00
Size of Farm	3, 327	8.08	0.00

Source: Author's calculation

6.2.10 Annual Income from Crops

Annual income from crops is an important indicator of agricultural activities and it determines the status of the farmers in the community. Table 6.10 points up regarding annual crop income of a farm in the study area. During survey year, average crop income of a farm in the study area is Tk.90,181.00 whereas crop income of a large farm is Tk.2,31,133.00. It is Tk.1,38,052.00 for medium farms, Tk.77,808.00 for small farms and Tk.52,953.00 for marginal farms in the study area. Similarly, at district level analysis, it is found that average annual crop income of a farm is Tk.1,00,619.00 in Thakurgaon district of the study area. It is Tk.86,325.00 in Rajshahi, Tk.80,624.00 in Kurigram and Tk.73,616.00 in Naogaon district. ANOVA test proves that different size of farms have a highly significant effect on annual crop income in the study area ($F_{3, 327}$ = 90.09, P = 0.00). Similarly, difference of districts also have significant effect on annual crop income of a farm ($F_{3, 327}$ = 10.6, P = 0.00).

If we analyze the income from total agriculture, we find that average annual agricultural income of a farm is Tk.1,08,602.00 whereas average annual agriculture income of a large farm is Tk.3,18,067.00 which is the highest and annual agriculture income of a marginal farm is Tk.62,038.00 which is the lowest among all sizes of farms in the study area. Highest average annual agriculture income of a farm is Tk.1,61,741.00 in Thakurgaon district the lowest average annual agriculture income of a farm is Tk.1,00,414.00 which is found in Naogaon district Appendix C.

Table 6.10: Annual Income from Crops (Tk.)

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	58,710	51,676	42,125	51,467	52,953
Small	86,100	61,120	75,192	96,833	77,808
Medium	122,307	152,857	140,152	144,189	138,052
Large	195,000	250,000	173,333	261,400	231,133
All	86,325	73,616	806,243	100,619	90,181

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	7.96	0.00
Size of Farm	3, 327	183.32	0.00

Source: Author's calculation

6.2.11 Annual Income from Non-Agricultural Sources

Nowadays, most of the farmers do not depend on agriculture entirely. Most of the farmers manage their livelihood from different sources of income. Thus, non-agriculture income along with agricultural income of a farm, provide better livelihood for the family. Table 6.11 depicts average annual non-agricultural income of a farm in the study area. Annual non-agricultural income of a farm in the study area is Tk.63,431.00 on an average whereas annual non-agriculture income of a large farm is Tk.1,12,000.00 and that of a small farm is Tk.53,075.00 in the study area. In Thakurgaon district, average annual non-agricultural income of a farm is Tk.65,819.00 which is seen as the highest annual non-agricultural income of a farm whereas the lowest average annual non-agricultural income Tk.50,627.00 is found in Rajshahi. Based on the ANOVA, it is clear that difference in size of the farms have a highly significant impact on average annual non-agricultural income of the farm household of the study area ($F_{3, 327}$ = 7.06, P = 0.00). However, difference in district do not have any difference in annual non-agriculture income of the farms ($F_{3, 327}$ = 1.29 P = 0.28).

Table 6.11: Annual Income from Non-Agriculture (Tk.)

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	52,581	63,054	55,000	67,733	60,708
Small	40,050	58,000	54,654	60,867	53,075
Medium	64,722	37,857	51,758	63,056	73,592
Large	105,000	126,000	103,333	94,000	112,000
All	50,627	63,414	57,271	65,819	634,31

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	1.29	0.28
Size of Farm	3, 327	7.06	0.00

Source: Author’s calculation

6.2.12 Annual Gross Income of a Farm

Gross income of a farm influences living standard of the household. Generally, the higher is the gross income, the higher is the living standard of the household. It also influences the decision of crop choice. Generally, farmers with higher gross income produce HVC in their farm and vice-versa. Table 6.12 gives a picture of annual gross income of farm households in the study area. Annual gross income of a farm household in the study area is Tk.1,72,033.00 on an average. However, a large farm in the study area earns Tk.4,30,067.00 annually and a marginal farm earns Tk.1,22,745.00 in the study area. In Thakurgaon district, average gross income of a farm household is Tk.1,87,934.00 which is the highest annual income whereas the lowest annual income (Tk.151646) of a farm household has been found in Naogaon district. Based on the ANOVA, it is clear that difference in farm size has a highly significant effect on annual gross income of a farm in the study area ($F_{3, 327}$ = 112.5, P = 0.00). Conversely, variation of district do not have significant effect on the gross income of the farms ($F_{3, 327}$ = 1.06, P = 0.37).

Table 6.12: Gross Income of a Farm Household (Tk./Yearly)

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	117,613	123,514	111,000	130,233	122,745
Small	138,175	133,460	142,396	178,450	145,588
Medium	216,863	216,429	217,879	225,611	236,704
Large	417,000	421,000	391,667	455,400	430,067
All	152,863	151,646	156,932	187,934	172,033

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	1.06	0.37
Size of Farm	3, 327	112.5	0.00

Source: Author's calculation

6.2.13 Livestock Asset of a Farm in the Study Area

Livestock asset of a farm is a supplementary source of income. Majority of the farms rear cattle and poultry to get nutrition as well as to add extra earning to their main income. It also gives income security to the farmers. Table 6.13 depicts the scenario livestock assets own by the households of the study area. Average livestock value of a farm household is Tk.54,827 in the study area. When looking at farm size wise, it is found that the average livestock value of a large farm is Tk.80,780. It is Tk.54,557 for medium farms, Tk.56,543 for small farms and Tk.48,983 for marginal farms in the study area. Similarly, livestock value of a farm in Naogaon district is Tk.69,766 which is the highest across the study districts. Livestock asset values are Tk.62,949 for Thakurgaon, Tk.50,911 for Kurigram and Tk.34,178 for Rajshahi district. The F test revealed that difference in farm size has significant effect on livestock asset owned by farm households in the study area ($F_{3, 327}$ = 11.83, P = 0.00). Similarly, difference of districts has also highly significant effect on the livestock asset of the farms ($F_{3, 327}$ = 2.33, P = 0.07).

Table 6.13: Value of Livestock Asset of the Sample Farm (Tk.)

Farm Size	District				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Marginal	35,926	53,624	56,513	54,743	48,983
Small	33,428	77,989	36,512	68,982	56,543
Medium	34,300	81,286	56,726	60,444	54,557
Large	21,000	90,860	96,800	85,000	80,780
All	34,178	69,766	50,911	62,949	54,827

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	2.33	0.07
Size of Farm	3, 327	11.83	0.00

Source: Author's calculation

6.2.14 Credit Access and Training Exposure of the Farmers in the Study Area

In the study area most of the farmers are poor. Therefore they need credit to finance input cost and family expenditure during cultivation period. Table 6.14 presents credit access by the farmers in the study area by size of farms. It is evident from the table that only 36% of the farms took credit during the survey period whereas among the credit receivers, 32% are marginal farms, 40% are small farms, 34% are medium farms and 35% are large farms who received credit during the reference period.

Table 6.14: Credit Access by the Farmers in the Study Area by Size of Farms (%)

Types of farm	Yes	No
Marginal	32	68
Small	40	60
Medium	34	36
Large	35	65
Total	36	64

Source: Author's calculation

Table 6.15 shows credit access by the farmers in the study area by types of farms. It is clear from the table that among the credit receivers, 23% of the specialized and 40% of diversified farms received credit during the survey year.

Table 6.15: Credit Access by Farmers in the Study Area by Types of Farms (%)

Types of farm	Yes	No
Specialized	23	77
Diversified	40	60
All	36	66

Source: Author's calculation

It is found from the analysis that education level of most of the farmers is very low and they are not familiar with the modern technology. As a result, they cannot use modern technology properly and therefore, remain reluctant to use these technologies. Table 6.16 demonstrates training exposure of the farmers in the study area by types of farms. It is clear from the table that during the survey period 48% specialized farmers and 31% diversified farmers in the study areas took training.

Table 6.16: Training Exposure of the Farmers in the Study Area by Type of Farms (%)

Types of farm	Yes	No
Specialized	48	52
Diversified	31	59
All	35	65

Source: Author's calculation

6.2.15 Distribution of Farms by Using Modern Technology

Increased productivity of agriculture has been achieved mainly by modernizing of agriculture. Modernization consists largely of using improved seeds, modern farm machinery like power tiller/tractor, harvester, thresher, weeder etc., chemical fertilizer, pesticides and modern irrigation. Table 6.17demonstrates the usage of modern technology in agricultural activities by the farms. It is found that 94.75% farms used power tiller/ tractor for land preparation and the highest number of power tiller/ tractor users have been found in Rajshahi district (97.8%). It is also evident from the table that 100% farms use chemical fertilizer and 45.19% farms use organic manure with chemical fertilizer. The highest numbers of organic manure users are found in Thakurgaon district and the lowest numbers of users are found in Rajshahi. It is also found that during the survey period, 12.54% farms own tractor/ power tiller whereas 24.27% own STW, 5.27% own thresher, 14% own weeder and 72.59% own spraying machine for use in their farms (Appendix C).

Table 6.17: Distribution of Farms by Using Modern Technology (%)

Machinery	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Power tiller / tractor	97.8	94.9	94.3	91.6	94.75
DTW	97.8	19.2	8.6	66.3	49.27
STW	73.6	97.0	94.3	94.0	89.50
Thresher	67.0	29.3	40.0	53.0	47.23
Weeder	87.9	35.4	50.0	9.6	46.06
Pesticide spraying machine	98.9	93.9	94.3	95.2	95.63
Chemical fertilizer	100.0	100.0	100.0	100.0	100.00
Organic manure	23.1	60.6	48.6	48.2	45.19

Source: Author's calculation

6.3 Practices of Crop Diversification among the Sample Farms

There are different methods to measure the level of crop diversification. Level of crop diversification can be measured by number of crops grown in a farm. If a farm grows a single crop in a cropping pattern, the farm is treated as specialized farm whereas a farm grows more than one crop is treated as diversified farm. Crop acreage is another way to measure crop diversification. Higher is the acreage of a single crop, the lower is the level of diversification of the farm. Apart from these, different indices of crop diversification are also used for this purpose.

6.3.1 Rice and Non-Rice Producing Farms in the Sample Districts

Whether farms are specialized or diversified can be measured by the crops produced in the farm. Generally, farms producing only rice are treated as specialized farms whereas non-rice producing farms are treated as diversified. Table 6.18 shows that there are 24% farms in the sample area which produce only rice whereas 75% farms produce both rice and non-rice crops in a cropping year. Analysis at disaggregate level shows that the highest numbers of single rice producing farms are found in

Kurigram district where 43% farms grow only rice followed by 34% in Naogaon, 18% in Thakurgaon and 2% farms in Rajshahi district. Conversely 95% farms in Rajshahi grow rice and non-rice crops followed by 81% in Thakurgaon, 66% in Naogaon and 57% in Kurigram. Thus, the Table indicates that Rajshahi district has the highest diversified farms among the sample districts.

Table 6.18: Rice and Non-Rice Growers in Sample Districts

Districts	Only rice growers (%)	Only non-rice growers (%)	Both rice and non-rice crops (%)
Rajshahi	2	3	95
Naogaon	34	0	66
Kurigram	43	0	57
Thakurgaon	18	1	81
All	24	1	75

Source: Author's calculation

6.3.2 Number of Crops Grown by the Sample Farms

Numbers of crops in a cropping pattern is an indicator of diversification. If the numbers of crops in a cropping pattern of a farm are more than one, the farm is considered as diversified farm. Table 6.19 presents numbers of crops grown in the sample villages. Among the sample farms, on an average, a farm grows 4.57 crops with maximum 17 crops in a cropping year.

Table 6.19: Average Number of Crops Cultivated by Farmers

Villages	Average	Maximum
Gholharia	6.70	17
Mallikpur	5.91	12
Fazilpur	5.37	10
Alidewana	3.13	6
Chhinaihat	3.70	7
Bajemujrai	2.91	4
Hatpara	6.02	14
Chapor	2.98	5
All	4.57	17

Source: Author's calculation

The farms of Gholharia villages of Rajshahi district have grown the highest number of crops whereas farms of Bajemujrai of Kurigram have grows the lowest number of crops. Farms of Gholharia have grown 6.70 crops followed by Hatpara (6.02), Mallikpur (5.91) and Fazilpur (5.37). In a cropping year, maximum number of crops (17) grown is in Gholharia of Rajshahi followed by Hatpara (14), Mallikpur (12) and Fazilpur (10). It is evident from table that among the sample farms, farms in Rajshahi district are more diversified than that of other districts in the sample.

6.3.3 Crop Acreage in the Sample Area

Crop acreage is also an indicator to measure intensity of crop diversification. If crop acreage is equally distributed, intensity of crop diversification will be maximized. In contrast, the higher the share of a single crop, the lower the intensity of crop diversification is. It is found from Table 6.20 that 67% of gross crop area is devoted to rice farming. Again, among the sample districts the highest rice crop acreage is found in Naogaon district and the lowest is in Rajshahi district. 82% of gross crop area was devoted to rice in Naogaon, 70% in Kurigram, 66% in Thakurgaon and only 31% in Rajshahi district. Therefore, from this count also it is clear that farms in Rajshahi are more diversified than that of other districts in the sample.

Appendix C exhibits the crop acreage in the sample village. It is found from the table that among the sample villages, the highest rice crop area is found in Alidewana of Naogaon and the lowest is in Gholharia of Rajshahi district. 85% of gross crop area is devoted to rice farming in Alidewana followed by Chapor 79%, Fazilpur 76%, and Bajemujrai 70%. Again, among the sample districts the highest rice crop area is found in Kurigram and the lowest is in Rajshahi district.

Table 6.20: Crop Acreage in the Study Area by Sample Districts (%)

District	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Rice	31	82	70	66	67
Wheat	8	2	2	13	5
Maize	6	0	2	13	3
Pulses	3	2	0	0	11
Oilseeds	0	3	2	6	4
Cash crop	10	2	2	3	4
Spices	10	2	1	1	3
Fruits	1	0	0	5	0
Vegetables	32	8	20	7	14

Source: Field Survey, 2013

Appendix C shows the crop acreage of the farms of different sizes. It is found from the table that among the sample farms, rice acreage of large farms is the highest whereas rice acreage of small farms is the lowest. Large farms grow rice in 69% of gross crop area followed by medium farm 67%, marginal farm 65% and small farms 57%. Therefore, it is clear that small farms are more diversified than that of others in the sample.

6.3.4 Level of Crop Diversification of the Sample Farms

Owing to different Agro-Ecological Zones (AEZ), different crops are grown in different areas. In addition, various factors influence farmers in taking decision of which crops to be produced and how much area of land is to be allocated for those crops. For these reasons, value of crop diversification index differs for different areas. Table 6.21demonstrates the intensity of crop diversity using three different indices of richness, evenness and concentration. All the indices clearly indicate that cropping pattern in the study area is diversified. Value of Entropy index (higher value indicates higher diversification) is 0.61 in the sample area and the highest value is found in Rajshahi district whereas lowest value in Naogaon. Similarly, value of HI (higher value indicates lower diversification) is 0.49 and the highest value is found in Naogaon districts and lowest value in Rajshahi district. Therefore, it is evident from the table that northern Bangladesh is more or less diversified region and among the sample districts level of diversification in Rajshahi is higher than that of other districts.

Table 6.21: Crop Diversification by Sample Districts

Districts	Entropy index	Herfindahl index
Rajshahi	0.75	0.23
Naogaon	0.35	0.68
Kurigram	0.42	0.54
Thakurgaon	0.64	0.48
All	0.61	0.49

Source: Author's calculation

Appendix C demonstrates the level of crop diversity using two different indices of richness, evenness and concentration. It is evident from the table that the highest value of Entropy index is found in Mallikpur in Rajshahi district whereas lowest value is 0.26 in Alidewana of Naogaon. Similarly, the highest value of HI is found Alidewana village of Naogaon district and lowest value is in Mallikpur of Rajshahi district. Therefore, it is evident from that the study region is more or less diversified region (Appendix C). From the discussion it can be conclude that among the sample districts, level of diversification in Rajshahi is higher than that of other districts.

Appendix C also presents farm size-wise intensity of crop diversity by using two different indices of richness, evenness and concentration. According the value of Entropy and Herfindahl index, marginal farms practice crop diversification more than those of others followed by small, medium and large farms.

6.4 Comparison of Diversified and Specialized Farms in the Sample Area

This section of the chapter makes a comparison between different characteristics of diversified and specialized farms. To make the comparison the study consider specialized farms those produce only a single crop in a cropping year and diversified farms produce more than one crop in a cropping year.

6.4.1 Comparison of Some Selected Characteristics of Farms

There are differences in the characteristics of the farmers of different type of farms. Some farmers are educated compared to others and some farmers have higher farming experiences than others. Therefore, this section tries to explore whether there is any significant difference in the socio-economic and demographic characteristics of diversified and specialized farms in the study area. It is found from Table 6.22 that the differences in farm size, household size, age, education and experience of the farmers, annual income from non-agriculture and livestock asset of diversified and specialized farm were not statistically significant. However, statistically significant differences are found in number of plots, annual family income, annual income from agriculture, annual income from crop, land distance from road, distance from marker and irrigation intensity. There are highly significant differences in annual income, income from agriculture and crops between diversified and specialized farms in the study area. Average annual total income of a diversified farm is Tk.176,041 whereas specialized farm income is Tk.141,675. Similarly, annual crop income of a diversified and specialized farm is Tk.93,412 and Tk.65,700, respectively. In short, income of diversified farm is much higher than that of specialized farm. Furthermore, it is also evident from the table that diversified farm has less irrigation intensity, less distance of market from the farm and less distance of plot from the road.

Table 6.22: Comparison of Mean Values of the Variables between Diversified and Specialized Farms

Variables	Mean Value		t value	Sig
	Diversified	Specialized		
Farm size	219	182	1.63	0.103
Household size	5.35	5.10	1.11	0.266
Number of plots	7.08	6.07	2.30	0.022**
Age of the farmer	43.25	43.07	0.13	0.896
Education of the farmer	5.00	4.90	0.24	0.807
Annual total family income	176,041	141,675	2.21	0.027**
Annual income from agriculture	112,470	79,300	3.35	0.001***
Annual income from non-farm source	63,571	65,375	-0.75	0.514
Distance of road from farm	1.30	1.50	-3.22	0.002***
Distance of market from farm	3.39	4.49	-4.63	0.000***
Extension contact	2.79	2.32	1.82	0.070*
Irrigation intensity	0.84	0.88	-3.75	0.000***

Source: Author's calculation

6.4.2 Association between Farm Size and Diversification

Objectives of farming are different among the farmers of different size of farms. Generally, it is assumed that farmers of small and marginal farms produce crops in order to ensure family food security from their agricultural activities whereas farmers of large and medium farms want to maximize profit from agriculture. Table 6.23 presents association between types and sizes of farms. It is clear from the table that 75.5% farmer of marginal farms practice crop diversification. Similarly, 74.7% of small farms and 79.1% of medium and large farms are diversified. From the χ^2 results it is evident that there is no significant relationship between types and sizes of farms. That means whether farm is marginal or small or medium and large these do not bear any effect on diversification at all.

Table 6.23: Association between Farm Size and Diversification

Size of Farms		Types of Farms		Total
		Specialized	Diversified	
Marginal	Count	26	80	106
	% within farm size	24.5	75.5	100.0
Small	Count	37	109	146
	% within farm size	25.3	74.7	100.0
Medium & Large	Count	19	72	91
	% within farm size	20.9	79.1	100.0
Total	Count	82	261	343
	% of Total	23.9	76.1	100.0

Chi-Square(χ^2) Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	0.646	2	0.724
Likelihood Ratio	0.658	2	0.719

Source: Author's calculation

6.4.3 Association between Regions and Diversification

There are 30 Agro Ecological Zones in Bangladesh and different AEZ is special to produce different crops. Therefore, researcher has tried to find out the regional effects on crop diversification.

Table 6.24: Association between Regions and Diversification

Division		Types of Farms		Total
		Specialized	Diversified	
Rajshahi	Count	37	153	190
	% within Division	19.5	80.5	100
Rangpur	Count	45	108	153
	% within Division	29.4	70.6	100
Total	Count	82	261	343
	% of Total	23.9	76.1	100

Chi-Square(χ^2) Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.601	1	0.032
Likelihood Ratio	4.580	1	0.032

Source: Author's calculation

Table 6.24 demonstrates association between regions and types of farm. It is clear from the table that during field survey 80.5% farm in Rajshahi division and 70.6% in

Rangpur division are diversified. From the lower part of the table, it is found that value of Pearson Chi-Square (χ^2) is 4.60 and value of likelihood ratio is 4.58. From the results, it is evident that there is highly significant relationship between regions and crop diversification of the farms. That means there is regional effect on crop diversification.

6.5 Conclusion

Most of the socio-economic and demographic characteristics of farm and farmers in the study area are found different in terms of districts and size of farms. Most of the farmers in the study area are of moderate aged and poorly educated. There is significant difference in the mean ages of the farmers of different size of farms and of different districts. However, no significant differences have found in their education level. Average farm size in the study area is small and three fourths of sample farms are diversified. In the sample area, more than two thirds of gross crop area devoted to rice and it is far less than that of national rice acreage in Bangladesh. The study area is a mediocre diversified area in Bangladesh. Calculated value of several crop diversification indices also substantiates the same.

The study found that defragmentation of land, total annual income, and income from agriculture of diversified farm is higher and irrigation intensity, distance of farm from road and distance of market from farm is lower than that of specialized farm. Mean difference of these variables of diversified and specialized farms is highly significant.

CHAPTER SEVEN

ANALYSIS OF DETERMINANTS OF CROP DIVERSIFICATION

7.1 Introduction

There are several factors that affect the level of crop diversification in the study area. In this chapter, these factors are identified and the effect of each factor on the level of crop diversification is analyzed in the context of the study area. These factors are identified using the estimated coefficients of the Tobit regression model. Moreover, the discussion covers the factors affecting decision of crop choice followed by the discussion of the reasons for growing those choice crops by the farms. The reasons for growing rice and not growing non-rice crops in the study area are also highlighted.

This chapter is presented into five sections. Section 7.2 discusses some motivational factors of growing choice crops which includes reasons for choice crops, reasons for growing rice and problems with growing non-rice crops. Determinants of crop diversification are discussed in Section 7.3 that discusses estimated result of Tobit model. Section 7.4 analyzes the regression results of the Tobit model by districts and by size of farms. Findings from Tobit Regression are presented in Section 7.5. Finally, this chapter ends with making conclusion in Section 7.6.

7.2 Motivation and Choice of Crops by Farmers

Farmers in the study area produce different types of crops like paddy, wheat, maize, vegetables, pulses, oil seeds, spices, etc. However, all farmers do not produce same crops, meaning that their choice of producing crops is different. It is evident that there are some factors which affect their decision of choosing crops they produced. Farmers grow crops for providing food for their families and they also wish to maximize their profit from crop production. In the study, the reasons for growing choice crops by the farms have been analyzed in two ways. Firstly, farmers were asked that in which consideration they have taken decision grow a specific crop. Secondly, influence of socio-economic and demographic situations of the farmers, infrastructural condition of the area, use of technology, etc. are analyzed as factors of crop diversification.

