EXPLORING TECHNICAL EFFICIENCY OF MAIZE CULTIVATION IN BANGLADESH: A CASE STUDY ON CHUADANGA DISTRICT

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CERTIFICATE

This is to certify that the thesis entitled ***"EXPLORING TECHNICAL EFFICIENCY OF MAIZE CULTIVATION IN BANGLADESH: A CASE STUDY ON CHUADANGA DISTRICT"*** *submitted to the Faculty of Agribusiness Management, Sher-e-Bangla Agricultural University, Sher-e- Bangla Nagar, Dhaka, in partial fulfilment of the requirements for the degree of* ***Master of Science (MS) in Agribusiness and Marketing,*** *embodies the result of a piece of bona fide research work carried out by* ***FATEMA-TUZ-ZOHURA, bearing Registration No. 15-06867*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by the Author.

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Dedicated to my Beloved Parents

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The Author

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ABSTRACT

In recent years, maize has emerged as a lucrative crop for Bangladeshi farmers, thanks to favorable environmental conditions characterized by abundant sunshine, well-fertilized soil and adequate moisture. This comprehensive study delves into various facets of maize farming including the socio-economic profile of farmers, profitability assessment, technical efficiency analysis, identification of influencing factors and resolution of encountered challenges. Focused on six villages within Begumpur and Baka unions, located in Chuadanga Sadar and Jibannagar upazilas of Chuadanga district, the study meticulously selected a representative sample of 60 maize farmers using a multi-sampling technique. In person interviews with respondents were conducted from December 2023 to January 2024 in order to gather data for the current study. To measure technical efficiency, the Cobb-Douglas stochastic frontier production function was employed. The bulk of maize farmers fall within the middle-aged demographic, constituting 50% of the respondents. Additionally, a significant proportion of these farmers have attained a secondary level of education. Moreover, the majority boast over a decade of experience in maize cultivation, with 41.67% reporting such tenure. Agriculture emerges as the primary occupation encompassing 88.30% of the respondents. Landholding patterns reveal that most farmers possess plots ranging from 2-5. Furthermore, irrigation practices are predominantly mechanized 83.30%. Lastly, a substantial 76,70% of respondents have not undergone any form of training. The profitability of maize cultivation was meticulously assessed through a profitability equation, revealing a total production cost of Tk. 205614.13 per hectare. Gross returns and gross margin stood at Tk. 329583.33 and Tk. 211543.70 per hectare respectively, resulting in a net return of Tk. 123969.20 per hectare. Impressively, the benefit-cost ratio (BCR) was calculated at 1.60, indicating that every Tk. invested in maize production generated Tk. 1.60 within the study area. Notably, parameters such as land preparation, pesticide cost, seed cost and human labor cost exhibited positive coefficients, with land preparation, pesticide and human labor being highly significant while seed cost was significantly affect the revenue at a 5 percent level. Further analysis revealed intriguing insights into factors affecting technical inefficiency. The inefficiency model exhibits no significant effect on technical efficiency and 38.3% farmer have technical efficiency level at 81-90%. However, despite the promising prospects, the study unearthed several challenges hampering maize production. These include labor shortages, susceptibility to natural calamities, inadequate irrigation facilities and a dearth of high-yielding hybrid maize varieties. Conclusively, the findings underscore the importance of tailored policies and programs by policymakers to address the specific needs and challenges confronting maize farmers. By doing so, these initiatives can significantly contribute to enhancing livelihoods, ensuring food security and fostering rural development within the region.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Bangladesh is an emerging nation with agriculture as the principal pillar of its economy. Agriculture serves as the prime catalyst driving Bangladesh's economic growth and has played an indispensable role in fostering socio-economic progress and sustainable development. It has facilitated the gradual betterment of both rural and overall economic conditions by ensuring food security, generating employment opportunities, nurturing human resources and alleviating poverty. In the fiscal year 2021-22, Bangladesh aimed for a targeted GDP growth rate of 7.25 percent which was notably higher than the 6.94 percent growth achieved in the previous fiscal year (BER, 2022). Among the total sectors of GDP in 2021-22 fiscal year, the growth of the agricultural sector slowed down by 2.20% to 11.50% (BER, 2022). With a total population of 165.2 million, Bangladesh stands as the 8th most populous country globally and experiences a population growth rate of 1.22 % and has a population density of 1119 persons per square kilometer (BBS, 2022). Being primarily an agriculturally based country more than 70% of the population and 40.6% of its labor force are directly or indirectly dependent on agriculture contributing 13.02% to the national GDP (BBS, 2021). In fiscal year 2021-22, the sectoral share of broad agriculture, industry and service was 11.50 percent, 37.07 percent and 51.44 percent respectively (figure 1.1) compared to the previous fiscal year's figures of 12.07 percent, 36.01 percent and 51.92 percent respectively (BER, 2022). Bangladesh being primarily reliant on agriculture, is acknowledged as one of the region’s most susceptible to the consequences of global warming and climate change and its exceptional geographic location, prevalence of floodplains, low elevation, high population density and heavy reliance on nature for resources and services contribute significantly to this vulnerability (KHANDOKER, et al., 2018). Many of the anticipated adverse effect of climate change, such as sea level rise, higher temperature, enhanced monsoon precipitation and an increase in drought intensity, will aggravate the existing stresses that already impede the development of Bangladesh, particularly by reducing food security (Quazi and Quddus, 2010).