From the literature, it is found that several forces influence the nature and pace of crop diversification from producing rice to high value corps. Earlier studies found that the process of diversification out of rice production is triggered by rapid technological change in agricultural production, improved rural infrastructure, and diversification in food demand patterns (Pingali & Rosegrant, 1995). These are broadly classified as demand and supply side forces. The demand side forces, assumed to influence crop diversification, include per capita income and urbanization, whereas, the supply side forces include: 1) infrastructure, that is, market structure and road connectivity 2) technology 3) relative profitability 4) risk with different crops 5) resource endowments such as irrigation and labor 6) socio-economic variables like pressure on land and literacy, etc. (Joshi *et al*, 2004).

In addition, farmers' decision as to which crops to grow is based on their own perception of potential and constraints associated with the crops, public policies concerning irrigation, technology and input-output price. Rahman and Talukder (2001) noted that there is a number of factors like agronomic suitability, financial and economic returns, technological changes, market infrastructures and the macro level price and trade policies, etc. which influence farmers' decision on which crops to grow. Similarly, Kumari *et al* (2010) opined that farmers' choice of particular crops to grow is influenced by the pull factor and push factor. Pull factors of growing choice crops is profitability while push factor is reducing risk of water scarcity and price shock or respond to diminishing returns in factor use.

In the study area, respondents were asked as to which things they consider before taking the decision of growing choice crops. They responded with multiple answers and spontaneously noted that they first think of family food security before taking decision of growing crops. They also consider market demand of the crops, profitability, input cost, immediate previous year crops' price, etc. Few of them added suggestions of agricultural extension officers, neighbors' suggestion and family tradition with the aforementioned attributes. Demonstration effect, crops cultivated by neighboring farms also influence the farmers to choose certain crops to grow. Table

7.1 and Figure 7.1 present the reasons for growing choice crops. In aggregated analysis, it is apparent from the table that 98.5% farms in the study area considered family food security before growing of particular crops. Similarly, 90.10% farms considered market demand of the crops, 87.80% farms thought about potential profit associated with the crops, 69.40% considered input cost and 59.50% cared for immediate earlier year's crop price.

Table 7.1: Reasons for Choice of Crops by Farm Size (%)

Reasons	Farm Size				All
	Marginal	Small	Medium	Large	
Market demand	92.5	89.0	88.2	93.3	90.1
Neighbors' suggestion	13.2	14.4	9.2	6.7	12.5
Neighbors' crops	17.9	23.3	28.9	13.3	22.4
Previous year's crop price	59.4	56.8	61.8	73.3	59.5
Input cost	75.5	70.5	56.6	80.0	69.4
Profitability	84.0	87.7	90.8	100.0	87.8
Food security of the family	100.0	99.3	97.4	86.7	98.5
Advice of extension officer	9.4	7.5	14.5	20.0	10.2
Family tradition	-	5.5	13.2	6.7	5.5

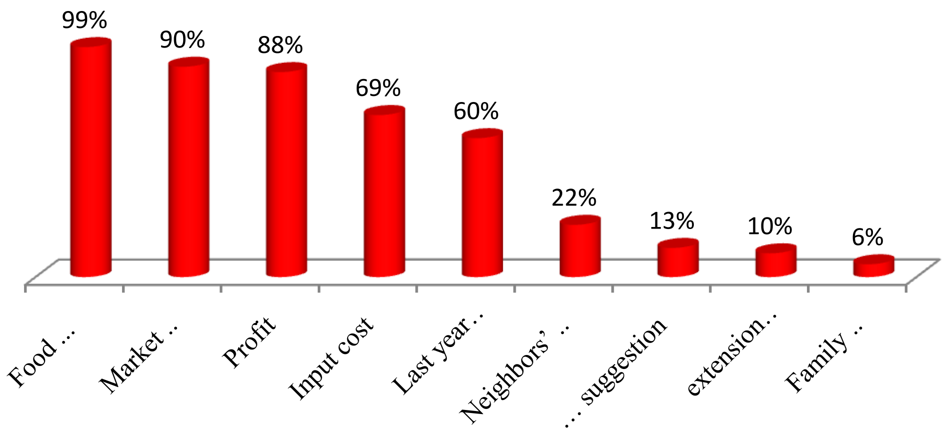
Source: Field Survey, 2013

In disaggregated analysis, it is found from the study that all of the marginal farms in the study area considered family food security as the reason for growing any crop. 92.5% farm holders valued market demand of the crops, 84% considered the potential of profit, 75.5% were responsive to input cost and 59.4% were influenced by preceding year's crop price. Similarly, in the case of small farms, 99.3% considered family food security before taking the decision to grow particular crop, 89% considers market demand of the crops, 87.7% considered the potential of profit, 70.5% had bearing about input cost and 56.8% cared about preceding year crop price before growing any crops in the study area. For the medium farms, 97.4% were influenced by family food needs, 90.8% by profitability, 88.2% by market demand and 61.8% by past year's crop price. In the case of large farms, 100% are motivated by profit earning before taking the decision of growing any crop, followed by 93.3% market demand, 86.7% think profit, 80.% consider input cost and 73.3% consider preceding year crop price.

Thus, it is found that marginal and small farms grow crops from the concern of food security of the family. On the other hand, large farms were found to consider profitability as the key motivational factor before growing crops. This happens, because food security is the prime concern to the rural poor people in Bangladesh. Those who lead their lives through agriculture need cash to manage their other basic needs and hence after a threshold level of family food security, farmers consider market demand of the crops, profitability, immediate preceding year's crop price and input cost before growing choice crops.

Similarly, it is found (Appendix D) that in Rajshahi district, 98.9% sample farms consider family food security in choosing specific crop to grow. Apart from food security, 90.10% think about profitability, 84.6% think about market demand and 60.4% consider input cost before growing any crop. In Naogaon, Kurigram and Thakurgaon districts also family food security occupies the highest consideration of the farmers which is shown by the responses of 98%, 98.6% and 98.8% farms in the three districts, respectively. Similarly, 92.9%, 87.1% and 95.2% farms cared for market demand of the crop in the three districts- Naogaon, Kurigram and Thakurgaon, respectively. Input cost and price of the crop in the previous year counted less attention of the farmers in the study area choosing crop for cultivation. The reasons for choosing crops for cultivation by the farms are also presented in the Figure 7.1.

Figure 7.1: Reasons for Choice of Crops by Farms Size (%)



Source: Field Survey, 2013

It is reported by many studies that rice is a water, pesticide and fertilizer consuming crop (Islam & Rashid, 2011). Continuous rice cultivation creates many environmental problems and reduces net margin of the farms. In spite of having such negative issues involved with rice cultivation, farmers keep producing it continuously. To explore the reasons, farmers were asked as to why they produced rice. Their opinions are reported in Table 7.2.

Table 7.2: Reasons for Growing Rice by Farm Size (%)

Reason	Farm size				All
	Marginal	Small	Medium	Large	
Food security for the family	100	99	99	98	99
Encouragement of extension worker	28	32	32	33	31
No alternative crops except rice	63	67	61	53	64
Price of rice is stable	18	16	16	13	17
Preservation of rice is easier	93	89	86	93	90
Less labor is required	75	69	76	73	72
Easier selling of rice	40	39	45	33	40
Input subsidy	12	13	7	7	11
Land is suitable for rice production	13	10	13	13	12

Source : Field Survey, 2013

It is evident from the table that among the multiple opinions, 99% farmers reported that food security concern forced them to produce rice. They think, rice production at least make sure three meals in a day for their family. 90% farmers quoted that preservation of rice was easier than that of other non-rice crops. 72% respondents opined that rice production required less human labor and 64% respondents confirmed that there was no alternative way except rice production. In addition, encouragement of extension worker; government procurement policy, government's subsidy in growing rice are also the reasons behind growing rice.

It is reported in various studies that producing non-rice crop especially potato, vegetables, spices etc. is at least as profitable as or more than that of rice. These high value crops not only offer financial gain but also create opportunity for employment generation as HVC requires excessive labor. These types of crops also help in increasing nutrient of soil. However, despite their higher returns, these crops are not cultivated widely due to high price risks associated with the marketing of such crops and their perishable nature. Farmers were asked as to why they did not interested in producing non-rice crops even provided with higher net returns of non-rice crops. Their responses are tabulated in Table 7.3. The table shows that 94% farmers reported that vegetables get rotten quickly and 91% respondents quoted that non-rice crops needed excessive labor. Again 60% farmers opined that it requires more capital to produce non-rice crops and they need to face problem at the time of selling. In addition, 49% farmers told that prices of non-rice crops are instable.

Table 7.3: Problems with Non-Rice Crops (%)

Reason	Districts				All
	Rajshahi	Naogaon	Kurigram	Thakurgaon	
Instable price	55	46	50	46	49
Problem at the time of selling	36	69	59	76	60
Vegetable gets rotten	97	91	96	94	94
Need excessive labor	95	91	93	86	91
Government imports a lot	13	-	47	10	16
Need more capital	20	3	1	1	7

Source : Field Survey, 2013

7.3 Determinants of Crop Diversification: Results of the Tobit Regression

There are many factors that are attributed to crop diversification. These factors are used in the study to measure the magnitude of their influence on crop diversification. As was mentioned before the Tobit regression analysis has been carried out in this regard. In the regression analysis, the dependent variables are crop diversification indices, where each index is a scalar constructed from the gross cropped area shares allocated to different crops. Here, two different types of indices have been used as the dependent variable - Entropy index, which has been adopted from the ecological indices of spatial diversity in species and Herfindahl Index, adopted from the marketing industry index of market concentration. Each index represents a unique diversity concept. Evenness, which combines both richness and relative abundance concept, is measured by Entropy index, and the concentration of crop type is measured by Herfindahl index.

In the estimation, out of the total 343 observations, 82 observations were censored on the left of 0.2 for the Entropy index and were censored on the right of 0.80 for the Herfindahl index, implying that these are the specialized farms. In Bangladesh, perfect and pure commercialization is absent amongst the farms. Every farm produces at least a few number of non-rice crops along with rice in a cropping year. Thus, a bench mark is set at 0.2 for Entropy Index and 0.8 for Herfindahl Index for this study. The Tobit coefficients, unlike the traditional multiple regression coefficients, cannot be interpreted directly. They only interpret the direction of effects of the explanatory variables on the dependent variable. The magnitude of the effects of the explanatory variable can in fact be explained by the estimated marginal effects calculated from the estimated coefficients (Mesfin *et al*, 2011). In Tobit regression, marginal effect includes both the influence of the explanatory variable on the probability of crop diversification as well as its intensity. More explicitly, the marginal effect takes into consideration that a change in an explanatory variable affects simultaneously the number of sample farmers diversifying their crops and the extent of diversification.

Table 7.4: Regression Results of the Tobit Model (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index[a]	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	.879***	7.28	-.078	-0.54
FS	-.027***	-3.55	.031***	3.51
HS	.015***	2.74	-.015**	-2.30
NP	.008***	2.62	-.009**	-2.45
AGE	-.001	-0.66	.001	0.45
EDU	.001	0.24	-.001	-0.15
TFI	.001***	3.05	-.001***	-3.18
NFI	-.001***	-3.08	.001***	3.27
DFR	-.120***	-6.03	.135***	5.70
DMF	-.016***	-3.49	.021***	3.97
EXC	-.004	-0.81	.002	0.33
IRR	-.429***	-3.77	.556***	4.09
CF	-.019	-1.10	.018	0.87
TE	-.111***	-5.94	.123***	5.55
MODEL DIAGNOSTIC				
Log likelihood	68.20		14.10	
χ^2 (13, 0.99)	137.36***		132.55***	
Censored obs.	82		82	
Number of observations	343		343	

Source: Estimated by researcher

***significant at 1 percent level ($p<0.01$); **significant at 5 percent level ($p<0.05$); *significant at 10 percent level ($p<0.10$).

[a]The Herfindahl index is an index of crop concentration. Therefore, a negative sign of the coefficient on the explanatory variable implies positive relationship with diversity and vice-versa.

Table 7.5 shows the marginal effects of the estimated Tobit model. It is seen in the table that the likelihood of crop diversity decreases significantly by an increase in the farm size. For example, a one acre increase in the farm size decreases the probability of crop diversity by 0.017 with respect to the Entropy Index and by 0.022 with respect to the Herfindahl Index. These marginal effects are derived from the estimated coefficients of the variable 'Farm Size' -0.027 for Herfindahl index and 0.031 for Entropy index. The results are significant at 1% level for both the indices. This result is consistent with the study of Mesfin *et al* (2011) but contradicts with the result of Abay *et al* (2009), Ashfaq *et al* (2008), Benin *et al* (2004) and Rehima *et al* (2013).

Table 7.5: Marginal Effects of the Tobit Model (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.017***	-3.55	.022***	3.51
HS	.010***	2.73	-.010***	-2.29
NP	.005***	2.62	-.006***	-2.45
TFI	.0003***	3.05	-.001***	-3.17
NFI	-.0004***	-3.08	.001***	3.27
DFR	-.077***	-6.00	.094***	5.68
DMF	-.010***	-3.50	.015***	3.98
IRR	-.274***	-3.77	.387***	4.08
TE[a]	-.067***	-6.22	.082***	5.78

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

***significant at 1 percent level (p<0.01), **significant at 5 percent level (p<0.05) and *significant at 10 percent level (p<0.10).

The reason behind the negative relationship between farm size and crop diversity may be that when the farm size reaches at a threshold level, farmers cannot manage the farm properly. After that saturated level, the bigger the farm size is, the lower the attention is paid to the farm. In addition, many of the large farms are operated by tenant farmers but they cannot operate independently as the owner of the land interferes in the decision of crop choice. Tenant farmers tend to specialize towards modern rice monoculture (Rahman, 2008). This is because, farming system in Bangladesh is largely based on arrangements related to rice production. In the most common tenure arrangement practiced in Bangladesh, the landlord receives one-third of the crop output share in case of rice (Rahman, 2008). Therefore, an increase in the farm size induces farmers to conventional rice farming.

Household size is positively related to promoting crop diversity. Increase in household size by one member increases the probability of crop diversification by 0.01 for both the indices as are shown by the marginal effects. Both the results are significant at 1% level. This result is compatible with the study of Mesfin *et al* (2011) and Rehima *et al* (2013). The implication is that, as household size increases, farmers are able to manage diversified portfolio of crops which increases the opportunity of high value non-rice and cash crops.

The positive sign of the coefficient of the 'number of plots' is highly significant with the crop diversification indices. Its marginal effects indicate that an addition of one plot led to increase the likelihood of crop diversification of a farm by 0.005 for Entropy index and by 0.006 for Herfindahl index. Both are significant at 1% level. This implies that farmers who operate on a higher number of plots may find it conducive for different crops which led to allocate multiple crops across different types of land. More fragmented farms with higher number of plots of the farm have higher number of crops that are likely to be grown more evenly since the farm plots are approximately of equal size. These results are in line with the findings of Abay *et al* (2009), Benin *et al* (2004), Gauchan *et al* (2005), Gebremedhin and Jaleta (2010), Mesfin *et al* (2011), Nagarajan *et al* (2007) and Rehima *et al* (2013) who found that land fragmentation is the most important determinant of crop diversification.

Similarly, an increase in the age of farmer promotes rice monoculture that is higher age decreases the likelihood of crop diversification. The education level of farmer is positively related with the probability of crop diversification. This result is supported by Rahman (2008). The ability of access to information increases with the increase in education. Therefore, educated farmers choose to adopt a diversified cropping system in order to take advantage of all the potential benefits arising from making such a choice, e.g., high returns from a particular crop, low cost of all resources, and distribution of scarce family labor evenly over a cropping year. The importance of knowledge and ability to absorb new information through formal education increase crop diversification (Ashfaq *et al*, 2008; Gauchan *et al*, 2005; Ibrahim *et al*, 2009; Rahman, 2008; Rehima *et al*, 2013).

The table shows that the coefficient of annual family income is positive and highly significant. It indicates that an increase in the yearly family income increases the probability of crop diversification but the degree of influence is very much low. Alternatively non-farm income of a family is negatively related to the probability of crop diversification. It is apparent from the table that distance of farm from road negatively influenced the probability of crop diversification. The level of significance is 1% and its magnitudes are 0.077 for Entropy index and 0.094 for Herfindahl index. Similarly, distance of market from the farm decreases the probability of crop diversity by 0.01 for Entropy index and by 0.015 for Herfindahl index at 1% level of significance. Distance of farm from road and distance of market are the proxy of infrastructure of the area. Better road connectivity and developed infrastructure promote crop diversification positively is apparent from the estimated result of the Tobit model.

Irrigation intensity is inversely related to the probability of crop diversification as is found from the table. It is found that an increase in the intensity by 1% (index value equal to 0.01) decreases the probability of crop diversification by 0.274 for Entropy index and 0.387 for Herfindahl index. In both the cases, the coefficients of irrigation intensity are highly significant at 1% critical level. This result corroborates with the finding of Benin *et al* (2004), Hossain *et al* (1990), Mahmud *et al* (1994) and Morris *et al* (1996). However, Mesfin *et al* (2011) and Vandeveer *et al* (1989) have found positive relation with irrigation and crop diversification.

Credit facility of the farmer is negatively related to the probability of crop diversification. Similarly, if training exposure moves from zero to one the extent of the likelihood of crop diversification decreases by 0.067 for Entropy index and by 0.082 for Herfindahl index. Most of the trainings received by the farmers are related to rice production and there is hardly any training conducted by the authority on the advantage and promotion of crop diversification. The results of the Tobit regression also shown that there is a negative and insignificant relationship between numbers of extension contacts per year and crop diversification although the scale of intensity is very low.

7.4 Disaggregated Analysis of Determinants of Crop Diversification

This section analyzes the regression results of the Tobit model by districts and by size of farms. The study has been conducted among the farm households of four districts of northern Bangladesh. These households are associated with in different size of farms. Therefore, disaggregated analysis has been performed to identify the key factors of crop diversification in the contexts of different districts and different size of farms. It is found that level of influence of the determinants of crop diversification varies across regions and size of farm.

Table 7.6: Regression Results of the Tobit Model for Rajshahi (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.316***	5.42	-.382	-1.38
FS	-.061***	-2.78	.064***	2.52
HS	.013	1.05	-.021	-1.43
NP	.019***	3.01	-.021***	-2.83
AGE	-.002	-1.16	.002	0.95
EDU	-.002	-0.36	.001	0.19
TFI	-.0001	-0.21	-.0001	0.32
NFI	.0003	0.59	-.0003	-0.56
DFR	-.048	-0.78	.064	0.90
DMF	-.006	-0.55	.005	0.37
EXC	-.008	-1.18	.009	1.11
IRR	-.876***	-3.81	.925***	3.51
CF	.018	0.51	-.021	-0.52
TE	.033	0.46	-.062	-0.76
MODEL DIAGNOSTIC				
Log likelihood	25.95		14.51	
χ^2 (13, 0.99)	37.85***		33.14***	
Censored obs.	14		14	
Number of observations	91		91	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

Table 7.6 shows the Tobit regression result for Rajshahi district. It is found from the table that farm size and irrigation intensity influence probability of crop diversification negatively whereas number of plots in a farm influences crop diversification positively. All the three variables are highly significant (p<0.01).

Table 7.7: Marginal Effects of the Tobit Model for Rajshahi (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.053***	-2.76	.056**	2.51
NP	.017***	3.00	-.018***	-2.83
IRR	-.765***	-3.79	.813***	3.50

Source: Estimated by researcher

***significant at 1 % level (p<0.01)

Table 7.7 presents the marginal effect of the estimated Tobit model (only significant variables are considered). It is found from the table that one acre increase of land in the farm size decreases probability of crop diversification by 0.053 for Entropy index and by 0.056 for Herfindahl index. Similarly, a 1% increase in irrigation intensity decreases the probability of crop diversification by 0.765 for Entropy index and 0.813 for Herfindahl index. However, increase of number of plots by one in the farm increases the probability of crop diversification by .017 for Entropy index and 0.018 for Herfindahl index.

Table 7.8 presents regression results of the Tobit model for Naogaon district. The table shows that farm size, age of the farmers, non-farm income, distance of market from farm, irrigation intensity and credit facility decrease the probability of crop diversification. On the other hand, total farm income increases the likelihood of crop diversification.

Table 7.8: Regression Results of the Tobit Model for Naogaon(details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	.922***	5.91	-.084	-0.40
FS	-.025*	-1.87	.038**	2.10
HS	-.006	-0.65	.006	0.48
NP	-.004	-0.63	.005	0.61
AGE	-.003**	-2.05	.003	1.49
EDU	-.005	-1.62	.005	1.11
TFI	.001**	2.24	-.001**	-2.45
NFI	-.001**	-2.02	.001**	2.10
DFR	-.011	-0.49	.014	0.49
DMF	-.020***	-4.08	.032***	4.74
EXC	-.004	-0.38	.001	0.05
IRR	-.408***	-2.81	.478**	2.43
CF	-.057**	-2.03	.064*	1.69
TE	.035	1.42	-.047	-1.40
MODEL DIAGNOSTIC				
Log likelihood	45.90		21.76	
χ^2 (13, 0.99)	50.53***		51.97***	
Censored obs.	31		31	
Number of observations	99		99	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

Table 7.9 shows that one acre of land added to the farm cause to decreases the probability of crop diversification by .014 and .024 for Entropy and Herfindahl indices, respectively. Both results are statistically significant. A one year increase in age of the farmers decreases the probability of crop diversification by 0.002 for Entropy index. It is significant at 5% level. Similarly, one thousand taka increase in total annual farm income increases probability of crop diversification by 0.001 for both the Entropy and Herfindahl indices whereas non-farm income decreases the same for both Entropy and Herfindahl indices. These are also significant at 5% level. Likewise, a one kilometre increase in the distance of market from the farm decreases the probability of crop diversification by 0.011 for Entropy index and 0.020 for Herfindahl index. In the same fashion, the probability of crop diversification decreases by 0.226 at 1% level of significance for Entropy index and 0.303 for Herfindahl index at 1% level of significance by a one percent increase in irrigation intensity. Again, increase of credit access from zero to one decreases the probability of crop diversification by 0.028 at 5% level of significance for Entropy index and 0.038 at 10% level of significance for Herfindahl index.

Table 7.9: Marginal Effects of the Tobit Model for Naogaon (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.014*	-1.87	.024**	2.10
AGE	-.002**	-2.03	.002	1.48
TFI	.001**	2.23	-.001**	-2.44
NFI	-.001**	-2.01	.001**	2.10
DMF	-.011***	-4.08	.020***	4.70
IRR	-.226***	-2.79	.303**	2.42
CF[a]	-.028**	-2.24	.038*	1.83

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

[***]significant at 1 percent level (p<0.01), [**]significant at 5 percent level (p<0.05) and [*]significant at 10 percent level (p<0.10).

Table 7.10 presents the regression results of the Tobit model for Kurigram district. The table shows that an increase in the farm size and irrigation intensity causes to decrease crop diversity while increase in the number of plots increases the likelihood of crop diversification. Table 7.11 shows the marginal effects of the Tobit model for the sample farms in Kurigram district. It is found from the table that one acre increase of land in the farm decreases the probability of crop diversification by 0.039 for Entropy index and by 0.057 for Herfindahl index. Both results are statistically significant at 1% significance level. Similarly, an in increase in the intensity of irrigation by one percent changes the probability of crop diversification by 0.44 for Entropy index and by 0.622 for Herfindahl index.

Table 7.10: Regression Results of Tobit the Model for Kurigram (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.11***	5.03	-.375	-1.23
FS	-.068***	-2.72	.089***	2.75
HS	.001	0.10	.004	0.25
NP	.013*	1.84	-.018*	-1.92
AGE	-.001	-0.42	.001	.32
EDU	-.002	-0.53	.002	.34
TFI	.0003	0.90	-.001	-1.33
NFI	-.001	-1.15	.001	1.49
DFR	-.031	-1.17	.042	1.16
DMF	-.009	-0.42	.011	0.36
EXC	.005	0.53	-.007	-0.55
IRR	-.758***	-4.02	.962**	3.67
CF	-.032	-1.14	.039	1.00
TE	-.026	-1.02	.036	1.00
MODEL DIAGNOSTIC				
Log likelihood	34.84		16.49	
χ^2 (13, 0.99)	34.81***		33.20***	
Censored obs.	20		20	
Number of observations	71		71	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

On the other hand, a one unit increase in the number of plots of a farm increases the likelihood of crop diversification by 0.007, at 10% level of significance, for the Entropy index and by 0.012, significance at 5% level, for the Herfindahl index.

Table 7.11: Marginal Effects of the Tobit Model for Kurigram (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.039***	-2.89	.057***	2.89
NP	.007*	1.88	-.012**	-1.95
IRR	-.440***	-3.96	.622***	3.64

Source: Estimated by researcher

***significant at 1 percent level (p<0.01), **significant at 5 percent level (p<0.05) and *significant at 10 percent level (p<0.10).

Table 7.12 presents the regression results of the Tobit model for Thakurgaon district. It is found from the table that positive changes in 'farm size', 'non-farm income', 'distance of market from farm' and 'irrigation intensity' decrease the probability of crop diversification, whereas number of plot increases the probability of crop diversification.

Table 7.12: Regression Results of the Tobit Model for Thakurgaon(details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	.897***	4.41	-.067	-0.28
FS	-.045***	-3.62	.043***	3.00
HS	-.005	-0.47	.007	0.60
NP	.026***	3.35	-.025***	-2.83
AGE	.002	0.18	-.001	-0.45
EDU	-.007	-1.41	.007	1.26
TFI	.0001	0.46	-.0001	-0.56
NFI	-.001**	-2.47	.001**	2.25
DFR	-.076	-1.40	.116*	1.85
DMF	-.066***	-4.54	.078***	4.66
EXC	.016	1.29	-.016	-1.14
IRR	-.335**	-1.93	.403**	2.03
CF	-.010	-0.42	.001	0.05
TE	-.007	-0.18	.001	0.01
MODEL DIAGNOSTIC				
Log likelihood	52.05		39.39	
χ^2 (13, 0.99)	82.51***		74.53***	
Censored obs.	17		17	
Number of observations	83		83	

Source: Estimated by researcher

***significant at 1 % (p<0.01); **significant at 5 % (p<0.05); *significant at 10 % (p<0.10).

Table 7.13 presents the marginal effects of the Tobit model for Thakurgaon district. It is found that increase of farm size by one acre decreases the probability of crop diversification by 0.04 for Entropy index and 0.038 for Herfindahl index. Both results are statistically highly significant (p<.01). Similarly, increase in total non-farm income by one thousand taka would decrease the probability of crop diversification by 0.001 with respect to both the Entropy and Herfindahl indices. Likewise, a one kilometre increases in the distance of the farm from road decreases the probability of crop diversification by 0.101, significant at 10% level, for the Herfindahl index and distance of market from the farm decreases the likelihood of crop diversification by 0.052 for Entropy index and 0.068 for Herfindahl index, both are significant at 1% level. In the same fashion, increase in irrigation intensity by 1% reduces the probability of crop diversification by 0.262 for the Entropy index and 0.353 for the Herfindahl index. However, one plot increase in the farm increases the probability of crop diversification by 0.020 for the Entropy index and 0.022 for the Herfindahl index.

Table 7.13: Marginal Effects of the Tobit Model for Thakurgaon (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.040***	-3.57	.038***	2.99
NP	.020***	3.31	-.022***	-2.82
NFI	-.001**	-2.46	.001**	2.25
DFR	-.060	-1.40	.101*	1.85
DMF	-.052***	-4.46	.068***	4.62
IRR	-.262*	-1.93	.353**	2.03

Source: Estimated by researcher

***significant at 1 percent level (p<0.01), **significant at 5 percent level (p<0.05) and *significant at 10 percent level (p<0.10).

Similar to the disaggregated analysis of the of the Tobit regression model across the various districts, the analysis is performed across farm size as well. Table 7.14 presents the Tobit regression results for the marginal farms. It is found from the table that probability of crop diversification is influenced by farm size, total farm income, non-farm income, distance of farm from road, distance of market from the farm, irrigation intensity and training exposure. These determinants affect the probability of crop diversification negatively except for total farm income. Table 7.15 presents the marginal effects from the Tobit regression for marginal farms. Marginal effects of the Tobit regression describe the magnitude of crop diversification. It is found from the table that a one acre increase in the farm size decreases the probability of crop diversification by 0.527 for Entropy index and 0.64 for Herfindahl index. Both results are statistically significant at 5% level (p<.05). Similarly, increase in non-farm income by one thousand taka increases the probability of crop diversification by 0.001, at 10% level of significance, for Entropy index and by 0.002, at 5% level of significance, for Herfindahl index. Likewise, increase in the distance of farm from road by one kilometre decreases the likelihood of crop diversification by 0.080, significant at 1% level, for Entropy index and by 0.092 for Herfindahl index and distance of market from the farm decreases the probability of crop diversification by 0.015 for Herfindahl index.

Table 7.14: Regression Results of the Tobit Model for Marginal Farms
(details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.31***	4.04	-.583	-1.56
FS	-.527**	-2.06	.640**	2.16
HS	.019	1.52	-.022	-1.51
NP	.006	0.83	-.007	-0.85
AGE	-.002	-1.12	.003	1.37
EDU	.007	1.28	-.009	-1.33
TFI	.002**	2.25	-.002**	-2.30
NFI	-.002*	-1.81	.002**	2.00
DFR	-.124***	-3.00	.131***	2.75
DMF	-.015	-1.62	.021*	1.91
EXC	-.010	-0.93	.005	0.44
IRR	-.794***	-2.75	.970**	2.90
CF	-.038	-1.04	.041	0.99
TE	-.082**	-1.98	.092*	1.93
MODEL DIAGNOSTIC				
Log likelihood	18.66		5.28	
χ^2 (13, 0.99)	51.05***		53.58***	
Censored obs.	25		25	
Number of observations	106		106	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

In the same fashion, likelihood of crop diversification decreases by 0.512 for Entropy index and by 0.685 for Herfindahl index. Both the results are significant at1% level. Again, movement of training exposure from zero to one decreases the probability of crop diversification by 0 .049 for Entropy index and 0.061 for Herfindahl index.

Table 7.15: Marginal Effects of the Tobit Model for Marginal Farms
(details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.340**	-2.05	.452**	2.15
TFI	.001**	2.25	-.002**	-2.30
NFI	-.001*	-1.81	.002**	2.00
DFR	-.080***	-2.98	.092***	2.74
DMF	-.010	-1.62	.015*	1.92
IRR	-.512***	-2.73	.685***	2.88
TE[a]	-.049**	-2.14	.061**	2.07

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

***significant at1% level (p<0.01), **significant at 5% level (p<0.05) and *significant at 10 % level (p<0.10).

Table 7.16 presents the Tobit regression analysis for the small farms. It is found from the table that the likelihood of crop diversification decreases by farm size, non-farm income, distance of farm from road, distance of market from farm, irrigation intensity and training exposure whereas it increases with the increase in number of plots.

Table 7.16: Regression Results of the Tobit Model for Small Farms (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	.901***	4.83	.005	0.02
FS	-.068***	-2.74	.076**	2.55
HS	.007	0.93	-.006	-0.60
NP	.008*	1.65	-.007	-1.23
AGE	.0001	0.11	-.001	-0.60
EDU	-.001	-0.22	.0003	0.06
TFI	.0003	1.19	-.0004	-1.55
NFI	-.001	-1.53	.001*	1.80
DFR	-.126***	-4.28	.150***	4.25
DMF	-.018***	-3.12	.025***	3.58
EXC	-.007	-1.00	.005	0.55
IRR	-.318**	-1.95	.326*	1.66
CF	.007	0.29	-.008	-0.26
TE	-.102***	-4.04	.111***	3.63
MODEL DIAGNOSTIC				
Log likelihood	41.02		17.32	
χ^2 (13, 0.99)	71.6***		68.80***	
Censored obs.	36		36	
Number of observations	146		146	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

Table 7.17 presents the marginal effects of the Tobit regression for small farms. It is found from the table that increase in farm size by one acre decreases the probability of crop diversification by 0.054 for Entropy index and 0.055 for Herfindahl index. Similarly, increase in total non-farm income by one thousand taka increases the likelihood of crop diversification by 0.001 for Herfindahl index. Likewise, increase in the distance of the farm by one kilometre from road decreases the likelihood of crop diversification by 0.083 and by 0.108, respectively, for Entropy index and Herfindahl index. Distance of market also has negative effect on crop diversification as shown by the marginal effect values 0.012 and by 0.018, respectively, for Entropy index and Herfindahl index. In the same fashion, likelihood of crop diversification decreases by extent of 0.210 for Entropy index and 0.235 for Herfindahl index. Training exposure also cause to decreases the probability of crop diversification by the small farms and increase in number of plots in the farm renders positive impact on crop diversification.

Table 7.17: Marginal Effects of the Tobit Model for Small Farms (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.045***	-2.74	.055**	2.54
NP	.005*	1.64	-.005	-1.23
NFI	-.0003	-1.53	.001*	1.80
DFR	-.083***	-4.28	.108***	4.25
DMF	-.012***	-3.13	.018***	3.58
IRR	-.210**	-1.95	.235*	1.65
TE[a]	-.064***	-4.23	.076***	3.78

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

[***]significant at 1 percent level (p<0.01), [**]significant at 5 percent level (p<0.05) and [*]significant at 10 percent level (p<0.10).

Table 7.18 presents the Tobit regression analysis for the medium and large farms. It is found from the table that the likelihood of crop diversification decreases by farm size, non-farm income, distance of the farm from road, distance of market from the farm, irrigation intensity and training exposure whereas, it increases by household size and number of plots.

Table 7.19 presents the marginal effect Tobit regression for medium and large farms. It is found from the table that increase in the farm size by one acre of land decreases the probability of crop diversification by the extent of 0.014 which is significant at 10% level, for Entropy index. Increase in household size by one member increases the likelihood of crop diversification by the extent 0.014 and by 0.016, for Entropy index and Herfindahl index, respectively.

Similarly, one additional plot in the farm cause to increase the likelihood of crop diversification by 0.006 point and 0.008 point for Entropy index and Herfindahl index, respectively, at 10% level of significance. However, increase in total non-farm income of taka one thousand decreases the probability of crop diversification by an amount 0.0004 and 0.001 for Entropy index and Herfindahl index, respectively, at 10% level of significance.

Table 7.18: Regression Results of the Tobit Model for Medium and Large Farm (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	.838***	3.57	-.162	-0.56
FS	-.021*	-1.84	.022	1.55
HS	.021**	2.34	-.022**	-1.96
NP	.009*	1.72	-.011*	-1.64
AGE	-.001	-0.70	.002	0.68
EDU	-.005	-0.94	.008	1.10
TFI	.0003	1.31	-.0003	-1.09
NFI	-.001*	-1.84	.001*	1.64
DFR	-.140***	-3.95	.171***	3.91
DMF	-.019*	-1.71	.025*	1.79
EXC	.007	0.89	-.007	-0.71
IRR	-.306	-1.35	.513*	1.83
CF	-.004	-0.13	.001	0.03
TE	-.118***	-3.65	.134***	3.33
MODEL DIAGNOSTIC				
Log likelihood	24.03			
χ^2 (13, 0.99)	42.42***		38.59***	
Censored obs.	21		21	
Number of observations	91		91	

Source: Estimated by researcher

***significant at 1 percent level (p<0.01); **significant at 5 percent level (p<0.05); *significant at 10 percent level (p<0.10).

Likewise, a one kilometre increase in the distance of the farm from road and distance of market from the farm decrease the likelihood of crop diversification by 0.093 and by 0.013, respectively, for Entropy index and by 0.123 and by 0.018, respectively, for Herfindahl index. These results are statistically significant at 1% level for Entropy and 5% level for Herfindahl index. Similarly, one percent increase in the irrigation intensity decreases the probability of crop diversification by an amount of 0.370, at 10% level of significance, for Herfindahl index. Like earlier cases, training exposure is found to have decreasing impact on the likelihood of crop diversification.

Table 7.19: Marginal Effects of the Tobit Model for Medium and Large Farm (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index		Dependent variable: Herfindahl Index	
	dy/dx	Z	dy/dx	Z
FS	-.014*	-1.84	.016	1.54
HS	.014**	2.31	-.016**	-1.95
NP	.006*	1.72	-.008*	-1.64
NFI	-.0004*	-1.83	.001*	1.64
DFR	-.093***	-3.92	.123***	3.88
DMF	-.013*	-1.71	.018*	1.79
IRR	-.202	-1.36	.370*	1.83
TE[a]	-.079***	-3.57	.097***	3.29

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

***significant at 1 percent level (p<0.01), **significant at 5 percent level (p<0.05) and *significant at 10 percent level (p<0.10).

Comparison of the Tobit Results across Districts

Table 7.20 presents the comparison of findings from the Tobit regression results across the sample districts. It is found from the table that farm size influences the likelihood of crop diversification in all the districts negatively, although the extent of influence varied across the districts. The coefficient of farm size is statistically highly significant for all the districts. Defragmentation of land which is proxied by number of plots affects crop diversification positively and it is highly significant at aggregate level and is also significant in all the districts except Naogaon district. The reason behind the number of plots is insignificantly related to the likelihood of crop diversification in the case of Naogaon district might be the fact that land in this district are mostly low-lying with available irrigation facility which is suitable for producing rice.

Total farm income influences the probability of crop diversification positively. At aggregate level, it is significant at 1% level of significance. However, total farm income does not influence the likelihood of crop diversification at district level except for Naogaon district. Non-farm income influences crop diversification negatively. At aggregate level, coefficient of non-farm income is significant at 1% level of significance whereas at district level, it influences the probability of crop diversification in Naogaon and Thakurgaon districts. Non-farm does not have any influence on crop diversification in Rajshahi and Kurigram district.

Distance of road from the farm, which reflects infrastructural development level in the sample, affects the likelihood of crop diversification negatively. It is found from the table that at aggregate level, coefficient of distance of road from the farm is significant at 1% critical level. However, at district level, distance of road from the farm does not have any influence on the probability of crop diversification except for the case of Thakurgaon district where it influences the probability of crop diversification negatively. Extension contact does not have any influence on the Likelihood of crop diversification either at aggregate level or disaggregated level.

Irrigation intensity influences the probability of crop diversification negatively. It is found from the table that coefficient of irrigation intensity is highly statistically significant for both the aggregate and district level. Credit facility does not influence probability of crop diversification either at aggregate level or district level, however, in Naogaon district, credit facility influences the likelihood of crop diversification negatively. Similarly, training exposure influences crop diversification negatively. It is found from the table that in aggregate level it is significant at 1% level whereas it is not significant at district level. Actually, in the sample villages very few farmers received training. This may be cause that the training exposure does not influence crop diversification significantly.

Although household size is found significant in the case of aggregate data, it turned insignificant for all the districts when disaggregated regression is performed. This might be due to reduced number of observations when disaggregation is done and household size does not vary much across districts. Coefficient of age of the farmers is significant in only Naogaon district reasons may be variation in the ages of the farmers in Naogaon. Education of the farmers does not have any significant influence on the probability of crop diversification. It is found from the table that education of the farmers is neither significant at aggregate level nor at disaggregated level.

Table 7.20: Comparison of Determinants of Crop Diversification by Districts (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index					Dependent variable: Herfindahl Index				
	All	Rajshahi	Naogaon	Kurigram	Thakurgaon	All	Rajshahi	Naogaon	Kurigram	Thakurgaon
FS	-.017***	-.053***	-.014*	-.039***	-.040***	.022***	.056**	.024**	.057***	.038***
HS	.010***	.012	-.004	.001	-.004	-.010***	-.018	.004	.003	.006
NP	.005***	.017***	-.002	.007*	.020***	-.006***	-.018***	.003	-.012**	-.022***
AGE	-.0004	-.002	-.002**	-.0003	.0002	.0004	.002	.002	.0004	-.001
EDU	.0004	-.002	-.003	-.001	-.010	-.0004	.001	.003	.001	.006
TFI	.0003***	-.0001	.001**	.0002	.0001	-.001***	.0001	-.001**	-.0004	-.0001
NFI	-.0004***	.0002	-.001**	-.0003	-.001**	.001***	-.0002	.001**	.001	.001**
DFR	-.077***	-.042	-.006	-.018	-.060	.094***	.056	.009	.027	.101*
DMF	-.010***	-.005	-.011***	-.005	-.052***	.015***	.004	.020***	.007	.068***
EXC	-.002	-.0070	-.002	.001	.0121	.001	.008	.0004	-.005	-.014
IRR	-.274***	-.765***	-.226***	-.440***	-.262*	.387***	.813***	.303**	.622***	.353**
CF[a]	-.012	.015	-.028**	-.018	-.008	.013	-.018	.038*	.025	.001
TE[a]	-.067***	.029	.020	-.015	-.005	.082***	-.056	-.030	.023	.0004

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

***significant at 1 percent level (p<0.01), **significant at 5 percent level (p<0.05) and *significant at 10 percent level (p<0.10).

Comparison of the Tobit Results across Different Size of Farms

Table 7.21 provides the comparison of Tobit regression results with respect to different size of farms. It is found from the table that most of the determinants have identical impact on crop diversification across different size of farms while the others have mix impact when different size of farms are taken into consideration. Non-farm income, distance of road from the farm, distance of market from the farm, irrigation intensity and training exposure have identical impacts on the likelihood of crop diversification in case of both aggregate data and district level data. However, mixed influence is found for the variables like household size, number of plots and total farm income. It is found that household size influences only medium and large farms, number of plots influences small, medium and large farm and total farm income influences marginal farm significantly. However, age and education of the farmers, extension contact and credit facility do not have any influence on the probability of crop diversification significantly.

Table 7.21: Comparison of Determinants of Crop Diversification by Farms Size (details in Appendix E)

Explanatory Variables	Dependent variable: Entropy Index				Dependent variable: Herfindahl Index			
	All	Marginal	Small	Medium and Large	All	Marginal	Small	Medium and Large
FS	-.017***	-.0340**	-.045***	-.014*	.022***	.452**	.055**	.016
HS	.010***	.012	.005	.014**	-.010***	-.015	-.004	-.016**
NP	.005***	.004	.005*	.0060*	-.006***	-.005	-.005	-.008*
AGE	-.0004	-.002	.0001	-.001	.0004	.002	-.001	.001
EDU	.0004	.005	-.001	-.004	-.0004	-.006	.0002	.006
TFI	.0003***	.001**	.0001	.0002	-.001***	-.002**	-.0003	-.0003
NFI	-.0004***	-.001*	-.0003	-.0004*	.001***	.002**	.001*	.001*
DFR	-.077***	-.080***	-.083***	-.093***	.094***	.092***	.108***	.123***
DMF	-.010***	-.010	-.012***	-.013*	.015***	.0145*	.018***	.018*
EXC	-.002	-.006	-.005	.004	.001	.004	.004	-.005
IRR	-.274***	-.512***	-.210**	-.202	.387***	.685***	.235*	.370*
CF[a]	-.012	-.024	.005	-.003	.013	.029	-.006	.001
TE[a]	-.067***	-.049**	-.064***	-.079***	.082***	.061**	.076***	.097***

Source: Estimated by researcher

[a]dy/dx is for discrete change of dummy variable from 0 to 1.

[***]significant at 1 percent level (p<0.01), [**]significant at 5 percent level (p<0.05) and [*]significant at 10 percent level (p<0.10).

7.5 Findings from the Tobit Regression

Results of this study clearly revealed that a host of farm and household related factors influence farmers' decision regarding crop diversification. When a farm diversifies with variety of crops, the farmer uses the opportunity to select crops that complement each other, given the nature of seasonality in demand for various inputs. It is found from the study that farm size is one of the important factors of crop diversification. It influence crop diversification negatively. It is also found that small farm size influence crop diversification more that than of other farm size. However, household size influences crop diversification positively that is the more the active family members in the farm, the higher the magnitude of crop diversification is. Similarly defragmented farm are more diversified.

Also, developed rural infrastructure significantly promotes adoption of a diversified cropping system. Infrastructure development in turn may also open up opportunities for management, marketing, storage and resource supplies, which complements crop diversification. For example, Ahmed and Hossain (1990) concluded that farms in villages with relatively developed infrastructure use relatively greater amounts of fertilizer and market a higher percentage of their agricultural products in Bangladesh. In this situation people practices various crop option on commercial basis. Evenson (1986) noted a strong relationship between roads and increased number of agricultural crops in the Philippines.

The cropping system in Bangladesh is largely influenced by access to water. It is found from the study that belying one expectation, irrigation facility results in decrease in crop diversification. It is found from the regression result that availability of irrigation is the single most important determinant of specialization towards modern rice monoculture. It is negatively related to crop diversification. This result corroborates with the finding of Hossain *et al* (1990), who noted that access to irrigation is a major determinant of the modern rice technology adoption in Bangladesh. In other words, crop diversification is significantly higher in areas with no irrigation facility, which corroborates with the conclusions of Mahmud *et al* (1994) and Morris *et al* (1996). In fact, wheat provides highest returns in non-irrigated zones and in areas that are unsuitable for *boro* rice (Morris *et al*, 1996). Benin *et al* (2004) reported similar effect but its influence was not significantly different from zero. It is found from previous studies that the existing irrigation systems constrain diversification because of the rigid designs of infrastructure and inflexible water delivery systems (Pingali, 2004) and this inflexibility prevents appropriate allocation of water to non-rice crops, constraining farmers to rice monoculture. But a conflicting picture was found from the study of Mesfin *et al* (2011) and Vandeveer *et al* (1989) who found positive relation with irrigation and crop diversification. Mesfin *et al* (2011) speak out that farmers, who have access to irrigation, have opportunity to grow more crops and it is also found in his study that farmers having access to irrigation grow vegetables on their farms.

The cropping pattern can be broadly classified into cropping under rain-fed and irrigated conditions, which again varies according to the degree of seasonal flooding (Rahman, 2008). Our finding might take support of the findings by Mahmud *et al* (1994). As mentioned earlier, although many non-cereals are more profitable than producing modern rice, their expansion has stagnated due to the incompatibility of the existing modern irrigation systems. In general, the proportion of non-cereal crops is lower under irrigated conditions as compared to rain-fed conditions (Mahmud *et al*, 1994).

7.6 Conclusion

There are several motivational factors of growing crops. Among them family food security, market demand, input cost and profitability of the crops are important. It is found from the study that marginal farms think about their family food security whereas large farms think profitability before growing choice crops. The study found that due to perishable nature of vegetables and requirement of excessive labor restrain them from producing non-rice crops.