Bangladesh is located in the subtropical monsoon region, which is characterized by seasonal variations in rainfall, humidity and temperature (Islam, 2004). Its land is suitable to cultivate different agricultural crops due to the agro-climatic zone (Uddin et al., 2015). The major crops are rice, wheat, maize, pulses, oilseeds, mango, jackfruit, litchi, banana, different types of vegetables etc. (Hasanuzzaman et al., 2014).

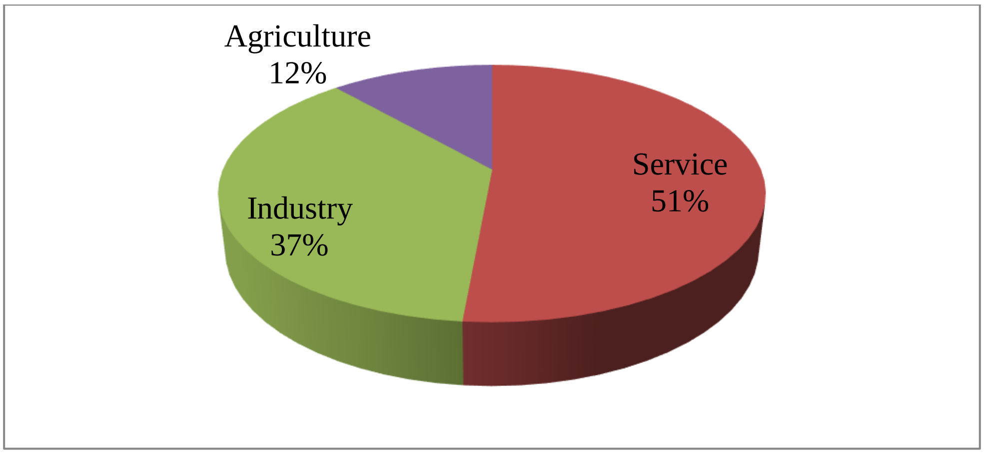

Figure 1.1: Contributions of three broad sectors to the country's GDP

Source: BER, 2022

In fiscal year 2021-22, the sectoral share of broad agriculture, industry and service was 11.50 percent, 37.07 percent and 51.44 percent respectively (figure 1.1) compared to the previous fiscal year's figures of 12.07 percent, 36.01 percent and 51.92 percent respectively (BER, 2022).

(In lakh MT.)

Table 1.1:Food Grains Production

Food Grains	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23***
Aus	22.89	21.34	27.09	27.20	30.12	32.85	32.45	36.90
Amon	134.83	136.56	139.94	140.55	155.02	144.38	149.58	163.45
Boro	189.38	180.16	195.76	203.89	201.81	198.85	209.77	215.34
Total Rice	**347.10**	**338.06**	**362.79**	**373.63**	**386.95**	**376.08**	**391.80**	**415.69**
Wheat	13.48	13.12	10.99	11.48	12.46	10.85	10.86	11.60
Maize	27.59	35.78	38.93	46.99	54.02	56.63	56.30	57.68
Total	**388.17**	**386.96**	**412.71**	**432.11**	**453.44**	**443.56**	**458.96**	**484.98**

Source: BBS,2022

Over the last few years, there has been an increasing trend in food production. Food grains production stood at around 458.96 lakh metric tonnes (MT) (BBS, 2022) & estimated production 484.98 lakh metric tonnes (Table 1.1).