Many factors influence the likelihood of crop diversification. Tobit regression estimated that farm size, defragmentation of the land, annual income of the family, non-farm income, infrastructure, irrigation intensity and training exposure influence the level of crop diversification significantly in aggregated level. However, in disaggregated analysis a little bit different picture is found from the estimation result. In general, defragmentation of land, annual family income and development infrastructure influence the probability of crop diversification positively whereas irrigation intensity and farm size influence it negatively.

CHAPTER EIGHT

ECONOMIC VIABILITY OF CROP DIVERSIFICATION

8.1 Introduction

In Bangladesh, it is observed that many non-rice crops offer higher returns to the farmers compared to rice. However, farmers, instead of maximizing financial or economic returns from their land, are more interested in producing rice. It happens as the farmers always remain on stress about the family's food security. This does not mean that farmers do not consider economic returns before growing crops. Actually, they consider economic returns after having reached to a threshold limit of producing staple food. Because of the high degree of rice based food habits, lower yield of some non-rice crops and favorable agro-climatic conditions, farmers grow rice although many non-rice crops offer comparatively high returns to them. As Bangladesh is almost to achieve self sufficiency in rice production, non-rice crops containing more protein and other food values like vegetables, pulses, spices are of increasing demand to the consumers and therefore, production of these crops is becoming economically more viable than that of rice. For example, the results of financial and economic analyses have shown that a number of crops such as potato, vegetables and onion have financial and economic returns that are significantly higher than those of paddy. On the other hand, wheat, sugarcane, and oilseeds have very low economic returns although private returns from sugarcane are quite high (Mahmud *et al*, 1994).

The present chapter is an attempt to analyze the economic viability of growing crops in the study area. The study has used net return and BCR analyses in this respect. Basic organization of this chapter is as follows: Section 8.2 discusses average yield of different crops in the study area. Section 8.3 discusses production cost of growing different crops. Economic viability of crop production is discussed in Section 8.4. Finally the chapter ends with a conclusion in Section 8.5.

8.2 Average Yield of Different Crops in the Study Area

Yield, output price and production cost of different crops are important indicators in economic return analysis of the crops. It is observed that in Bangladesh, there is higher yield gap between expected yield and actual yield of the crops which is attributable to climatic variations, and some socio-economic and demographic characteristics of the farms and farmers. Table 8.1 presents the scenario of average yield of different crops produced under different size of farms. In aggregate analysis average yield per *bigha aus* rice is 570 kg, *aman* 640 kg, *boro* 962 kg, wheat 573 kg, maize 1,067 kg, *musur* 195 kg, mustard 192 kg, jute 327 kg, chili 1,738 kg, potato 3,292 kg and yield of different vegetables per bigha ranges between 2,500 kg to 4,000 kg. Yield of different crops per bigha in Bangladesh is still considered very low in comparison to that in many other countries of the world.

Table 8.1: Average Yield of Different Crops by Farm Size (Kg/ *bigha*)

Crops	Marginal	Small	Medium	Large	All
Aus	567	569	575	588	570
Aman	634	632	639	654	640
Boro	952	957	965	987	962
Wheat	587	570	567	545	573
Maize	1,066	1,084	1,036	1,050	1,067
Musur	180	240	170	200	195
Mustard	194	187	199	186	192
Jute	322	330	331	300	327
Chili	1,800	1,687	1,788	1,700	1,738
Onion	1,551	1,516	1,526	1,400	1,520
Garlic	988	951	1,048	940	983
Potato	3,322	3,332	3,228	3,175	3,292
Brinjal	3,320	3,574	3,554	3,267	3,482
Bot. gourd	2,823	2,760	2,876	3,133	2,868
Pumpkin	2,750	2,400	2,133	-	2,454
Ash gourd	3,300	3,232	3,220	3,600	3,274
point gourd	2,262	2,346	2,220	1,860	2,272
Yard long bean	2,457	2,424	2,800	1,800	2,429
Cucumber	2,394	2,415	2,200	2,400	2,376
Bitter gourd	2,377	2,391	2,150	1,800	2,309
Tomato	3,520	4,020	4,725	3,840	4,023
Cauliflower	2,520	2,950	2,914	3,000	2,838
Cabbage	3,200	3,926	3,760	3,800	3,734

Sources: Author’ calculation

In the disaggregated analysis, it is found from the table that yield rate of majority of crops grown in marginal and small farms are a little bit higher than that of others except for rice. There is a debate in Bangladesh agriculture regarding productivity of different size of farms. Some studies hold that small farms are more productive than others but inverse result was also found from other studies. Reasons behind the higher yield of the small and marginal farms are use of their family labor and their highest devotion to the agricultural activities while large and medium farms use hired labor for agricultural work. Of course, family labor employs more attention than hired labor does and that is why productivity of small farms is comparatively high. Majority of the small farms are subsistence in nature and the households have to manage their lives with the earning from agriculture and accordingly they take great challenges to increase yield of different crops. Because of the smallness of the farms, it is easier to manage and to pay full attention to all the plots under the farm.

Yield of wheat in marginal farms is also higher (587kg/*bigha*) than that of others (545kg/*bigha for large farms*). In case of spices also, yield of the marginal farms is the highest and yield of pumpkin and ash gourd are shown to be the highest for the marginal farms. On the average, a small farm grows 27.14 kg of maize per *bigha* which is higher compared to that of other type of farms. Similarly, in case of pulse production, yield of small and marginal farms is higher than that of others. In case of potato, brinjal, pointed gourd, bitter gourd and cabbage production, yields of small farms are again higher than that of other farms. However, yield of mustard and jute of medium farms are the highest among all size of farms.

Contrary to others, the large farms are found to be more efficient in rice production. It is found from the study that yield of *aus* rice in large farms is 588 kg per *bigha* followed by medium farms 575 kg, small farms 569 kg and marginal farms 567 kg. In case of *aman* production, yield of large farms is 654 kg, medium farms 639 kg, small farms 632 kg and yield of marginal farms is 634 kg. Similarly, in case of *boro* production, yield of large farms is again higher than those of others. Average yield of *boro* rice in large farms is 987 kg per *bigha* followed by medium farms 965 kg, small farms 957 kg and marginal farms 552 kg. The reason might be that rice production is highly dependent on irrigation, fertilizer and pesticide use and large farmers might benefit from an economy of scale effect in producing rice with large acreage.

In Bangladesh due to variations in nature, agro-climatic conditions and soil structure, same crops do not grow across all the regions in the country. Agro-climatic conditions influence crop choice by the farms in different areas. Moreover, yield of different crops is also not same in all the areas. Putting it differently, some areas are specialized for production of some crops rendering higher yield rate of those crops while the other areas good for other crops.

Table 8.2: Average Yield of Different Crops by Districts (Kg/ *bigha*)

Crops	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Aus	540	536	--	619	570
Aman	673	655	594	640	640
Boro	943	954	942	1,003	962
Wheat	579	550	525	582	573
Maize	1,044	1,130	993	1,104	1,067
Musur	220	-	-	180	195
Mustard	193	191	191	190	192
Jute	346	314	353	271	327
Chili	1,797	1,638	1,665	1,697	1,738
Onion	1,603	1,388	-	1,457	1,520
Garlic	1,024	1,004	-	830	983
Potato	3,672	3,266	3,163	3,081	3,292
Brinjal	4,527	3,311	3,172	3,109	3,482
Bot. gourd	2,786	3,400	2,820	-	2,868
Pumpkin	2,560	2,533	2,200	-	2,454
Ash gourd	3,400	3,284	3,040	-	3,274
Point gourd	2,377	2,314	1,860	2,300	2,272
Yard long been	2,749	2,114	2,100	-	2,429
Cucumber	2,498	2,442	2,100	-	2,376
Bitter gourd	2,461	2,145	1,600	2,240	2,309
Tomato	4,695	3,275	-	3,343	4,023
Cauliflower	-	2,500	3,111	2,767	2,838
Cabbage	3,200	3,233	3,400	4,260	3,734

Sources: Author' calculation

Table 8.2 shows average yields of different crops in the sample districts in northern Bangladesh. It is clear from the table that there are variations in crops under choice and yields across the sample districts. As is found from the table, average yield of *aus*, *boro* and wheat grown in Thakurgaon is the highest among the sample districts. Average yield of *aus* in Thakurgaon is 619 kg per *bigha* followed by Rajshahi 540 kg and Naogaon 536 kg (*aus* is not cultivated in Kurigram district). Similarly, average yield of *boro* rice in Thakurgaon is 1,003 kg per *bigha* followed by Naogaon 954 kg, Rajshahi 943 kg and Kurigram 942 kg. Average yield of T. *aman* in Rajshahi is higher than that of other districts in the study area. It is 673 kg in Rajshahi, 655 kg in Naogaon, 640 kg in Thakurgaon and 594 kg in Kurigram. In Naogaon district, the average yield of maize is 1,130 kg per *bigha* followed by Thakurgaon 1,104 kg, Rajshahi 1,044 kg and Kurigram 993 kg per *bigha*. It is clear from the table that only the sample farms of Rajshahi and Thakurgaon districts were found to grow pulses and yield of pulses is higher in Rajshahi than that in Thakurgaon. Average yield of mustard is almost the same across the sample districts. The highest yield of jute is found in Kurigram, it is 353 kg per *bigha* followed by Rajshahi 346 kg, Thakurgaon 314 kg and Naogaon 271 kg. Table 8.2 also shows that yield of spices in Rajshahi districts is the highest. In Rajshahi, average yield of chili, onion and garlic is 1,797 kg, 1,606 kg and 1,024 kg per *bigha*, respectively. It is 1,638 kg, 1,388 kg and 1,004 kg respectively, in Naogaon and 1,697 kg, 1,457 kg and 830 kg, respectively in Thakurgaon district. Sample farms Kurigram district were not found to cultivate onion and garlic. In case of potato, the highest yield is 3,672 kg per *bigha* found in Rajshahi followed by 3,266 kg in Naogaon, 3,163 kg in Kurigram and 3,081 kg in Thakurgaon districts. It is apparent from the table that yield rate of major vegetables grown in Rajshahi district is higher than those of others.

The table clearly presents that Rajshahi district grows the highest number of crops amongst the sample districts. Besides, most of the non-cereal crops' yield is also higher in Rajshahi than that of other districts. The reasons behind growing the highest number of crops and obtaining higher yield in Rajshahi district is the farmers' motivation for profit, fertile soil, infrastructural facilities, available irrigation facilities, vicinity to urban centre etc. It is opined by many people that huge demand for different crop by the people of the metropolis, marketing facility in and from the city and irrigation facility provided by the BMDA are some of the reasons behind growing different crops and the comparatively high yield in Rajshahi district. One thing is also clear from the above discussion suitability of soil also influence the choice of crops by the farms. It is found during the data collection that soil of Rajshahi district is fertile and conducive for various crops to grow while the soil of Naogaon district although fertile is mostly conducive to grow rice only.

Due to variation in yields and condition of soil fertility along with climate variability, farms of different sizes and different districts obtained different level of returns for different crops. Table 8.3 presents gross returns of different crops. It is found from the table that price of per 40 kg *aus* paddy is Tk.562, *aman* paddy is Tk.656 and *boro* paddy is Tk.558. Similarly, per 40 kg *musur* at prices Tk.2,138. Again, price of per 40 kg jute is Tk.1,306, chili Tk.711, onion Tk.694 and garlic Tk.1,433. Likewise, per 40 kg potato, cucumber, tomato, cabbage prices are Tk.369, Tk.529, Tk.464 and Tk.445, respectively. Thus, a farm obtained a gross return (value of total product) is Tk.8,702 from cultivation of *aus* paddy per *bigha* land. *Aman* Tk.11,510 *boro* Tk.14,410, wheat, Tk.13,100 and maize Tk.12,888. Similarly, gross return is Tk.46, 673 from per *bigha* tomato cultivation. Cabbage Tk.41,562, cauliflower Tk.33,174, brinjal Tk.38,685, yard long bean Tk.35,037, potato Tk. 30,351, chili Tk.30,893, onion Tk.26,354, garlic Tk. 35,202, jute Tk.12,187, etc.

Table 8.3: Gross Returns from Different Crops (per *bigha*)

Crops	Yield (Kg)	Unit Price (Tk./40kg)	Main crop (Tk.)	By product	GR (Tk.)
Aus	570	562	8,002	700	8,702
Aman	640	656	10,510	1,000	11,510
Boro	962	558	13,410	1,000	14,410
Wheat	573	901	12,900	200	13,100
Maize	1,067	543	14,488	400	14,888
Musur	195	2,138	10,431	-	10,431
Mustard	192	1,792	9,604	-	9,604
Jute	327	1,306	10,687	1,500	12,187
Chili	1,738	711	30,893	-	30,893
Onion	1,520	694	26,354	-	26,354
Garlic	983	1,433	35,202	-	35,202
Potato	3,292	369	30,351	-	30,351
Brinjal	3,482	444	38,685	-	38,685
Bot. gourd	2,868	398	28,544	-	28,544
Pumpkin	2,454	364	22,309	-	22,309
Ash gourd	3,274	368	30,121	-	30,121
point gourd	2,272	533	30,276	-	30,276
Yard long been	2,376	577	35,037	-	35,037
Cucumber	2,309	529	31,420	-	31,420
Tomato	4,023	464	46,673	-	46,673
Cauliflower	2,838	468	33,174	-	33,174
Cabbage	3,734	445	41,562	-	41,562

Sources: Author’s calculation.

Thus, it is found that gross returns from vegetables, spices, jute and oilseed etc. are higher than rice, wheat, maize etc. In short, gross returns from non-rice crops are comparatively high. This is because of the higher yields and prices of different vegetables than that of rice.

8.3 Production Cost of Growing Different Crops

Not only gross returns but also input cost is also important for analyzing economic viability of any crop. Higher production cost reduces profit margin of the farms. Input cost, particularly, is a significant determinant of choice of crops. Generally, farmers are reluctant to grow those crops that incurs higher input cost and comparatively low output price. Inputs are not used equally in growing different crops. Some crops need higher amount of some inputs and some crops need lower amount. For example, *boro* needs higher degree of irrigation whereas wheat and maize need less irrigation and pulses necessitate no irrigation. Similarly, some crops require more fertilizer and pesticides compared to others.

Requirement of labor is also varied across crops which results in variation of costs across crops. Table 8.4 presents labor requirement for different crops in the study area. It is found from the table that average labor (man-day) requirement for cultivation of *aus* paddy is 12, *aman* 13, and *boro* 16. Similarly, wheat, maize and pulse require 12, 16 and 8 labors, respectively, in the whole production process of these crops. Likewise, production of vegetables, spices, jute and potato require 25, 28, 18 and 22 labors, respectively, on the average for per *bigha* of land.

Table 8.4: Labor Requirement for Different Crops (Mandays/*bigha*)

Name of Crops	Mean	Maximum	Minimum	SD
Aus	12	15	10	1.08
Aman	13	16	11	1.18
Boro	16	20	13	1.13
Wheat	12	16	10	1.08
Maize	16	19	12	1.44
Pulse	8	7	9	0.46
Vegetables	25	32	14	3.40
Spices	28	34	23	2.98
Jute	18	21	13	1.55
Potato	22	26	18	1.52

Source: Author's calculation

Table 8.5 presents wage rate of labor in the study area during the data collection period. It is found that average wage of labor was Tk.234 per day in the study area. When the districts are considered, wage rate is Tk.241 in Rajshahi district, Tk.215 in Naogaon, Tk.227 in Kurigram and Tk.256 in Thakurgaon. Thus, it can be noted that there is difference in wage of labor across the sample districts which is statistically different as shown by the F value (F3, 339 = 24.94). In Thakurgaon and Rajshahi districts there are ample opportunities of non-farm activities this may be the reason of higher wage rate of labor in these district.

Table 8.5: Wage Rate in the Study Area (Tk./day)

District	Mean	$F_{3, 339}$	
		Value	Sig
Rajshahi	241	24.94	0.00
Naogaon	215		
Kurigram	227		
Thakurgaon	256		
Total	234		

Source: Author's calculation

Production cost of a farm for different crops constitute the total cost of producing those crops which include fixed cost (land rent), labor cost, tilling cost, seed cost, fertilizer cost, pesticide cost and irrigation cost. Table 8.6 presents production cost of different crops in the study area. In aggregated analysis, it is evident from the table that production costs of potato, vegetables, spice are higher than those of other crops and production cost of other crops. It is found that total cost of potato cultivation per *bigha* is Tk.20,305. It is Tk.10,266 for jute, Tk.16,876 for spices, Tk.18,082 for vegetables, Tk.10,843 for maize and Tk.11,763 for *boro* paddy production. In disaggregated analysis, it is found from the table that in spices production the major share of total cost is labor cost. Labor cost of spices production is Tk.6,519 followed by vegetables Tk.5,922, potato Tk.5,219, jute Tk.4,098, maize Tk.3,724 and *boro* Tk.3,655. If it is analyzed in terms of percentage, it is found that share of labor cost of the total cost varies among different crops, e.g., labor cost of cereals ranges from 28% to 35% of total cost. Labor cost of wheat is 28% of the total cost whereas it is 35% for *aus* and *aman* paddy, 31% for *boro* and 34% for maize production. Share of labor cost of jute production is the highest among the crops, which is 40% of total cost. It is 39% for spices and 34% for vegetables.

Table 8.6: Production Cost of Different Crops in the Study Area (Tk./*bigha*)

Crops	TC	TFC	TVC and % of Total cost					
			Labor	Tilling	Seed	Fertilizer	Pesticide	Irrigation
Aus	7,939	1,819	2,758 (35)	847 (11)	456 (6)	1,092 (14)	492 (6)	475 (6)
Aman	8,967	2,205	3,153 (35)	930 (10)	502 (6)	1,268 (14)	476 (5)	433 (5)
Boro	11,763	2,390	3,655 (31)	1,007 (9)	736 (6)	1,865 (16)	615 (5)	1,495 (13)
Wheat	9,991	2,615	2,841 (28)	1,020 (10)	767 (8)	2,058 (21)	--	690 (7)
Maize	10,843	1,994	3,724 (34)	968 (9)	572 (5)	2,369 (22)	548 (5)	668 (6)
Pulse	5,700	1,422	1,798 (32)	638 (11)	355 (6)	1,251 (22)	236 (4)	--
Mustard	5,966	1,335	1,679 (28)	837 (14)	345 (6)	1,285 (22)	265 (4)	220 (4)
Vegetables	18,082	2,830	5,922 (33)	1,030 (6)	2,499 (14)	3,142 (17)	1,568 (9)	1,091 (6)
Spices	16,876	2,707	6,519 (39)	1,059 (6)	1,392 (8)	3,178 (19)	1,216 (7)	805 (5)
Jute	10,266	2,477	4,098 (40)	982 (10)	383 (4)	1,470 (14)	428 (4)	428 (4)
Potato	20,305	2,435	5,219 (26)	1,027 (5)	5,873 (29)	3,276 (16)	1,692 (8)	783 (4)

Source: Author's calculation
(.) indicates % of total cost

In the study area, tillage cost of mustard is 14% of the total cost and it is the highest among different crops. Tillage cost of cereals, pulses and jute differ from 9% to 11% of total cost, and it is 6% for vegetables and 5% for potato. Share of seed cost to the total cost is the highest for potato production which is 29% of total cost. Seed cost of vegetables is also comparatively high. It is 17% of total cost. Seed cost of cereals, pulses, mustard and others is almost same.

Fertilizer cost of wheat, maize, pulses and mustard are 21% to 22% of total cost and it is 14% to 16% for paddy, potato and jute. Vegetables and spices need 17% and 19% of total cost respectively as fertilizer cost. Wheat does not require any pesticide cost whereas in vegetables, pesticide cost is the highest proportion to the total cost. It is 9% of total cost. Cereal, jute and mustard need 4% to 6% of total cost as pesticide cost. *Boro* paddy needs the highest proportion of irrigation cost to the total cost and it is 13% of the total cost. Pulses necessitate no irrigation cost and other crops need 4% to 7% cost of total cost as irrigation cost.

From the discussion it is found that major share of total cost is calculated for human labor to produce most of the crops. In the case of potato production major share of total cost is incurred for purchasing of seed as potato requires higher amount of seed compared to other crops. It is also found that human labor cost of major non-cereal crops is higher than that of cereal which indicates non-cereal crops generate more employment for agriculture laborer.

8.4 Economic Viability of Crop Production

Economic viability of production of a crop is the real returns from that crop in terms excess of input cost of that crop. Farms always want to maximize their returns from a crop by increasing yield and minimizing input cost. In other words, making profit and utility maximization are the strong desire of the farmers. In order to earn respectable economic returns, production cost is an important factor and accordingly it plays a dominant role in the decision making process of the farms regarding choice of crop. Net return and benefit cost ratio (BCR) of crops are widely used to analyze comparative profitability of the crops. Crops production is considered profitable if net return is positive. Similarly, if BCR of the crops is greater than one, the crops are considered as profitable one. In this study costs and returns are calculated based on actual market price paid and received by the farmers during production and harvesting period of the crops.

8.4.1 Net Return and Benefit Cost Ratio Analysis of Different Crops in the Study Area

Table 8.7 presents cost-benefit scenario of various crops grown in the study area. The study analyzes net returns and BCR to explore economically viable cropping patterns. It is found from the table that higher gross return is generated from vegetables production such as gross return from tomato is Tk.46,673 per *bigha* followed by cabbage Tk.41,562, brinjal Tk.38,685 and garlic Tk.35,202. Similarly, it is Tk.30,893 for chili, Tk.30,351 for potato, Tk.14,410 for *boro*, Tk.10,431 for *masur* and Tk.9,604 for mustard. Comparatively high yields and prices inflate the gross returns of these crops. Thus, it is clear that majority of higher return offering crops are vegetables. It is also found that gross return from rice is comparatively very low.

However, higher gross return does not necessarily mean higher profit. It needs to analyze net return and BCR to find out the profitable ones. Net return and BCR analysis includes Total cost incurred and gross return obtained from the crops. Higher gross return and lower total cost increases net return and BCR of the crops. From the analysis highest net return is found from cabbage and it is Tk.26,453 per *bigha* followed by tomato Tk.22,167, brinjal Tk.21,192, yard long bean Tk.19,658, cauliflower Tk.18,319 and garlic Tk.17,653. When rice is considered, it is found that net return is Tk.764 for *aus*, Tk.2,582 from *aman*, and Tk.2,646 from *boro*. The highest BCR is found from turmeric. The BCR of turmeric is 2.84 followed by cabbage (2.75), yard long bean (2.28), cauliflower (2.23), pumpkin (2.22), brinjal (2.21), ash gourd (2.03), garlic (2.01), tomato (1.9) and chili (1.85). Similarly, BCR of *aus* is 1.1, jute (1.18), *boro* (1.22), *aman* (1.28), wheat (1.31), maize (1.37) and potato (1.45).

It is clear from the table that farmers earn higher returns from the production of vegetables and lower returns from the cereal crops. It is also apparent from the table that the lowest returns come from paddy. Mustard, pulses and spices provide comparatively high returns. Reasons behind higher returns from vegetables, spices and pulses production are higher yield, higher market price and comparative low input cost. However, causes of comparatively low returns from cereals are higher input cost and lower market price.

Rapid urbanization, change of taste, infrastructural development and economic growth change the food habit of the people and accordingly demand for vegetables, pulses and spices are also increasing gradually. Increasing demand of vegetables, pulses and spices pushes the price of these crops upward. Moreover, due to higher yield and facilities of quick transportation of vegetables to town area, farms receive higher returns. Although returns from pulse is comparatively low, its input cost is also lower but higher demand makes the price go up and ultimately farms get higher returns. Furthermore, theses crops are labor intensive and in most cases, farms use their family labor to produce them. This is another advantage of these crops.

Table 8.7: Net Return and BCR of Crops in the Study Area(Tk./*bigha*)

Crops	A	B	C	D	E	F
	GR	TVC	TC	GM (A-B)	NR (A-C)	BCR (A/C)
Aus	8,702	6,119	7,939	2,583	764	1.10
Aman	11,510	6,584	8,967	4,926	2,542	1.28
Boro	14,410	9,375	11,765	5,036	2,646	1.22
Wheat	13,100	7,376	9,991	5,725	3,109	1.31
Maize	14,888	8,843	10,855	6,045	4,034	1.37
Musur	10,431	4,825	6,138	5,606	4,294	1.70
Mustard	9,604	4,466	6,315	5,138	3,289	1.52
Jute	12,187	7,655	10,296	4,532	1,892	1.18
Chili	30,893	13,924	16,727	16,969	14,166	1.85
Onion	26,354	15,097	18,044	11,257	8,310	1.46
Garlic	35,202	14,875	17,549	20,327	17,653	2.01
Potato	30,351	17,871	20,863	12,480	9,487	1.45
Brinjal	38,685	14,897	17,493	23,788	21,192	2.21
Pumpkin	22,309	6,733	10,067	15,576	12,242	2.22
Ash gourd	30,121	10,725	14,827	19,396	15,294	2.03
point gourd	30,276	15,355	19,632	14,920	10,644	1.54
Yard long bean	35,037	11,340	15,379	23,697	19,658	2.28
Cucumber	31,420	14,033	18,238	17,387	13,182	1.72
Tomato	46,673	20,094	24,507	26,580	22,167	1.90
Cauliflower	33,174	12,421	14,855	20,753	18,319	2.23
Cabbage	41,562	12,757	15,110	28,806	26,453	2.75

Source: Author's calculation

It is stated earlier that net returns from cereals are lower than those of all other crops grown in the sample area. Because yield of *aus* and *aman* paddy and wheat is comparatively low and so is the market price of output, consequently net returns are low from the crops. Yield of *boro* and maize is comparatively high and their input cost is also higher with lower market price of output, as a result, returns are lower. Distorted and defective market system deprives the farmers from getting fair returns from their products. Indebtedness and lack of the storage facility compel the farmers to sell their crops especially paddy during the harvesting time. Infestation of intermediaries, government's untimely procurement of rice and the farmers' urgent need for cash eat up the major portion of the returns from the crops (Bayes, 2012).

8.4.2 Net Return and Benefit Cost Ratio Analysis of Groups of Crops

Table 8.8 presents net return and BCR of groups of crops in the study area. It is found that net returns of non-rice crops are higher than that of cereal crops. Net return of vegetables is higher which is Tk.14,320 followed by spices Tk.12,955, maize Tk.4,034, oilseed Tk.3,289 whereas net return of paddy is Tk.2,395. Similarly, BCR of vegetables is higher than that of all the groups of crop in the study area. BCR of vegetables is 1.80 followed by spices 1.76, pulses 1.58, oilseeds 1.52, maize 1.37, wheat 1.31, paddy 1.24 and jute 1.18. It is evident from the table that net return and benefit cost ratio of non-rice crops is higher than that of rice. Moreover, most of the non-rice crops need more labor, which is also income of the farms. Thus, considering all these aspects of economic return, it can be said that economic viability of crop diversification is be higher than that of rice based monoculture.

Table 8.8: Net Return and BCR by Group of Crops (Tk./*bigha*)

Crops	A	B	C	D	E	F
	GR	TVC	TC	G M (A-B)	NR (A-C)	BCR (A/C)
Paddy	12,465	7,745	10,070	2,395	2,395	1.24
Wheat	13,100	7,376	9,991	5,725	3,109	1.31
Maize	14,888	8,843	10,855	6,045	4,034	1.37
Pulses	8,748	4,466	5,553	3,195	3,195	1.58
Oilseed (Mustard)	9,604	4,466	6,315	5,138	3,289	1.52
Spices	30,045	14,282	17,090	15,763	12,955	1.76
Vegetables	32,177	14,926	17,857	17,251	14,320	1.80
Cash crop (jute)	12,187	7,655	10,296	4,532	1,892	1.18

Source: Author's calculation

8.4.3 Net Return and Benefit Cost Ratio of Different Crops by Sample Districts

It is found from the above discussion that there are differences in yield rate of different crops in different districts due to different agro-climatic conditions of the area. Similarly, there are differences in input cost and output prices because of different market situations and infrastructure in the regions. Therefore, different districts may have variations in net returns and BCR of different crops.

Table 8.9 presents (details in appendix F) the net return and BCR analysis of crops in the sample districts. In case of paddy production, the highest net return is found in Thakurgaon district and the net return is Tk.2,564 followed by Naogaon Tk.2,516, Kurigram Tk.2,327 and Rajshahi Tk.1,956. In case of wheat, highest net return is found in Thakurgaon Tk.3,509 followed by Naogaon Tk.3,001, Rajshahi Tk.2,752 and Kurigram Tk.2,308. Reasons behind the highest net return of paddy and wheat in Thakurgaon are the higher yield and price of paddy (*aus* and *boro*) and wheat. The highest net return of vegetables is found Tk.16,737 in Rajshahi followed by Naogaon Tk.15,011, Kurigram Tk.11,866 and Thakurgaon Tk.10,813. Net return of spices is Tk.14,135 in Rajshahi, Naogaon Tk.13,707, Kurigram 12,000 and Thakurgaon Tk.1,430. Yield and price of vegetables and spices in Rajshahi is higher than that of other districts in the study area. In addition, demand of vegetables and spices is higher compared to other district in the study area that pushes the price of these crops comparatively high.

In BCR analysis, the highest BCR of paddy is found in Thakurgaon and Naogaon (1.26), followed by Rajshahi (1.18) and Kurigram (1.22). The highest BCR of jute is 1.45 found in Kurigram followed by Rajshahi (1.18), Naogaon (1.16) and Thakurgaon (1.05). In case of pulses, farmers of Rajshahi district get the highest BCR 1.70 followed by Kurigram (1.50) and Thakurgaon (1.46). The highest BCR of vegetables is found 1.87 in Rajshahi, followed by 1.84 in Naogaon, 1.69 in Kurigram and 1.62 in Thakurgaon. In case of spices production, BCR is 1.81 in Rajshahi, 1.85 in Naogaon, 1.75 in Kurigram and 1.89 in Thakurgaon.

Table 8.9: Net Return and BCR Analysis of Crops by Districts(Tk./*bigha*)

Crops	Rajshahi		Naogaon		Kurigram		Thakurgaon	
	NR	BCR	NR	BCR	NR	BCR	NR	BCR
Paddy	1,956	1.18	2,516	1.26	2,327	1.22	2,564	1.26
Wheat	2,752	1.27	3,001	1.32	2,308	1.24	3,509	1.35
Maize	3,660	1.34	4,308	1.82	2,948	1.27	4,280	1.39
Mustard	2,363	1.36	3,246	1.56	2,279	1.38	2,872	1.47
Jute	1,999	1.18	1,530	1.16	4,333	1.45	1,444	1.05
Pulses	4,081	1.70	2,825	1.50	-	-	2,547	1.46
Spices	14,135	1.81	13,707	1.85	12,000	1.75	14,430	1.89
Vegetables	16,737	1.87	15,011	1.84	11,866	1.69	10,813	1.62

Source: Author's calculation

8.4.4 Net Return and Benefit Cost Ratio of Different Crops by Farm Size

There are differences in the usage of various inputs in producing different crops among the farms. In case of labor usage, marginal and small farms employ more family labor than hired labor whereas medium and large farms do totally opposite to what marginal and small farms do. Furthermore, marginal and small farms can give more attention to crops than medium and large farms as small farms cultivate limited number of plots and smaller farms. Therefore, small farms have the greater opportunity to get higher benefit from growing crops.

Table 8.10 (details in appendix F) exhibits the cost benefit analysis according to different types of farms. It is obvious from the table that from all the crops marginal and small farms get higher benefit than that of medium and large farms except for spices production. Another important thing is that all types of farms receive higher BCR from non-rice crops even from non-cereal crops. Putting it in different way, it can be said that benefit cost ratio of vegetables, spices, pulses and mustard is higher than those of paddy, wheat, maize and jute. Here the study concludes that any type of farms can inflate their profit by distributing their land for different crops rather than rice based monoculture. In short, crop diversification strategy offers more profit to the farmers which are apparent from the discussion.

Table 8.10: Cost Benefit Analysis of Crop by Farm Size (Tk./*bigha*)

Crops	Marginal		Small		Medium		Large	
	NR	BCR	NR	BCR	NR	BCR	NR	BCR
Paddy	2,503	1.25	2,281	1.22	2,231	1.22	2,362	1.23
Wheat	3,341	1.33	3,012	1.30	3,140	1.32	2,395	1.24
Maize	4,063	1.38	4,356	1.40	3,497	1.32	3,633	1.34
Mustard	3,199	1.54	2,876	1.48	3,164	1.53	2,367	1.39
Jute	2,023	1.20	1,775	1.17	2,210	1.21	1,023	1.10
Pulses	3,384	1.59	3,683	1.64	2,063	1.39	3,500	1.64
Spices	14,014	1.81	13,314	1.80	15,274	1.91	13,488	1.80
Vegetables	14,697	1.82	13,954	1.77	14,081	1.78	13,794	1.78

Source: Author’s calculation

8.4.5 Net Return and Benefit Cost Ratio Analysis of Different Cropping Patterns in the Study Area

Different farms include different crops in their cropping patterns and returns from the different patterns are different. By calculating net return and BCR of different cropping patterns, comparisons are made among the patterns towards the economic viability of them.

Table 8.11: Net Return and Benefit Cost Ratio Analysis of Different Cropping Patterns in the Study Area (Tk./*bigha*)

Cropping Pattern	A	B	C	D	E	F
	GR	T VC	TC	G M (A-B)	NR (A-C)	BCR (A/C)
Aus + T. *Aman* + *Boro*	34,622	22,078	28,671	12,544	5,952	1.21
Aus + T. *Aman*+ Potato	50,563	30,574	37,769	19,988	12,793	1.34
Aus+ T. *Aman* + Mustard	29,816	17,170	23,221	12,647	6,595	1.28
Jute + Vegetables + Wheat	57,465	29,956	38,144	27,508	19,321	1.51
Maize + T. *Aman* + Potato	56,748	33,298	40,685	23,450	16,063	1.39
Jute + T. *Aman* + Wheat	36,797	21,614	29,254	15,183	7,543	1.26
Jute + T. *Aman* + Potato	54,047	32,110	40,126	21,938	13,921	1.35
Vegetables + T. *Aman*+ Spices	73,732	35,792	43,915	37,940	29,817	1.68
Vegetables +T. *Aman*+ Vegetables	75,864	36,436	44,682	39,428	31,182	1.70

Source: Author's calculation

Table 8.11 presents net return and BCR of different cropping pattern in the study area. The study has excluded yearly crops from the analysis. There are several cropping patterns in the sample districts and the study has selected major cropping patterns for analysis. It is found that net return and BCR of the cropping pattern containing rice in all three season is Tk.5,952 and 1.21, respectively. In the same cropping pattern, if potato is included instead of *boro* rice then net return increased to Tk.12,793 and BCR increased to 1.34, respectively, that is, the later cropping pattern offers more than double return in a cropping year. Net return from the pattern vegetables + T. *Aman* + vegetables is Tk.31,182 and BCR is 1.70. Again, net return and BCR of the pattern vegetables + T. *Aman* + spices is Tk.29,817 and 1.68, respectively. Net return of jute + vegetables + wheat pattern is Tk.19,321and BCR is 1.51. Net return of *Aus*+ T. *Aman* + Mustard pattern is Tk.6,595 and BCR is 1.28. Net return and BCR of the pattern Maize + T. *Aman* + Potato are Tk.16,063 and 1.39 respectively. Similarly, net return of Jute + T. *Aman* + Wheat pattern is Tk.7,543 and its BCR is 1.26. Again, net return of Jute + T. *Aman* + Potato is Tk.13,921 and its BCR 1.35. It is found from earlier discussion that rice based cropping pattern offer comparatively low net return and low BCR whereas most of the non-rice based pattern offer higher net return and BCR. This happens because of higher yields and market prices of non-rice crops in the study area. Thus, it can be concluded that non-rice based cropping pattern is economically more viable than rice based cropping pattern.

8.5 Conclusion

In economic viability analysis, yield, input cost and output price are the important issues to be considered. Small and marginal farms' productivity is comparatively high. Almost all crops' yield produced by marginal and small farms is found to be higher than that of others in the study area. On average, yield of vegetables is higher in Rajshahi whereas yield of rice is higher in Thakurgaon in the study areas. Average yield of spices in Rajshahi is the highest in the study area. In farming activities, labor cost of a farm is considered as income of the family. Labor cost of crop production is the highest amongst the inputs costs. On average, labor cost of a crop is one fifth to two fifths of the total cost. Average labor cost for growing vegetables, spices and jute is higher than that of other crops. These indicate that these types of crops generate more employment than that of other crops.

Net return of vegetables and spices are significantly higher than those of rice wheat and maize. In terms of cropping pattern, vegetables, spices base cropping pattern offer more returns than that of rice based cropping pattern. Again, non-rice crops especially vegetable, spices and jute create more employment generation than that of cereal, especially rice. Therefore, considering different aspects of crop production, this chapter concludes that vegetables, spices, potato based cropping patterns are economically more viable than others.

CHAPTER NINE

MAJOR FINDINGS AND CONCLUSION

9.1 Introduction

This chapter begins highlights the major findings towards the objectives of the study. At the end, some policies are recommended on the basis of major findings. The major findings of the study have been shown in Section 9.2. The implications of the major findings are shown in Section 9.3 and in Section 9.4, some policies are recommended on the basis major findings of the study. Finally, limitation of the present study and scope for further study are shown in Section 9.5.

9.2 Major Findings of the Study

This study is an effort to investigate the degree of crop diversification, its determinants and economic viability in the context of northern Bangladesh. The economic viability of crop diversification depends upon profitability of the farms. This implies that the practice of crop monoculture or crop diversification depends upon the returns accrues to the farms from the cultivation of different crops by the farmers. This study tries to focuses on these issues. In this regard, the study set some specific objectives, which are mentioned in chapter one.

Chapter one is an introductory chapter that gives a clear idea about the research problem, objectives and importance of the study. The scope of the present study is clarified in this chapter. In the problem statement observed that the practice of rice monoculture has reduced the amount of the production of non-rice crops like pulses, oilseeds, vegetables, fruits and most of the spices in Bangladesh over the years and the people of the country have been facing shortage of these non-rice crops. As a result of rice-monoculture, Bangladesh has to import non-rice crops and for this purpose the country has to expend foreign exchange that could be used in other development activities. In addition, rice monoculture has also been causing to decrease of soil nutrient and in turn the productivity of land. Again, it creates many environmental problems like declining of ground water table, increase in arsenic and soil salinity, increases in crop pests and diseases etc. Further, it increases the use of chemical fertilizer, pesticides and irrigation as rice is a highly water, fertilizer and pesticide consuming crop. Excessive use of chemical fertilizers and pesticides has adverse effects on the fertility of land, quality of surface water and fish habitat. Thus, crop diversification could be an appropriate strategy to overcome such economic and environmental problems that arise from rice monoculture. Thus, chapter one helps to find the scope of the present study.

In chapter two, a comprehensive review of earlier literature regarding different aspects of crop diversification is provided. This chapter mainly analyzed the conceptualization of crop diversification, its measurement index and determinants of crop diversification. It also analyzes the empirical models that are used in earlier studies. Earlier studies have applied different indices to measure the level of crop diversification. Among different indices, HI and EI are commonly used indices earlier studies. It is also observed that the factors of crop diversification found in different studies are almost similar but the contributions of these factors to crop diversification are mixed and inconclusive. Again, different econometric models have been applied by the researchers to estimate the influence of the factors on crop diversification. Most of the studies applied Multiple Linear Regression, Logit, Probit and Tobit models considering the nature of dependent variable. Similarly, in the case of profitability analysis, most of the researchers applied conventional profit function and cost benefit analysis of individual crops. It is found from the earlier studies that most of the studies are of survey type and their analyses are based on time series data. Few studies have been carried out empirically on crop diversification. Finally, chapter two, thus, helps to find out the research gap of earlier studies that helps to carry out a comprehensive study on crop diversification in northern Bangladesh.

Chapter three discusses the production performance and crop patterns in Bangladesh. It is found from this chapter that yield and production of major crops has been increased by manifolds after four decades of independence. The production of cereal crops has increased at a large extent. For example, rice has increased more than two and half folds, wheat and maize production has also increased considerably but increase of production of other minor crops such as oilseeds, pulses, spices and fruits are comparatively low as land acreage of these crops has been decreasing. It is also found that more than three fourth of the farms are small and there is a continuous decreasing trend in average farm size in Bangladesh. Net cultivable land has been decreasing gradually whereas gross cropped area and cropping intensity has been increasing is revealed from the study. It is found that the level of crop diversification is low in Bangladesh and the degree of crop diversification of small farms is more than that of others. It is also evident that there prevails slow but steady increasing trend in the degree of crop diversification in the country. Weak infrastructure, bad road connectivity, high transaction cost and existing irrigation system are some constrains in the way of crop diversification. With this discussion a comprehensive portrayal of Bangladesh agriculture with respect to crop diversification is presented in this chapter.

In chapter four, the state of crop diversification in the context of northern Bangladesh is analyzed. The study found that most of the farms in the study area are marginal. The highest numbers of marginal farms are found in Rajshahi district and the lowest one are found in Kurigram. T. *Aus* + T. *Aman* + *Boro*, fallow + T. *Aman* + *Boro*, and fallow + fallow + *Boro* are common crop patterns across the sample districts. However, Rajshahi and Thakurgaon districts produce, apart from rice, a variety of vegetables such as, potatoes, papayas, tomatoes, pulses and oilseeds. It is also found that major portion of the net cultivable land is used two times in a cropping year. There are also sufficient amount of triple cropped area in the study area. In the study area, the highest cropping intensity is found in Thakurgaon and Naogaon holds the lowest cropping intensity.

In the study area, almost two-thirds of the total cultivable lands are devoted to rice production. The highest rice producing area is Naogaon and the lowest one is Rajshahi. Farms of Rajshahi and Thakurgaon grow higher number of crops compared to those of other two districts. It is found from the study that the study area is more diversified area compared to other areas in Bangladesh. Magnitude of crop diversification in the study area is higher than that at the national level. Among the sample district, Rajshahi district is the highest crop diversified area and Naogaon is the lowest crop diversified area. The advantage of crop diversification are found that it increases the income of the farms, creates employment opportunities, reduces risk of losing all crops by natural calamities and provides opportunity to off-set the loss of one crop by the returns from other crops.

Chapter Five discussed the research methodology used in the study. The study has used farm level cross sectional data for the cropping year 2012-13. To see the state of crop diversification this study measured the degree of crop diversification using two different crop diversification indices, viz., Entropy and Herfindahl indices. In addition, two-way ANOVA and independent sample 't' test have been carried out to compare the mean differences of some characteristics of the farms and farmers in the study area. Chi-square (χ^2) test has also been used to test the association of categorical variables of the farms. To estimate the magnitude of the factors of crop diversification, Tobit regression model was used. In the model index value of crop diversification was the depended variable and selected factors of crop diversification were explanatory variables. By random sampling technique, a total of 343 farms were selected from eight villages of four districts of which two from Rajshahi division and two from Rangpur division which constitute northern Bangladesh.

In chapter six, the socio-economic and demographic characteristics of the sample farms are analyzed. It is found that there are significant differences among almost all the socio-economic and demographic characteristics across districts and across farm size except the level of education of the sample farmers of the sample districts. In the study area, most of the sample farms use power tiller/tractor for ploughing, every farms use chemical fertilizer and around 50% farms use organic manure with chemical fertilizer. Among the sample farms, around one tenth of sample farms have their own power tillers/tractors for tilling their land and almost one fourth of the sample farms have STW.

In the study area, three fourths of sample farms are diversified and one fourths are specialized which grow rice only. It is found from the study that most of the farmers in the study area are of moderate age and poorly educated. It is also revealed that farms are on the average small in the study area. On an average, a farm grows 4.57 crops with maximum 17 crops in a cropping year. The highest numbers of crops are grown in Rajshahi district among the sample districts. It is revealed from the study that value of EI of crop diversification is 0.61. In this context, we may conclude that the study area is moderately diversified area in Bangladesh.

The study found that average number of plots, total family income and farm income of a diversified farm are higher and irrigation intensity, distance of road and distance of market from a diversified farm are lower than those of specialized farm. Mean difference of these variables of a diversified and a specialized farm is highly significant.

Survey data reveals that about one third of sample farms received agricultural credit and among the sample farms almost one fourth of the specialized farms and two fifths of diversified farms received agricultural credit. During the survey period, around half of specialized farms and around one third of diversified farms in the study areas receive training. There is no significant relationship between type farms and size of farms. Four fifths of sample farms in Rajshahi division and around two thirds in Rangpur division are diversified and there is highly significant relationship between regions and practice of crop diversification of the farms. Chapter three, four and six together helped achieve the first objective of the study.

In chapter seven, it is found that food security of the family is the main concern at the time of choosing crops. Farmers also consider market demand, profitability, input cost, immediate previous year crops' price, etc. before growing any crop. Advice of agricultural extension officer, neighbors' suggestion and family tradition are also considered before growing any crops. Among the sample farms, all of the marginal farms thought about the food security of their families whereas all large farm owners think about profit to grow crops.

Most of the sample farmers reported that food security concern forces them to grow rice. More than fourth fifths of the sample farms quoted that storage of rice is easier than that of other non-rice crops. Again, more than two thirds respondents opined that rice production requires comparatively less labor and almost two thirds respondents told that there is no alternative way of rice production. In addition, encouragements of agriculture extension officers, government procurement policy and government's subsidy to rice are also the reasons behind growing rice. The study found that farms are not interested in growing non-rice crops as vegetables is perishable, non-rice crops demand excessive labor, it requires more capital, farms face problem to sell non-rice crops and prices of these crops are instable.

Tobit regression results revealed that crop diversification is influenced by farms size, number of plots, annual income of the family, non-farm income, infrastructure, irrigation intensity and training exposure. Among them, number of plots, annual family income and infrastructure affect the probability of crop diversification positively whereas irrigation intensity and farm size affect it negatively. Thus, this chapter helped achieve the second objective of the study.

Chapter eight discusses the profitability of crop diversification of the sample farms. It is found from the chapter that average yield of most of the crops grown by the small and marginal farms are higher than that of medium and large farms. On average, yield of vegetables is comparatively high in Rajshahi district. Rajshahi district produces the highest number of crops among the study districts. It is also found that yield of rice is higher in Thakurgaon than that of other study districts.

It is revealed that on an average, share of labor cost is 20%-40% of the total cost for all the crops. It is also revealed that average labor cost of vegetables spices and jute are higher than that of rice. As non-rice crops require more labor, it generates employment opportunity. It is found that a non-rice crop is more profitable than that of rice. Net return of vegetables, spices, potato is higher compared to rice production. This chapter concludes that cropping pattern with vegetables, spices, pulses and oilseed is more profitable than that rice. In summary, diversified cropping pattern is more profitable than rice monoculture. This chapter helped achieve the third objective of this study

9.3 Policy Implications Based on Findings

This chapter is basically designed to analyze policy implications regarding crop diversification and to propose further policies for enhancing the practice of crop diversification in Bangladesh which accomplishes the fourth objective of the study. Based on the findings, this study generates a number of implications that will be of interest to policy makers. These implications are discussed in this section.

Firstly, as it is found from the study that almost two thirds of gross crop area is devoted to rice cultivation, rice monoculture has an implication for the environment. It degrades soil fertility, increases crop specific pests and diseases, declines water table, and creates many others environmental problems directly or indirectly. Accordingly, these problems reduce yield and productivity of soil and also make the farming activities expensive. As a result, farmers are getting reluctant to farming activities and also becoming interested to non-farm or off-farm activities. This situation is a matter of important concern for the country with respect to food security. To manage this situation government can take necessary steps by enhancing the practice of crop diversification as it minimizes costs and yield risks of rice monoculture.

Secondly, it is found that the main reason of producing rice is ensuring food security for the family. Hence, it may be indicative that diversification with non-rice crops requires intensification of rice production to meet growing food demand for the population and also at the same time, freeing up land for other crops. However, this require significant enhancement in agricultural productivity through advanced research and extension services, especially in the face of declining the availability of cultivable land in the country.

Thirdly, it is found that the economic returns of non-rice crops like vegetables, potato and spices are higher than that of rice. Due to high price risks of non-rice crops and its perishable nature farmers are less interested to grow them although they make high returns. The development of agro-processing industries and marketing networks may provide effective means for reducing instability in prices. Moreover, the development of rural infrastructure may be prerequisite for integrating rural markets with each other and with urban markets that may help to move of these perishable crops quickly. At the same time, cold storages need to be established to protect the perishable crops from getting damaged. These policies may help to exploit the potential of crop diversification in the country.

Fourthly, one important constraint of crop diversification is the irrigation and water arrangement system. Irrigation system in Bangladesh is not suitable for growing non-rice crops. This system does not allow rice and non-rice crops to be planted in the same service units. It discourages the use of modern irrigation for growing high-value but risky non-rice crops. It is, therefore, necessary to devise and introduce water management systems that allow rice and non-rice crops to be grown within the same service units.

Fifthly, in the context of promoting crop diversification, an important policy concern is the potential scope for promoting such an irrigation technology as that is represented by hand tube wells and pumps. These labor-intensive irrigation techniques to be advantageous for small farms and for growing crops like potatoes, vegetables and spices.

9.4 Policy Suggestions

The last objective of the study is to recommend some policies aiming at enhancing crop diversification practice in Bangladesh. The policy suggestions generated from the policy implication and the study findings may be useful to policy makers as well as decision makers of the concerned authority. Therefore, this study put forward following policy suggestions for enhancing crop diversification practice in the country.

1. As higher numbers of crops grow in *Rabi* season than that of other seasons, *Rabi* season should be used to produce different types of non-rice crops which reduce the usage of underground water. In *Rabi* season, various non-rice crops like vegetables, spices and other shorter duration crops should be grown in accordance with land quality.

2. As rice monoculture has many adverse effects on the environment, farms should include at least one non-rice crop in their cropping pattern. Similarly, some portion of cultivable land should be allocated for producing spices. Likewise, a shorter duration leguminous crop should be grown between early *aman* and late *boro*.

3. Proper facilities to non-rice crops production like supplying of quality seeds, supplying of fertilizer and insecticides, and also the irrigation equipments should be provided with reasonable subsidy by the relevant organizations of

the government. As it encourages farmers to cultivate diversified crops to make a balanced agriculture for the Bangladesh economy.

4. Concerned authority should arrange massive training programs on appropriate natural storage, processing techniques of the perishable crops along with practicing crop diversification. In addition, government should establish storage and processing facilities for perishable crops and arrange modern transport with refrigeration facilities. These initiatives would make farmers encouraged in practicing crop diversification.

5. Extension activities should be strengthen to promote practice of crop diversification to enhance farms' income. It helps maintaining eco-friendly agriculture and better soil quality for long-term sustainability. Government should undertake program of massive publicity on various advantages of crop diversification.

6. Government imports different minor crops containing very high protein by exhausting valuable foreign currency. These crops should be produced in Bangladesh by contact farming or encouraging farmers with subsidy or cash intensive.

7. Most of the large farmers remain absent from land. To enhance the practice of crop diversification government should bring this type of land to the small farmers on the basis of leasing so that small farmer can give highest attention to the land. This will surely increase practice crop diversification.

8. Government should provide credit facility and incentives on practicing crop diversification. In this respect, government should give direction to the commercial banks, NGOs and other financial institution to spread their credit program to the farmers who want to practice crop diversification.

9. Government should ensure well road connectivity and developed marketing facility so that farmers can move their crops to a better destination easily and quickly.

9.5 Limitation of the Study and Recommendation for Further Research

Crop diversification is an important issue in Bangladesh. There are multi-dimensional aspects of crop diversification like determinants, patterns, profitability, environment, production efficiency, poverty elevation, food security etc. By conducting a single study, it is very difficult to extract all aspects of it. It claims a number of studies from different aspects. The study, however, could not touch all the aspects of crop diversification. In addition, the study was confined into eight villages of northern part of Bangladesh which do not portray the situation of the whole country. Again, there are some additional aspects of agriculture related to crop diversification which could not be covered under the scope of this study, inclusion of which could have given interesting results for the readers. Therefore, this study recommends conducting further study on aspects like environmental aspect of crop diversification, impact of crop diversification on poverty and household food security, crop diversification and horticulture crops, economic/technical efficiency of diversified crops in Bangladesh, etc.

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APPENDICES

Appendix A: Questionnaire on An Economic Analysis of Crop diversification in Northern Bangladesh

Respondent name (decision maker regarding agriculture in family)...

Village ....Union ....

Thana ....District ....Mobile no ....

Q.1 Would you please tell me………

1. How old are you?	2. Educational qualification (in years)	3. Your main profession?	4.Supported profession (morethan one acceptable)	5. Farming experience (in years)	6. Agriculture training (in number)

Familial information			
7. Number of your family members	8. Earning members in your family	9. Main source of your family income?	10. Other sources of your family income (more than one acceptable)
11. Number of educated family members	12 Number of family members help in agricultural work	13. Have any permanent agril laborer (in number)	14. Engaged any farmers organization (in year)

Land related information

15. Total land of your family with homestead (in decimal)	16. Homestead (with tress and bamboo bush) land (in decimal)	17. Orchard (in decimal)
18. Total cultivated area (in decimal) in last year	19. Own cultivated land (in decimal) in last year	20. Land taken in as share cropping for cultivation (in decimal) in last year
21. Land give out as share cropping for cultivation (in decimal) in last year	22. Lease in land for cultivation (in decimal) in last year	23. Lease out land for cultivation (in decimal) in last year
24. Mortgage-in land for cultivation (in decimal) in last year	25. Mortgage-out land for cultivation (in decimal) in last year	26. Total irrigated land (in decimal) in last year

Q.2Would you please tell how fertile your land is?

Type of fertility	Code
Excellent fertile	1
More than average fertile	2
Average fertile	3
Somewhat less fertile	4
Infertile	5

Q.3 Would you please tell regarding types of your land

	Land type	Quantity in decimal
3.1	High land	
3.2	Medium land	
3.3	Low land	

Q.4Would you please tell how many decimal land are single crop, double crop, triple crop and quadruple crop?

	Land	Quantity in decimal
4.1	Single cropland	
4.2	Double cropland	
4.3	Triple cropland	
4.4	Quadruple cropland	

Q.5 Would you please tell how many plots of land you cultivated last year? ....

Q.6 Would you please tell how far the cultivated land from your home?

Within …..km

Q.7Would you please tell how many times you contacted with agriculture officer?

7.1 You yourself	7.2 Agriculture officer himself
……………..times	……………..times

Q.8 Would you please tell how you take decision before cultivating any crop?

Attributes	Code
Market demand	01
Neighbors advice	02
Neighbors cultivation	03
Preceding years output price	04
Input cost	05
Profit	06
Food security of Family	07
Advice of extension officers	08
Family tradition	09
Others………….	

Q.9Would you please tell which of the following agricultural material you use in cultivation?

Name of the implements	Code
Traditional plough	01
Cows, buffaloes for cultivation	02
Spade, sickle, chopper etc.	03
Ladder	04
Power tiller/tractor	05
DTW	06
STW	07
Water pump	08
Low lift pump	09
Thresher	10
Weeder	11
Insecticide sprayer	12
Chemical fertilizer	13
Organic fertilizer	14
Others	

Q.10 Would you please tell which of the following implements you have and what are the market value of that implements?

	Name of the implements	Number	Market value (Tk.)
01	Traditional plough		
02	Cows, buffaloes for cultivation		
03	Spade, sickle, chopper etc.		
04	Ladder		
05	Power tiller/tractor		
06	DTW		
07	STW		
08	Water pump		
09	Low lift pump		
10	Thresher		
11	Weeder		
12	Insecticide sprayer		
	Others		

Q.11 Would you please tell about the following attributes?

	Attributes	Taka
01	Land rent for one year	
02	Daily wage for agriculture labor (without food)	
03	Daily wage for agriculture labor (with food for one meal)	
04	Cost of cultivation (with tractor/ power tiller) per plough/ bigha	
05	Cost of cultivation (with cows/ buffalos) per plough/ bigha	
06	Irrigation cost each time/ bigha	
07	Irrigation cost each Boro season/ bigha	
08	Price of Boro seedling for per bigha	
09	Price of Aman seedling for per bigha	
	Others	

Q.12Would you please tell how you know the price of agricultural input and output?

Means of knowing price	Code
From neighbors farmers	1
At the time of buy and sale	2
Through television/ news paper	3
Others	

Q.13Would you please tell what types of crops are cultivated by you last year and how many decimal of that crop?

SL	1. Name of crops	2. In decimal	3. Owned land in decimal	4. Others land in decimal
01				
02				

Q.14Would you please tell how the per bigha production of …… crops cultivated last year?

SL	1. Name of the crops	2. Production per bigha (in mound)?	3. Price per mound	4. Straw per bigha (in mound)?	5. Price per mound straw?
01					
02					

Q.15Would you please tell how the per bigha production cost of …… crop?

	Cost head (Taka)	Name of crop		
01	Cost of land cultivation			
02	Cost of purchasing seed/ seedling			
03	Cost of seed sowing/planting			
04	Cost of purchasing and spraying chemical fertilizer			
05	Cost of organic manure			
06	Cost of purchasing and using pesticide			
07	Cost of weeding			
08	Cost of irrigation			
09	Cost of harvesting			
10	Cost of collecting crops from land			
11	Cost of threshing			
12	Cost of transport in selling output			
	Other cost......................			
	Total labor needed			
99	Total cost			

Q.16Would you please tell where you sell your produce generally?
Place...................................., Distance ....km, Transport cost ....Taka.

Q.17Would you please tell whether your family have the following dairy and poultry?

	Dairy	Number	Present value		Poultry	Number	Present value
01	Cow			05	Duck		
02	Buffalo			06	Hen		
03	Goat			07	Pigeon		
04	Sheep			08	Koel		

Q.18 Would you please tell whether your family have any orchard or nursery?

	Orchard	Area (in decimal)		Orchard	Area (in decimal)
01	Mango		04	Guava	
02	Litchi		05	Palm	
03	Jackfruit		06	Nursery	

Q.19 Would you please tell whether your family have any Fish farm or hatchery?

	Matter	Area (in decimal)
01	Fish farm/pond	
02	Hatchery	

Q.20Would you please tell how your family's annual income from agriculture is?

	Name of the sources	Taka
01	Income from crop	
02	Income from share cropping/ rented land	
03	Income from dairy, poultry etc.	
04	Income from fish farm, hatchery and pond	
05	Income from nursery, orchard, trees etc.	

Q.21Would you please tell how your family's annual income from non-agriculture is?

	Name of the sources	Taka
01	Service	
02	Selling labor	
03	Remittances	
04	Pension	
05	Business	
	Others	

Q.22 Would you please tell whether you took loan for agriculture purpose last year and from which source and how much. How you returned that loan. Yes= 1 no= 2 loan, if yes asked following questions.

	Name of the source	How much money taken	How much money returned	How many installment
01	Kith and kin's, friends			
02	Land lord			
03	NGO			
04	Bank			
	Others			

Q.23 Would you please tell whether you receive any subsidy or cash incentive from government?

	Code	If yes in what type of that help
Yes	1	
No	2	

Q.24Would you please tell, what is the advantages of cultivating different type of crops after harvesting a crop?

Statement	Code	Statement	Code
Increases soil fertility	01	Decreases crop diseases	14
Reduces soil erosion	02	Reduces insect attract	15
No water logging in the crop field	03	Beneficial insects remain alive	16
No salinity in the crop field	04	Reduces weeds of the crop	17
No compaction of the soil	05	Increases yield	18
Reduces fertilizer cost	06	Increases production	19
Decreases insecticide cost	07	Not declining underground water level	20
Does not harm human health	08	Does not mix chemical objects with water	21
Does not affect flora and fauna	09	No arsenic with underground water	22
Does not harm acqua resources	10	No pollution of adjacent water bodies	23
Nutritious food is available	11	Increases employment	24
Balanced food is available	12	Increases income	25
Reduces import cost	13	Increases women participation in agriculture	26

Q.25 Would you please tell, What is the advantages of cultivating different crop in a season rather than single crop such as cultivating rice, wheat, maize, vegetables, pulse, oilseed etc. in different plots rather than a single crop?

Statement	Code	Statement	Code
No risk of all crop loses during natural calamities	01	No risk in declining all crop prices	06
Makes up loses of one crop with other crop	02	No problem with bumper production	07
Nutritious food is available	03	Increases employment	08
Balanced food is available	04	Increases income	09
Reduces import cost	05	Increases women participation in agriculture	10

Q.26Would you please tell, why most of the farmers are interested growing paddy in most cases?

Statement	Code	Statement	Code
For familial food security	01	Yield of paddy comparatively high	07
Encouragement of agriculture officer	02	Easy paddy preservation	08
Neighbors advice	03	Low labor cost for paddy production	09
No alternative crop without paddy	04	Government buy paddy	10
Paddy offer more profit	05	Government offer subsidy to paddy	11
Paddy price is stable	06	Others................	

Q.27 Would you please tell, why most of the farmers are not interested of growing vegetables, oilseeds, pulses, cash and spices crops in most cases?

Statement	Code
Fluctuation of prices	01
Problems of selling	02
Problems of preservation	03
It demand more laborer	04
Government imports a lot	05
It needs more cash	06

Q. 28Would you please tell, how far the following places from your village and how much does it cost to travel there?

	Name of the places	Distance (KM)	Travelling cost
01	Primary school		
02	Secondary school		
03	College		
04	Local hat bazaar		
05	Bulk product hat bazaar		
06	Cold storage		
07	Fertilizer selling point		
08	Rice mill		
09	Union office		
10	Upazila town		
11	District town		
12	Agriculture office		
13	Bank		
14	Post office		
15	Pacca road		
16	Bus station		
17	Rail station		
18	Electricity office		
19	Health center		

Appendix B: Pearson Correlation Analysis

Table B.1: Pearson Correlation Analysis

	FS	HS	NP	AGE	EDU	TFI	NFI	FDR	DMF	EXC	IRR	CF	TE
FS	1												
HS	.30**	1											
NP	.65**	.25**	1										
AGE	.19**	.36**	.15**	1									
EDU	.033	-.15**	-.02	-.48**	1								
TFI	.77**	.40**	.51**	.20**	.07	1							
NFI	.20**	.42**	.13*	.14*	-.01	.64**	1						
FDR	.16**	.15**	.23**	.13*	-.04	.07	.13*	1					
DMF	.01	-.04	.14**	-.06	-.05	-.10	-.13*	.07	1				
EXC	.56**	.30**	.49**	.09	.03	.51**	.25**	.23**	.06	1			
IRR	-.31**	-.18**	-.33**	-.12*	-.01	-.30**	-.10	-.043	.10	-.29**	1		
CF	.06	-.03	.04	-.11*	.12*	.07	-.07	-.17*	-.20**	.01	-.11*	1	
TE	.24**	-.04	.10	.25**	-.04	.19**	.03	.11*	.03	.20**	-.10	-.01	1

Appendix C

Table C.1: Earning Members in the Family

Types of Farm	Districts				
	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Marginal	1.19	1.35	1.25	1.47	1.33
Small	1.63	1.60	1.69	1.37	1.58
Medium	2.06	1.43	1.85	1.39	1.75
Large	2.50	3.20	1.67	1.40	2.20
All	1.58	1.58	1.71	1.41	1.57

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	4.11	0.01
Type of Farmer	3, 327	6.65	0.00
Districts * Types of Farm	9, 327	3.14	0.00

Source: Field survey, 2013

Table C.2: Annual Income from Agriculture (Tk.)

Farm Size	Districts				
	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Marginal	65032	60459	56000	62500	62038
Small	98125	75460	87742	117583	92512
Medium	152141	178571	166121	162556	163112
Large	312000	295000	288333	361400	318067
All	102237	88232	99661	122114	108602

ANOVA Table

Sources	DF	F Stat	
		Value	Sig
Districts	3, 327	7.96	0.00
Size of Farm	3, 327	183.32	0.00
Districts * Size of Farm	9, 327	5.31	0.00

Source: Field survey, 2013

Table C.3: Farmers Having Modern Machinery (%)

Machinery	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Power tiller / tractor	2.2	21.2	8.6	16.9	12.54
STW	17.6	25.4	22.9	31.4	24.27
Thresher	7.7	7.1	2.9	2.4	5.25
Weeder	25.27	6.1	22.9	1.2	14.00
Pesticide spraying machine	72.5	88.9	58.6	65.1	72.59

Source: Field survey, 2013

Table C.4: Village-wise Crop Acreage (%)

Villages	Rice	Wheat	Maize	Pulses	Oilseed	Cash	Spice	Fruit	Veg
Gholharia	28	7	3	1	0	13	12	0	35
Mallikpur	34	8	9	2	1	7	8	1	29
Fazilpur	76	3	1	2	4	1	2	0	12
Alidewana	85	1	0	0	3	3	2	0	6
Chhinaihat	59	1	4	0	0	2	2	0	32
Bajemujrai	70	2	2	0	2	2	1	0	21
Hatpara	52	7	12	3	7	5	1	0	14
Chapor	79	12	1	3	4	2	0	0	1

Source: Field Survey, 2013

Table C.5: Crop Acreage in the Study Area by Types of Farms (%)

Crops	Marginal	Small	Medium	Large	All
Rice	65	57	67	69	67
Wheat	6	4	6	5	5
Maize	4	3	2	5	3
Pulses	6	2	1	2	11
Oilseeds	2	3	3	7	4
Cash crop	3	3	4	3	4
Spices	3	3	2	1	3
Fruits	0	0	0	0	0
Vegetables	15	11	15	9	14

Source: Field Survey, 2013

Table C.6: Value of Crop Diversification by Study Villages

Districts	Entropy index	Herfindahl index
Gholharia	0.71	0.24
Mallikpur	0.74	0.23
Fazilpur	0.40	0.59
Alidewana	0.26	0.73
Chhinaihat	0.44	0.45
Bajemujrai	0.41	0.53
Hatpara	0.68	0.32
Chapor	0.36	0.64

Source: Field Survey, 2013. Computed by researcher

Table C.7: Value of Crop Diversification by Farm Size

Districts	Entropy index	Herfindahl index
Marginal	0.58	0.34
Small	0.52	0.45
Medium	0.52	0.48
Large	0.51	0.50

Source: Field Survey, 2013. Computed by researcher

Appendix D

Table D.1: Reasons of Growing Choice Crops by Districts (%)

Reasons	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Market demand	84.6	92.9	87.1	95.2	90.10
Neighbors' suggestion	23.1	10.1	-	14.5	12.50
Neighbors' crops	11.0	14.1	40.0	30.1	22.40
Preceding year crop price	47.3	58.6	60.0	73.5	59.50
Input cost	60.4	80.8	64.3	69.9	69.40
Profit	90.1	77.8	91.4	94.4	87.80
Food security of the family	98.9	98.0	98.6	98.8	98.50
Advice of extension officer	8.8	15.2	8.6	7.2	10.20

Source: Field Survey, 2013

Table D.2: Reasons of Growing Rice Crops (%)

Reason	Rajshahi	Naogaon	Kurigram	Thakurgaon	All
Food security for the family	100	100	97	98	99
Encouragement of extension worker	21	49	27	23	31
No alternative crops except rice	18	91	80	69	64
Price of rice is stable	11	20	23	13	17
Preservation of rice is easer	93	95	76	92	90
Lesser labor is required	96	68	69	55	72
Government purchase rice	32	32	67	36	40
Government provide subsidy in rice	12	9	24	1	11
Land is more suitable for rice	7	3	----	39	12

Source : Field Survey, 2013

Table D.3: Reasons for not Growing Non- Rice Crops (%)

Reason	Marginal	Small	Medium	Large	all
Instable price	45	45	61	53	49
Problem in selling time	68	53	59	73	60
Vegetable gets rotten	92	95	96	93	94
Need excessive labor	91	92	89	93	91
Government imports a lot	9	22	14	-	16
Need more capital	8	7	5	-	7

Source : Field Survey, 2013

Appendix E: Tobit Regression

Determinants of Crop Diversification at Aggregate Level

Table E.1: Tobit Regression Using Entropy Index

Number of obs =343
LR chi^2(13) = 137.36
Prob> chi^2= 0.0000
Log likelihood = 68.201472
Pseudo R^2= 144.0951

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.026559	.007473	-3.55	0.000	-.0412597	-.0118583
HS	.0149952	.0054668	2.74	0.006	.004241	.0257493
NP	.008165	.0031131	2.62	0.009	.0020409	.0142891
AGE	-.0006359	.0009669	-0.66	0.511	-.0025379	.0012661
EDU	.0006864	.0028391	0.24	0.809	-.0048986	.0062714
TFI	.0005281	.000173	3.05	0.002	.0001878	.0008684
NFI	-.0007255	.0002353	-3.08	0.002	-.0011885	-.0002626
DRF	-.1198943	.0198953	-6.03	0.000	-.159032	-.0807566
DMF	-.0156665	.0044867	-3.49	0.001	-.0244927	-.0068403
EXC	-.0038083	.0047269	-0.81	0.421	-.013107	.0054905
IRR	-.4292413	.1137969	-3.77	0.000	-.6531001	-.2053826
CF	-.0192124	.0174852	-1.10	0.273	-.053609	.0151841
TE	-.1107462	.0186344	-5.94	0.000	-.1474035	-.074089
cons	.878632	.1207479	7.28	0.000	.6410994	1.116165
sigma	.1419742	.006539			.1291108	.1548377

Obs. summary: 82 left-censored observations at EI<=.2
261 uncensored observations
0 right-censored observations

Table E.2: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI\|.2<EI<1) (predict, e(.2, 1))= .38560398

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		x
FS	-.0169667	.00478	-3.55	0.000	-.026334	-.007599	2.14955
HS	.0095794	.00351	2.73	0.006	.002709	.01645	5.28863
NP	.005216	.00199	2.62	0.009	.001312	.00912	6.84257
AGE	-.0004062	.00062	-0.66	0.511	-.001618	.000805	43.207
EDU	.0004385	.00181	0.24	0.809	-.003116	.003993	4.97959
TFI	.0003374	.00011	3.05	0.002	.000121	.000554	172.338
NFI	-.0004635	.00015	-3.08	0.002	-.000758	-.000169	63.43148
DRF	-.0765921	.01277	-6.00	0.000	-.101623	-.051562	1.35073
DMF	-.0100082	.00286	-3.50	0.000	-.015609	-.004407	3.65539
EXC	-.0024328	.00302	-0.80	0.421	-.008358	.003492	2.67638
IRR	-.2742123	07274	-3.77	0.000	-.416786	-.131638	.851895
CF*	-.0121648	.01098	-1.11	0.268	-.033677	.009348	.358601
TE*	-.06704	.01078	-6.22	0.000	-.088171	-.045909	.35277

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.3: Tobit Regression Using Herfindahl Index

Number of obs = 343
LR $chi^2(13)$ = 132.55
Prob> chi^2 = 0.0000
Log likelihood = 14.097864
Pseudo R^2 = 1.2702

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	.031317	.0089148	3.51	0.001	.01378	.048854
HS	-.0150204	.0065402	-2.30	0.022	-.0278861	-.0021547
NP	-.0091499	.0037273	-2.45	0.015	-.0164823	-.0018176
AGE	.0005205	.0011575	0.45	0.653	-.0017565	.0027975
EDU	-.0004987	.0033963	-0.15	0.883	-.0071799	.0061825
TFI	-.0006577	.0002071	-3.18	0.002	-.001065	-.0002504
NFI	.0009209	.0002817	3.27	0.001	.0003668	.001475
DRF	.135004	.0236723	5.70	0.000	.0884363	.1815718
DMF	.0212901	.0053565	3.97	0.000	.0107529	.0318274
EXC	.0018793	.0056604	0.33	0.740	-.0092557	.0130144
IRR	.5559852	.1359981	4.09	0.000	.2884527	.8235177
CF	.0182751	.0209193	0.87	0.383	-.0228769	.059427
TE	.123399	.0222369	5.55	0.000	.0796551	.1671428
cons.	-.0783363	.1444091	-0.54	0.588	-.3624148	.2057422
sigma	.1705775	.0079446			.1549491	.186206

Obs. summary: 0 left-censored observations
261 uncensored observations
82 right-censored observations at HI>=.8

Table E.4: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8))= .55351451

variabl	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	.0217979	.00621	3.51	0.000	.009619	.033977	2.14955
HS	-.0104548	.00456	-2.29	0.022	-.019401	-.001509	5.28863
NP	-.0063687	.0026	-2.45	0.014	-.011461	-.001277	6.84257
AGE	.0003623	.00081	0.45	0.653	-.001217	.001942	43.207
EDU	-.0003471	.00236	-0.15	0.883	-.00498	.004286	4.97959
TFI	-.0004578	.00014	-3.17	0.002	-.000741	-.000175	172.338
NFI	.000641	.0002	3.27	0.001	.000256	.001026	63.43148
DRF	.0939684	.01655	5.68	0.000	.061525	.126411	1.35073
DMF	.0148188	.00372	3.98	0.000	.007525	.022113	3.65539
EXC	.0013081	.00394	0.33	0.740	-.006417	.009033	2.67638
IRR	.3869886	.09483	4.08	0.000	.201121	.572857	.851895
CF*	.0126424	.01438	0.88	0.379	-.01555	.040835	.358601
TE*	.0820332	.01419	5.78	0.000	.054224	.109843	.35277

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Determinants of Crop Diversification byDistrict wise

Table E.5: Tobit Regression Using Entropy Index (Rajshahi District)

Number of obs = 91
LR $chi^2(13)$ = 37.85
Prob> chi^2 = 0.0003
Log likelihood = 25.95205
Pseudo R^2 = -2.6942

EI	coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.0610482	.0219966	-2.78	0.007	-.1048401	-.0172564
HS	.0132806	.0126288	1.05	0.296	-.0118614	.0384227
NP	.0194008	.0064534	3.01	0.004	.0065531	.0322484
AGE	-.002098	.0018131	-1.16	0.251	-.0057077	.0015116
EDU	-.0020434	.005657	-0.36	0.719	-.0133055	.0092188
TFI	-.0000755	.0003623	-0.21	0.836	-.0007967	.0006458
NFI	.000264	.000444	0.59	0.554	-.00062	.0011479
DRF	-.0479246	.0617096	-0.78	0.440	-.170779	.0749299
DMF	-.0061218	.0111958	-0.55	0.586	-.0284109	0161673
EXC	-.0080802	.0068509	-1.18	0.242	-.0217193	.0055589
IRR	-.8760463	.2300741	-3.81	0.000	-1.334089	-.418004
CF	.017666	.0347925	0.51	0.613	-.0516004	.0869325
TE	.0326583	.0711156	0.46	0.647	-.108922	.1742386
cons	1.315746	.2426774	5.42	0.000	.8326121	1.798879
sigma	.1411132	.011921			.1173802	.1648461

Obs. summary: 14 left-censored observations at EI<=.2
77 uncensored observations
0 right-censored observations

Table E.6: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .48196483

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	-.0532818	.01928	-2.76	0.006	-.09107	-.015493	1.806264
HS	.0115911	.01102	1.05	0.293	-.009999	.033181	5.31758
NP	.0169326	.00564	3.00	0.003	.005872	.027994	7.26593
AGE	-.0018311	.00158	-1.16	0.247	-.004933	.00127	39.3941
EDU	-.0017834	.00494	-0.36	0.718	-.01146	.007893	5.05495
TFI	-.0000659	.00032	-0.21	0.835	-.000686	.000554	152.863
NFI	.0002304	.00039	0.59	0.552	-.000529	.00099	50.6274
DRF	-.0418277	.05386	-0.78	0.437	-.1474	.063745	1.09945
DMF	-.005343	.00977	-0.55	0.585	-.024497	.013811	4.43407
EXC	-.0070522	.00598	-1.18	0.238	-.018764	.00466	2.24176
IRR	-.764597	.20152	-3.79	0.000	-1.15958	-.369617	.848462
CF*	.0154556	.0305	0.51	0.612	-.044319	.07523	.406593
TE*	.0290833	.06444	0.45	0.652	-.097221	.155387	.065934

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.7: Tobit Regression Using Herfindahl Index(Rajshahi District)

Number of obs = 91
LR $chi^2(13)$ = 33.14
Prob> chi^2= 0.0016
Log likelihood = 14.516118
Pseudo R^2 = 8.0640

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	.0635309	.0252273	2.52	0.014	.0133072	.1137546
HS	-.0206568	.0144676	-1.43	0.157	-.0494595	.0081459
NP	-.0209682	.0074007	-2.83	0.006	-.0357018	-.0062346
AGE	.001968	.0020771	0.95	0.346	-.0021673	.0061032
EDU	.0012616	.0064862	0.19	0.846	-.0116514	.0141746
TFI	.0001345	.0004146	0.32	0.746	-.0006908	.0009599
NFI	-.0002831	.0005086	-0.56	0.579	-.0012956	.0007295
DRF	.0638472	.0708207	0.90	0.370	-.0771459	.2048404
DMF	.0047239	.0128326	0.37	0.714	-.0208238	.0302717
EXC	.0087131	.0078409	1.11	0.270	-.0068969	.024323
IRR	.9250157	.2636538	3.51	0.001	.4001212	1.44991
CF	-.0207823	.0399132	-0.52	0.604	-.1002434	.0586788
TE	-.0622621	.081519	-0.76	0.447	-.2245539	.1000297
cons	-.3823456	.2779165	-1.38	0.173	-.9356349	.1709436
sigma	.1620446	.0137439			.1346826	.1894067

Obs. summary: 0 left-censored observations
77 uncensored observations
14 right-censored observations at HI>=.8

Table E.8: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .45873823

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	.0558665	.02228	2.51	0.012	.012205	.099528	1.806264
HS	-.0181648	.01272	-1.43	0.153	-.043097	.006768	5.31758
NP	-.0184386	.00652	-2.83	0.005	-.031225	-.005652	7.26593
AGE	.0017306	.00183	0.95	0.343	-.001849	.00531	39.3941
EDU	.0011094	.0057	0.19	0.846	-.010069	.012288	5.05495
TFI	.0001183	.00036	0.32	0.746	-.000596	.000833	152.4363
NFI	-.0002489	.00045	-0.56	0.578	-.001125	.000628	50.6274
DRF	.0561447	.0623	0.90	0.367	-.065964	.178253	1.09945
DMF	.004154	.01128	0.37	0.713	-.017964	.026272	4.43407
EXC	.0076619	.00689	1.11	0.266	-.005846	.02117	2.24176
IRR	.8134218	.23273	3.50	0.000	.357285	1.26956	.848462
CF*	-.0183018	.03518	-0.52	0.603	-.087257	.050653	.406593
TE*	-.0556768	.07354	-0.76	0.449	-.199817	.088463	.065934

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.9: Tobit Regression Using Entropy Index (Naogaon District)

Number of obs = 98
LR $chi^2(13)$ = 50.53
Prob> chi^2 = 0.0000
Log likelihood= 45.900819
Pseudo R^2 = -1.2244

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.0249059	.0133283	-1.87	0.065	-.051406	.0015943
HS	-.0063815	.0097547	-0.65	0.515	-.0257764	.0130134
NP	-.0036093	.0056896	-0.63	0.528	-.0149218	.0077032
AGE	-.0027409	.0013342	-2.05	0.043	-.0053936	-.0000882
EDU	-.0054664	.003364	-1.62	0.108	-.012155	.0012221
TFI	.0008082	.0003615	2.24	0.028	.0000896	.0015269
NFI	-.000869	.0004299	-2.02	0.046	-.0017237	-.0000144
DRF	-.0107662	.0218319	-0.49	0.623	-.0541739	.0326416
DMF	-.0200178	.0049067	-4.08	0.000	-.0297738	-.0102619
EXC	-.0035715	.0094747	-0.38	0.707	-.0224098	.0152667
IRR	-.4081994	.1452288	-2.81	0.006	-.6969531	-.1194457
CF	-.0567045	.0278853	-2.03	0.045	-.1121481	-.001261
TE	.034701	.0244587	1.42	0.160	-.0139295	.0833315
cons	.9216457	.1559338	5.91	0.000	.6116075	1.231684
sigma	.0872834	.007992			.071393	.1031737

Obs. summary: 31 left-censored observations at EI<=.2
67 uncensored observations
0 right-censored observations

Table E.10: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .29888569

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	-.0137726	.00736	-1.87	0.061	-.028198	.000653	1.91684
HS	-.0035289	.00539	-0.65	0.512	-.014088	007031	5.16449
NP	-.0019959	.00315	-0.63	0.526	-.008165	.004173	6.80673
AGE	-.0015157	.00075	-2.03	0.042	-.002978	-.000053	42.419
EDU	-.0030229	.00187	-1.62	0.106	-.006685	.000639	4.82612
TFI	.0004469	.0002	2.23	0.026	.000055	.000839	151.646
NFI	-.0004806	.00024	-2.01	0.044	-.000948	-.000013	63.41367
DRF	-.0059536	.01207	-0.49	0.622	-.029609	.017702	1.59439
DMF	-.0110696	.00271	-4.08	0.000	-.016389	-.005751	4.47449
EXC	-.001975	.00525	-0.38	0.707	-.012255	.008305	3.12265
IRR	-.225729	.08077	-2.79	0.005	-.38403	-.067428	.86
CF*	-.0282609	.01259	-2.24	0.025	-.052943	-.003579	.193878
TE*	.0195257	.01405	1.39	0.165	-.008012	.047064	.418367

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.11: Tobit Regression Using Herfindahl Index (Naogaon District)

Number of obs = 98
LR $chi^2(13)$ = 51.97
Prob> chi^2= 0.0000
Log likelihood = 21.759027
Pseudo R^2= 6.1518

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	.0382186	.018172	2.10	0.038	.0020879	.0743494
HS	.0062897	.01308	0.48	0.632	-.0197169	.0322963
NP	.0046763	.0077091	0.61	0.546	-.0106513	.020004
AGE	.0027191	.0018222	1.49	0.139	-.0009039	.0063421
EDU	.0051143	.0045906	1.11	0.268	-.0040131	.0142417
TFI	-.0011998	.00049	-2.45	0.016	-.002174	-.0002255
NFI	.0012205	.0005803	2.10	0.038	.0000667	.0023743
DRF	.0144811	.0298321	0.49	0.629	-.0448331	.0737953
DMF	.0317794	.0067102	4.74	0.000	.0184377	.0451211
EXC	.0006259	.0129559	0.05	0.962	-.0251339	.0263857
IRR	.4783045	.1971131	2.43	0.017	.0863909	.8702182
CF	.0644783	.0381493	1.69	0.095	-.0113726	.1403293
TE	-.0468287	.0334736	-1.40	0.165	-.1133832	.0197258
cons	-.0837296 .	2115113	-0.40	0.693	-.5042708	.3368116
sigma	.1202014	.0112305			.0978722	.1425306

Obs. summary: 0 left-censored observations
67 uncensored observations
31 right-censored observations at HI>=.8

Table E.12: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .64439896

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	.0241893	.0115	2.10	0.035	.001659	.04672	1.91684
HS	.0039809	.00827	0.48	0.630	-.012233	.020195	5.16449
NP	.0029598	.00488	0.61	0.544	-.006607	.012526	6.80673
AGE	.001721	.00116	1.48	0.138	-.000553	.003994	42.419
EDU	.003237	.00291	1.11	0.266	-.002467	.008941	4.82612
TFI	-.0007594	.00031	-2.44	0.015	-.001368	-.00015	151.646
NFI	.0007725	.00037	2.10	0.036	.000051	.001494	63.414
DRF	.0091654	.01888	0.49	0.627	-.027837	.046168	1.59439
DMF	.0201138	.00428	4.70	0.000	.011724	.028503	4.47449
EXC	.0003961	.0082	0.05	0.961	-.015677	.01647	3.12265
IRR	.3027282	.12525	2.42	0.016	.057252	.548204	.86
CF*	.0377131	.02065	1.83	0.068	-.002752	.078178	.193878
TE*	-.0300762	.02187	-1.38	0.169	-.072935	.012783	.418367

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.13: Tobit Regression Using Entropy Index (Kurigram District)

Number of obs = 71
LR $chi^2(13)$ = 34.80
Prob> chi^2 = 0.0009
Log likelihood = 34.846836
Pseudo R^2= -0.9973

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.0682316	.025066	-2.72	0.009	-.1184066	-.0180566
HS	.0011602	.0116504	0.10	0.921	-.0221606	.0244811
NP	.0126005	.0068348	1.84	0.070	-.0010809	.0262819
AGE	-.0006012	.0014436	-0.42	0.679	-.0034908	.0022884
EDU	-.0020772	.0039409	-0.53	0.600	-.0099658	.0058113
TFI	.0002828	.000314	0.90	0.371	-.0003457	.0009113
NFI	-.0004658	.0004042	-1.15	0.254	-.0012749	.0003432
DRF	-.0307192	.0263503	-1.17	0.248	-.0834651	.0220267
DMF	-.009076	.0213573	-0.42	0.672	-.0518273	.0336753
EXC	.0050323	.0094962	0.53	0.598	-.0139763	.024041
IRR	-.7579446	.1886159	-4.02	0.000	-1.1355	-.3803888
CF	-.0323739	.0283012	-1.14	0.257	-.0890249	.0242771
TE	-.0261327	.0256827	-1.02	0.313	-.0775421	.0252768
cons	1.106724	.2199845	5.03	0.000	.6663766	1.54707
sigma	.0912144	.0095728			.0720524	.1103765

Obs. summary: 20 left-censored observations at EI<=.2
51 uncensored observations
0right-censored observations

Table E.14: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .30826537

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	-.0396201	.0137	-2.89	0.004	-.066468	-.012772	2.08142
HS	.0006737	.00677	0.10	0.921	-.012586	.013933	5.38535
NP	.0073168	.00388	1.88	0.059	-.000291	.014925	5.52789
AGE	-.0003491	.00084	-0.42	0.676	-.001989	.001291	46.3717
EDU	-.0012062	.00229	-0.53	0.598	-.00569	.003278	5.02634
TFI	.0001642	.00018	0.91	0.361	-.000188	.000516	156.932
NFI	-.0002705	.00023	-1.17	0.243	-.000725	.000184	57.2712
DRF	-.0178377	.01523	-1.17	0.242	-.047696	.01202	1.51479
DMF	-.0052702	.0124	-0.42	0.671	-.029578	.019038	2.89437
EXC	.0029221	.0055	0.53	0.595	-.007848	.013693	2.42554
IRR	-.4401165	.1111	-3.96	0.000	-.65786	-.222373	.849437
CF*	-.0182174	.01552	-1.17	0.240	-.048636	.012201	.323944
TE*	-.0152239	.01503	-1.01	0.311	-.044678	.01423	.521127

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.15: Tobit Regression Using Herfindahl Index (Kurigram District)

Number of obs = 71
LR $chi^2(13)$ = 33.20
Prob> chi^2 = 0.0016
Log likelihood = 16.488763
Pseudo R^2 = 148.6341

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	.0887798	.0322594	2.75	0.008	.0242057	.153354
HS	.0040214	.0160984	0.25	0.804	-.0282031	.036246
NP	-.017827	.009296	-1.92	0.060	-.036435	.0007811
AGE	.0006432	.0019925	0.32	0.748	-.0033452	.0046316
EDU	.0018651	.0054598	0.34	0.734	-.0090638	.0127941
TFI	-.0005636	.0004252	-1.33	0.190	-.0014147	.0002874
NFI	.0008248	.0005542	1.49	0.142	-.0002846	.0019343
DRF	.0422668	.0363482	1.16	0.250	-.030492	.1150256
DMF	.0106017	.0296716	0.36	0.722	-.0487924	.0699958
EXC	-.0072511	.0131506	-0.55	0.583	-.0335749	.0190727
IRR	.9616631	.2618276	3.67	0.001	.4375583	1.485768
CF	.0394039	.0392154	1.00	0.319	-.0390941	.117902
TE	.0358253	.0356686	1.00	0.319	-.0355731	.1072237
cons	-.3754727	.3046646	-1.23	0.223	-.9853252	.2343797
sigma	.1272709	.0135208			.100206	.1543357

Obs. summary: 0 left-censored observations
51 uncensored observations
20 right-censored observations at HI>=.8

Table E.16: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .63142274

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	.0574228	.01987	2.89	0.004	.018472	.096373	2.08142
HS	.0026011	.01041	0.25	0.803	-.017809	.023011	5.38535
NP	-.0115305	.00591	-1.95	0.051	-.023122	.000061	5.52789
AGE	.000416	.00129	0.32	0.747	-.002107	.002939	46.3717
EDU	.0012064	.00353	0.34	0.733	-.005713	.008126	5.02634
TFI	-.0003645	.00027	-1.35	0.179	-.000896	.000167	156.932
NFI	.0005335	.00035	1.50	0.133	-.000162	.001229	57.2712
DRF	.0273381	.02343	1.17	0.243	-.018591	.073267	1.51479
DMF	.0068572	.01919	0.36	0.721	-.030756	.04447	2.89437
EXC	-.00469	.00848	-0.55	0.580	-.021315	.011935	2.42554
IRR	.6220033	.1709	3.64	0.000	.28705	.956956	.849437
CF*	.0248515	.02419	1.03	0.304	-.022553	.072256	.323944
TE*	.023233	.02321	1.00	0.317	-.022259	.068725	.521127

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.17: Tobit Regression Using Entropy Index (Thakurgaon District)

Number of obs = 83
LR $chi^2(13)$ = 82.51
Prob> chi^2 = 0.0000
Log likelihood = 52.048063
Pseudo R^2 = -3.8216

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.0449234	.0124004	-3.62	0.001	-.0696552	-.0201915
HS	-.004523	.0095677	-0.47	0.638	-.0236051	.0145591
NP	.0256801	.0076658	3.35	0.001	.0103911	.0409691
AGE	.00027	.0015267	0.18	0.860	-.0027749	.0033149
EDU	-.006674	.0047494	-1.41	0.164	-.0161463	.0027983
TFI	.0000963	.0002102	0.46	0.648	-.0003229	.0005154
NFI	-.0007221	.0002929	-2.47	0.016	-.0013063	-.000138
DRF	-.0764606	.0546199	-1.40	0.166	-.1853966	.0324754
DMF	-.066304	.014614	-4.54	0.000	-.0954506	-.0371573
EXC	.0155501	.0120539	1.29	0.201	-.0084906	.0395908
IRR	-.3352933	.1737603	-1.93	0.058	-.6818473	.0112607
CF	-.0096369	.0229757	-0.42	0.676	-.0554604	.0361867
TE	-.0065576	.0360919	-0.18	0.856	-.0785406	.0654254
cons.	.8969185	.2032802	4.41	0.000	.4914889	1.302348
sigma	.0912144	.0081815			.0748969	.107532

Obs. summary: 17 left-censored observations at EI<=.2
66 uncensored observations
0right-censored observations

Table E.18: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .35178049

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	-.0350898	.00982	-3.57	0.000	-.05434	-.015839	2.34468
HS	-.0035329	.00747	-0.47	0.636	-.018177	.011111	5.13361
NP	.0200588	.00606	3.31	0.001	.008177	.03194	5.82867
AGE	.0002109	.00119	0.18	0.860	-.002125	.002547	45.0602
EDU	-.0052131	.00372	-1.40	0.162	-.012512	.002086	5.03614
TFI	.0000752	.00016	0.46	0.647	-.000246	.000397	187.9336
NFI	-.0005641	.00023	-2.46	0.014	-.001013	-.000115	65.8193
DRF	-.0597237	.04264	-1.40	0.161	-.143303	.023855	1.19819
DMF	-.0517903	.0116	-4.46	0.000	-.074534	-.029047	2.48554
EXC	.0121463	.00943	1.29	0.198	-.00633	.030623	2.83133
IRR	-.2618988	.13569	-1.93	0.054	-.527852	.004054	.849398
CF*	-.0075348	.01799	-0.42	0.675	-.042796	.027726	.53012
TE*	-.0051153	.02811	-0.18	0.856	-.06021	.04998	.445783

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.19: Tobit Regression Using Herfindahl Index (Thakurgaon District)

Number of obs = 83
LR $chi^2(13)$ = 74.53
Prob> chi^2 = 0.0000
Log likelihood= 39.394193
Pseudo R^2 = -17.5028

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	.0428838	.0143043	3.00	0.004	.0143547	.0714129
HS	.0066068	.011021	0.60	0.551	-.0153739	.0285874
NP	-.0249738	.0088223	-2.83	0.006	-.0425692	-.0073784
AGE	-.0007948	.001756	-0.45	0.652	-.004297	.0027074
EDU	.0068724	.0054483	1.26	0.211	-.0039939	.0177387
TFI	-.0001354	.0002419	-0.56	0.578	-.0006179	.0003471
NFI	.00075	.0003338	2.25	0.028	.0000844	.0014156
DRF	.1156497	.0626313	1.85	0.069	-.0092645	.2405638
DMF	.0779442	.016739	4.66	0.000	.0445593	.1113291
EXC	-.0158654	.0138923	-1.14	0.257	-.0435727	.0118418
IRR	.4030233	.1987876	2.03	0.046	.006554	.7994926
CF	.0012658	.0263413	0.05	0.962	-.0512703	.0538019
TE	.0005114	.0410836	0.01	0.990	-.0814274	.0824501
cons	-.0663921	.2339435	-0.28	0.777	-.5329777	.4001935
sigma	.1057719	.0096802			.0864654	.1250784

Obs. summary: 0 left-censored observations
66 uncensored observations
17right-censored observations at HI>=.8

Table E.20: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .58802177

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	.0375419	.01257	2.99	0.003	.012901	.062182	2.34468
HS	.0057838	.00965	0.60	0.549	-.013123	.02469	5.1261
NP	-.0218629	.00775	-2.82	0.005	-.037058	-.006668	5.8267
AGE	-.0006958	.00154	-0.45	0.651	-.003706	.002314	45.0602
EDU	.0060163	.00478	1.26	0.208	-.003348	.015381	5.03614
TFI	-.0001185	.00021	-0.56	0.576	-.000533	.000296	187.934
NFI	.0006566	.00029	2.25	0.025	.000084	.001229	65.8193
DRF	.1012435	.05482	1.85	0.065	-.006195	.208682	1.19819
DMF	.0682348	.01477	4.62	0.000	.039289	.097181	2.48554
EXC	-.0138891	.01216	-1.14	0.254	-.037731	.009953	2.83133
IRR	.3528197	.17392	2.03	0.042	.011942	.693697	.849398
CF*	.0011082	.02306	0.05	0.962	-.044097	.046313	.53012
TE*	.0004476	.03596	0.01	0.990	-.070035	.070931	.445783

(*) dy/dx is for discrete change of dummy variable from 0 to 1

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Determinants of Crop Diversification by Farmer wise

Table E.21: Tobit Regression Using Entropy Index (Marginal Farms)

Number of obs = 106
LR $chi^2(13)$ = 51.05
Prob> chi^2 = 0.0000
Log likelihood = 18.655557
Pseudo R^2 = 3.7153

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	-.5273395	.2566083	-2.06	0.043	-1.036913	-.0177662
HS	.018754	.0123395	1.52	0.132	-.0057499	.0432578
NP	.0060512	.0073121	0.83	0.410	-.0084692	.0205716
AGE	-.0023521	.002095	-1.12	0.264	-.0065124	.0018083
EDU	.0071303	.005567	1.28	0.203	-.0039246	.0181853
TFI	.0021058	.0009347	2.25	0.027	.0002496	.003962
NFI	-.0016729	.0009264	-1.81	0.074	-.0035125	.0001668
DRF	-.1235114	.0411302	-3.00	0.003	-.2051878	-.041835
DMF	-.0153063	.0094762	-1.62	0.110	-.0341242	.0035115
EXC	-.0098981	.0106303	-0.93	0.354	-.0310078	.0112116
IRR	-.7940127	.2892213	-2.75	0.007	-1.368349	-.2196765
CF	-.0378054	.0361979	-1.04	0.299	-.1096872	.0340764
TE	-.0819016	.0413671	-1.98	0.051	-.1640485	.0002452
cons	1.307238	.3236336	4.04	0.000	.6645656	1.94991
sigma	.1502023	.0123882			.1256017	.1748029

Obs. summary: 25 left-censored observations at EI<=.2
81 uncensored observations
0 right-censored observations

Table E.22: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1))= .39835424

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	-.3400353	.1659	-2.05	0.040	-.665199	-.014872	.43879
HS	.0120928	.00797	1.52	0.129	-.003535	.027721	4.74528
NP	.0039019	.00471	0.83	0.408	-.005337	.013141	5.14151
AGE	-.0015167	.00135	-1.12	0.261	-.004164	.00113	38.3943
EDU	.0045977	.00359	1.28	0.200	-.002432	.011628	5.13208
TFI	.0013578	.0006	2.25	0.024	.000175	.002541	122.745
NFI	-.0010787	.0006	-1.81	0.071	-.002248	.000091	60.7082
DRF	-.0796417	.02674	-2.98	0.003	-.13205	-.027234	1.34198
DMF	-.0098697	.00609	-1.62	0.105	-.021802	.002063	3.54245
EXC	-.0063824	.00689	-0.93	0.354	-.019878	.007113	2.15094
IRR	-.5119896	.18757	-2.73	0.006	-.879622	-.144358	.863113
CF*	-.023874	.0224	-1.07	0.287	-.06778	.020032	.320755
TE*	-.0491059	.02295	-2.14	0.032	-.09409	-.004122	.216981

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.23: Tobit Regression Using Herfindahl Index (Marginal Farms)

Number of obs = 106
LR $chi^2(13)$ = 53.58
Prob> chi^2 = 0.0000
Log likelihood = 5.2789561
Pseudo R^2 = 1.2454

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
FS	.6398355	.2964996	2.16	0.034	.051046	1.228625
HS	-.0214857	.0142462	-1.51	0.135	-.0497758	.0068044
NP	-.0071656	.0084456	-0.85	0.398	-.0239369	.0096057
AGE	.0033182	.0024173	1.37	0.173	-.001482	.0081185
EDU	-.0085714	.0064317	-1.33	0.186	-.0213434	.0042006
TFI	-.0024774	.0010767	-2.30	0.024	-.0046155	-.0003393
NFI	.002132	.001067	2.00	0.049	.0000132	.0042509
DRF	.1305014	.0473762	2.75	0.007	.0364217	.2245812
DMF	.0208201	.0108971	1.91	0.059	-.0008193	.0424596
EXC	.0053908	.0122678	0.44	0.661	-.0189706	.0297523
IRR	.9702675	.3342236	2.90	0.005	.3065656	1.633969
CF	.0412683	.0418014	0.99	0.326	-.0417409	.1242775
TE	.0919343	.0475568	1.93	0.056	-.0025041	.1863728
cons	-.5834686	.3733962	-1.56	0.122	-1.324959	.1580222
sigma	.173975	.014472			.1452365	.2027134

Obs. summary: 0 left-censored observations
81 uncensored observations
25 right-censored observations at HI>=.8

Table E.24: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .54376087

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
FS	.4516253	.21006	2.15	0.032	.039924	.863327	.4388
HS	-.0151656	.01008	-1.50	0.132	-.034918	.004587	4.74528
NP	-.0050578	.00596	-0.85	0.396	-.01674	.006625	5.14151
AGE	.0023422	.00171	1.37	0.170	-.001003	.005688	38.5943
EDU	-.0060501	.00454	-1.33	0.182	-.014943	.002843	5.13208
TFI	-.0017486	.00076	-2.30	0.022	-.003241	-.000256	122.745
NFI	.0015049	.00075	2.00	0.046	.000029	.002981	60.708
DRF	.0921139	.03368	2.74	0.006	.026109	.158119	1.34198
DMF	.0146958	.00767	1.92	0.055	-.000338	.02973	3.54245
EXC	.0038051	.00867	0.44	0.661	-.013196	.020806	2.15094
IRR	.6848594	.23771	2.88	0.004	.218953	1.15077	.863113
CF*	.0286414	.02853	1.00	0.315	-.027282	.084565	.320755
TE*	.0610118	.0295	2.07	0.039	.003195	.118828	.216981

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.25: Tobit Regression Using Entropy Index (Small Farms)

Number of obs = 146
LR $chi^2(13)$ = 71.60
Prob> chi^2 = 0.0000
Log likelihood = 41.019987
Pseudo R^2 = -6.8561

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	-.0677129	.0247003	-2.74	0.007	-.116569	-.0188567
HS	.0073933	.0079886	0.93	0.356	-.0084079	.0231944
NP	.0075626	.0045888	1.65	0.102	-.0015139	.0166391
AGE	.0001461	.0013614	0.11	0.915	-.0025467	.0028388
EDU	-.0008536	.0039507	-0.22	0.829	-.0086679	.0069607
TFI	.000299	.000251	1.19	0.236	-.0001975	.0007954
NFI	-.0005141	.000336	-1.53	0.128	-.0011788	.0001506
DRF	-.1259177	.029432	-4.28	0.000	-.1841331	-.0677023
DMF	-.0183366	.0058817	-3.12	0.002	-.0299704	-.0067028
EXC	-.007483	.0074677	-1.00	0.318	-.0222538	.0072878
IRR	-.3177465	.1627601	-1.95	0.053	-.6396796	.0041866
CF	.0070405	.0245855	0.29	0.775	-.0415887	.0556697
TE	-.1022915	.0253032	-4.04	0.000	-.1523402	-.0522427
cons	.9006028	.186652	4.83	0.000	.531411	1.269795
sigma	.1263988	.0089957			.1086056	.1441919

Obs. summary: 36 left-censored observations at EI<=.2
110 uncensored observations
0 right-censored observations

Table E.26: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .37190303

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	-.0448777	.0164	.151	0.006	-.07703	-.012725	1.8697
HS	.0049	.0053	0.93	0.355	-.005482	.015282	5.20548
NP	.0050122	.00305	1.64	0.100	-.000965	.010989	6.24658
AGE	.0000968	.0009	0.11	0.915	-.001671	.001865	44.5548
EDU	-.0005657	.00262	-0.22	0.829	-.005699	.004567	4.65753
TFI	.0001981	.00017	1.19	0.233	-.000128	.000524	145.588
NFI	-.0003407	.00022	-1.53	0.126	-.000777	.000095	53.075
DRF	-.0834538	.0195	-4.28	0.000	-.121682	-.045226	1.30274
DMF	-.0121529	.00388	-3.13	0.002	-.019762	-.004544	3.81712
EXC	-.0049595	.00496	-1.00	0.318	-.014685	.004766	2.22603
IRR	-.2105912	.10817	-1.95	0.052	-.422606	.001424	.855616
CF*	.004678	.01638	0.29	0.775	-.027427	.036783	.39726
TE*	-.0639517	.01511	-4.23	0.000	-.093568	-.034336	.342466

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.27: Tobit Regression Using Herfindahl Index (Small Farms)

Number of obs = 146
LR $chi^2(13)$ = 68.80
Prob> chi^2 = 0.0000
Log likelihood = 17.324287
Pseudo R^2 = 2.0145

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	.0759401	.0298224	2.55	0.012	.0169525	.1349278
HS	-.0057741	.0096351	-0.60	0.550	-.024832	.0132837
NP	-.0068092	.0055447	-1.23	0.222	-.0177764	.0041581
AGE	-.0009806	.001644	-0.60	0.552	-.0042323	.0022712
EDU	.0003041	.0047607	0.06	0.949	-.0091123	.0097206
TFI	-.0004688	.0003033	-1.55	0.125	-.0010688	.0001311
NFI	.0007323	.0004059	1.80	0.073	-.0000705	.0015351
DRF	.1499868	.035322	4.25	0.000	.0801213	.2198523
DMF	.025354	.0070894	3.58	0.000	.0113315	.0393766
EXC	.0049396	.0090196	0.55	0.585	-.0129008	.02278
IRR	.3255379	.1964023	1.66	0.100	-.0629382	.714014
CF	-.0078565	.0296692	-0.26	0.792	-.066541	.050828
TE	.11066	.0304691	3.63	0.000	.0503934	.1709267
cons	.0045926	.2250961	0.02	0.984	-.4406388	.449824
sigma	.1531766	.011021			.1313774	.1749758

Obs. summary: 0 left-censored observations
110 uncensored observations
36 right-censored observations at HI>=.8

Table E.28: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .56999416

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	.0547779	.02154	2.54	0.011	.012569096986		1.8697
HS	-.0041651	.00695	-0.60	0.549	-.017789	.009459	5.20548
NP	-.0049116	.004	-1.23	0.220	-.01276	.002937	6.24658
AGE	-.0007073	.00118	-0.60	0.551	-.00303	.001615	44.5548
EDU	.0002194	.00343	0.06	0.949	-.006512	.00695	4.65753
TFI	-.0003382	.00022	-1.55	0.122	-.000767	.000091	145.588
NFI	.0005282	.00029	1.80	0.071	-.000046	.001102	53.0753
DRF	.1081899	.02548	4.25	0.000	.058253	.158126	1.30274
DMF	.0182886	.0051	3.58	0.000	.008289	.028288	3.81712
EXC	.0035631	.00651	0.55	0.584	-.009201	.016327	2.22603
IRR	.23482	.1419	1.65	0.098	-.043308	.512948	.855616
CF*	-.0056787	.02149	-0.26	0.792	-.047801	.036443	.39726
TE*	.0760954	.02012	3.78	0.000	.03667	.115521	.342466

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.29: Tobit Regression Using Entropy Index (Medium and Large Farms)

Number of obs = 91
LR chi^2(13) = 42.42
Prob> chi^2 = 0.0001
Log likelihood = 24.031455
Pseudo R^2 = -7.5238

EI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	-.0209377	.0113495	-1.84	0.069	-.0435327	.0016574
HS	.0207613	.0088811	2.34	0.022	.0030804	.0384421
NP	.0090962	.0052825	1.72	0.089	-.0014204	.0196127
AGE	-.0014613	.0020922	-0.70	0.487	-.0056265	.002704
EDU	-.0054092	.0057738	-0.94	0.352	-.016904	.0060855
TFI	.0003364	.0002561	1.31	0.193	-.0001736	.0008463
NFI	-.0006718	.0003641	-1.84	0.069	-.0013967	.0000532
DRF	-.1404051	.0355705	-3.95	0.000	-.2112205	-.0695897
DMF	-.0190919	.0111461	-1.71	0.091	-.041282	.0030983
EXC	.0067206	.007511	0.89	0.374	-.0082327	.0216739
IRR	-.306367	.2261628	-1.35	0.179	-.7566226	.1438885
CF	-.0041854	.0323472	-0.13	0.897	-.0685838	.060213
TE	-.1182175	.0324277	-3.65	0.000	-.182776	-.0536589
cons	.8376331	.2346171	3.57	0.001	.3705463	1.30472
sigma	.1308246	.0116344			.1076624	.1539868

Obs. summary: 21 left-censored observations at EI<=.2
70 uncensored observations
0 right-censored observations

Table E.30: Marginal Effects after Tobit Regression Using Entropy Index

y = E(EI|.2<EI<1) (predict, e(.2, 1)) = .37710413

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	-.0138184	.00753	-1.84	0.066	-.028577	.00094	4.85143
HS	.0137019	.00594	2.31	0.021	.002068	.025336	6.05495
NP	.0060033	.0035	1.72	0.086	-.000857	.012863	9.78022
AGE	-.0009644	.00138	-0.70	0.485	-.003672	.001743	46.4176
EDU	-.00357	.00381	-0.94	0.349	-.011034	.003894	5.31868
TFI	.000222	.00017	1.31	0.190	-.00011	.000554	312.643
NFI	-.0004434	.00024	-1.83	0.067	-.000917	.00003	83.2198
DRF	-.0926641	.02363	-3.92	0.000	-.138969	-.046359	1.43791
DMF	-.0126002	.00735	-1.71	0.086	-.027003	.001803	3.52747
EXC	.0044354	.00496	0.89	0.371	-.005287	.014158	4.01099
IRR	-.2021952	.14904	-1.36	0.175	-.494306	.089915	.826044
CF*	-.002756	.02125	-0.13	0.897	-.044406	.038894	.340659
TE*	-.0787596	.02205	-3.57	0.000	-.121981	-.035538	.527473

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table E.31: Tobit Regression Using Herfindahl Index(Medium and Large Farms)

Number of obs = 91
LR $chi^2(13)$ = 38.59
Prob> chi^2 = 0.0002
Log likelihood = 6.9251116
Pseudo R^2 = 1.5598

HI	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FS	.021737	.0140689	1.55	0.126	-.0062721	.0497461
HS	-.0216859	.0110401	-1.96	0.053	-.0436651	.0002934
NP	-.0107587	.0065442	-1.64	0.104	-.0237872	.0022698
AGE	.0017766	.0025941	0.68	0.495	-.0033878	.0069411
EDU	.0078611	.0071574	1.10	0.275	-.0063881	.0221103
TFI	-.0003477	.000318	-1.09	0.278	-.0009808	.0002853
NFI	.0007431	.0004523	1.64	0.104	-.0001575	.0016436
DRF	.1708134	.0436795	3.91	0.000	.0838542	.2577727
DMF	.0245471	.0136824	1.79	0.077	-.0026923	.0517866
EXC	-.006608	.0093483	-0.71	0.482	-.0252191	.012003
IRR	.5133783	.2799284	1.83	0.070	-.0439162	1.070673
CF	.0011583	.0401094	0.03	0.977	-.0786933	.08101
TE	.1339768	.0402578	3.33	0.001	.0538297	.214124
cons	-.1619907	.2909241	-0.56	0.579	-.7411761	.4171947
sigma	.1630915	.0146697			.1338863	.1922968

Obs. summary: 0 left-censored observations
70 uncensored observations
21 right-censored observations at HI>=.8

Table E.32: Marginal Effects after Tobit Regression Using Herfindahl Index

y = E(HI|0<HI<.8) (predict, e(0, .8)) = .55512712

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
FS	.0156486	.01016	1.54	0.124	-.004268	.035566	4.85143
HS	-.0156118	.00802	-1.95	0.052	-.031325	.000102	6.05495
NP	-.0077453	.00473	-1.64	0.101	-.017013	.001522	9.78022
AGE	.001279	.00187	0.68	0.494	-.002383	.004941	46.4176
EDU	.0056593	.00515	1.10	0.272	-.004437	.015756	5.31868
TFI	-.0002503	.00023	-1.09	0.275	-.0007	.000199	312.643
NFI	.000535	.00033	1.64	0.102	-.000106	.001176	83.2198
DRF	.1229701	.03167	3.88	0.000	.060907	.185033	1.43791
DMF	.0176717	.00985	1.79	0.073	-.001628	.036971	3.52747
EXC	-.0047572	.00673	-0.71	0.480	-.017951	.008437	4.01099
IRR	.3695855	.20144	1.83	0.067	-.02523	.764401	.826044
CF*	.0008335	.02885	0.03	0.977	-.055711	.057378	.340659
TE*	.0968796	.02942	3.29	0.001	.039211	.154548	.527473

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Appendix F: Cost Benefit Analysis

Table F.1: Cost Benefit Analysis (Rajshahi)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12798	7881	10842	4916	1956	1.18
Wheat	13052	7021	10301	6031	2752	1.27
Maize	14456	8359	10796	6097	3660	1.34
Mustard	8988	5125	6625	3863	2363	1.36
Jute	12831	7841	10831	4990	1999	1.18
Pulses	9901	4320	5820	5581	4081	1.70
Spices	31630	14520	17494	17110	14135	1.81
Vegetables	35953	14853	19216	21099	16737	1.87

Source: Field survey, 2013.

GR =Gross Returns, TVC= Total variable cost, TC= Total cost, GM= Gross margin, NM= Net margin, BCR= Benefit cost ratio over total cost

Table F.2: Cost Benefit Analysis (Naogaon)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12293	7335	9777	4958	2516	1.26
Wheat	12303	6426	9303	5877	3001	1.32
Maize	18463	7655	10155	10808	8308	1.82
Mustard	8993	4247	5747	4746	3246	1.56
Jute	11399	7390	9869	4009	1530	1.16
Pulses	8500	4175	5675	4325	2825	1.50
Spices	29791	13584	16084	16207	13707	1.85
Vegetables	32818	14807	17808	18011	15011	1.84

Source: Field survey, 2013.

Table F.3: Cost Benefit Analysis (Kurigram)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12718	8187	10390	4531	2327	1.22
Wheat	11840	7033	9533	4808	2308	1.24
Maize	14013	9567	11066	4447	2948	1.27
Mustard	8331	4552	6052	3779	2279	1.38
Jute	13965	7424	9633	6541	4333	1.45
Spices	27963	13525	15963	14438	12000	1.75
Vegetables	29123	14846	17257	14278	11866	1.69

Source: Field survey, 2013.

Table F.4: Cost Benefit Analysis (Thakurgaon)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12399	7892	9835	4507	2564	1.26
Wheat	13573	7992	10064	5582	3509	1.35
Maize	15168	9165	10887	6003	4280	1.39
Mustard	8961	4589	6089	4372	2872	1.47
Jute	10123	7678	9678	2444	444	1.05
Pulses	8115	4261	5568	3855	2547	1.46
Spices	30683	14353	16253	16330	14430	1.89
Vegetables	28249	15371	17435	12878	10813	1.62

Source: Field survey, 2013.

Table F.5: Cost Benefit Analysis (Marginal Farmer)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12653	7735	10150	4918	2503	1.25
Wheat	13456	7414	10115	6042	3341	1.33
Maize	14830	8766	10767	6064	4063	1.38
Mustard	9130	4431	5931	4699	3199	1.54
Jute	12261	7578	10238	4683	2023	1.20
Pulses	9156	4356	5772	4801	3384	1.59
Spices	31210	14399	17196	16811	14014	1.81
Vegetables	32630	14782	17934	17848	14697	1.82

Source: Field survey, 2013.

Table F.6: Cost Benefit Analysis (Small Farmer)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12501	7769	10220	4732	2281	1.22
Wheat	12974	7389	9962	5585	3012	1.30
Maize	15197	8776	10841	6421	4356	1.40
Mustard	8811	4435	5935	4376	2876	1.48
Jute	12036	7662	10262	4375	1775	1.17
Pulses	9475	4293	5793	5183	3683	1.64
Spices	30027	14058	16713	15969	13314	1.80
Vegetables	32143	14892	18188	17251	13954	1.77

Source: Field survey, 2013.

Table F.7: Cost Benefit Analysis (Medium Farmer)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR (A/C)
Paddy	12465	7901	10234	4565	2231	1.22
Wheat	13053	7362	9913	5691	3140	1.32
Maize	14474	8998	10977	5476	3497	1.32
Mustard	9184	4520	6020	4664	3164	1.53
Jute	12514	7722	10304	4792	2210	1.21
Pulses	7375	3938	5313	3438	2063	1.39
Spices	32058	14033	16783	18024	15274	1.91
Vegetables	32233	15212	18152	17021	14081	1.78

Source: Field survey, 2013.

Table F.8: Cost Benefit Analysis (Large Farmer)

Crops	A	B	C	D	E	G
	GR	T VC	TC	G M (A-B)	NM (A-C)	BCR(A/C)
Paddy	12458	7767	10096	4690	2362	1.23
Wheat	12305	7163	9910	5142	2395	1.24
Maize	14420	9288	10788	5133	3633	1.34
Mustard	8414	4547	6047	3867	2367	1.39
Jute	11283	7635	10260	3648	1023	1.10
Pulses	8950	4200	5450	4750	3500	1.64
Spices	30293	14405	16805	15888	13488	1.80
Vegetable	31452	14704	17658	16748	13794	1.78

Source: Field survey, 2013.