1.2 Present Status of Maize in Bangladesh

Maize, one of the world's oldest crops, is renowned for its versatility, high grain yield, and numerous applications while its expansion in Bangladesh faced challenges during the 1960s due to the government's emphasis on promoting a rice-based Green Revolution, recent years have witnessed a remarkable surge in maize production and yield (Rahman, et al., 2016).

Maize (*Zea mays* L.) is one of Bangladesh's major crops cultivated in the Kharif and Rabi seasons and grows well in sandy loam and heavy clay loam soils and suitable temperatures between 12°C and 29°C (Hasnain, et al., 2017). It is used as a raw material in food processing industries to prepare food for human consumption and raw maize is used as livestock feed. Bangladesh has the opportunity to increase the maize cultivation area and yield for its soil conditions, topography, and climate (Hossain et. Al., 2015). Maize production has more than doubled as a result of improved seed varieties, chemical fertilizers, pesticides, and irrigation facilities (Hoque, et al., 2021). As a new crop, maize is being grown in different parts of the country because of its higher productivity and profitability.

Maize cultivation area expanded from 1,16,8000 acres in 2019-20 to 1,18,2000 acres in 2021-22. The yield rate also rose from 3,438 kg per acre to 3,605 kg per acre during the same period. Consequently, the total maize production volume reached 4,26,2000 metric tonnes in 2021-22 (Table 1.2 and 1.3).

Table 1.2: Area, yield rate and Production of crops 2019-20 to 2021-22

Crop	**2019-2020**			**2020-2021**			**2021-2022**		
	Area 000' acres	Per acre yield (kg)	Production 000' M. tonnes	Area 000' acres	Per acre yield (kg)	Production 000' M. tonnes	Area 000' acres	Per acre yield (kg)	Production 000' M.tonnes
Maize	1168	3438	4016	1186	3471	4116	1182	3605	4262

Source: BBS, 2022

Table 1.3:Indices and area production of Maize (Base 1984-85=100)

Crop	Area					Production				
	2017-18	2018-19	2019-20	2020-21	2021-22	2017-18	2018-19	2019-20	2020-21	2021-22
Maize	10617	11806	12505	12720	12678	100554	109154	122792	125885	130332

Source: BBS, 2022

Total area under production of kharif maize and rabi maize separately were 41 acres and 1,15,435 acres in Chuadanga district in 2021-22. Total production were 84 M. Ton and 5,48,051.67 M. Ton for kharif maize in Chuadanga dictrict in 2021-22. In case of rabi maize the amount were much more higher and these were 4,88,639 M. Ton in same year (Table 1.4 and 1.5).

Table 1.4: Area and production of Kharif Maize in Chuadanga district.

District	2019-20		2020-21		2021-22	
	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M.tonnes)
Chuadanga	72	166	49	98	41	84
Bangladesh	192426	487277	206440.73	552764.08	197283.40	548051.67

Source: BBS, 2022

Table 1.5:Area and production of Rabi Maize in Chuadanga district.

District	2019-20		2020-21		2021-22	
	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M.tonnes)
Chuadanga	1,19,370	5,03,179	1,17,887	5,17,165	1,15,435	4,88,639
Bangladesh	973167.80	3528029.08	979210.77	3563674.38	984415.51	3713793.07

Source: BBS, 2022

Total area under production of kharif maize and rabi maize were 1,15,476 acres in Chuadanga district whereas total production were 4,88,723 M. Ton for kharif maize in Chuadanga dictrict in 2021-22 (Table 1.6).

Table 1.6: Area and production of Maize (Rabi & Kharif) in Chuadanga district.

District	2019-20		2020-21		2021-22	
	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M. tonnes)	Area (acres)	Production (M.tonnes)
Chuadanga	1,19,442	5,03,345	1,17,936	5,17,263	1,15,476	4,88,723

Source: BBS, 2022

1.3 Nutritive value of Maize

Maize's status as a staple food worldwide is due to its nutritional value containing many starches as well as proteins and fats. Maize contains vitamin B, folic acid, vitamin C, pro-vitamin A etc. It contains many important nutrients for the human body including it is also rich in phosphorus, magnesium, manganese, zinc, copper, iron, selenium and contains trace amounts of potassium and calcium. Although maize is low in fat and sodium, it is a good source of dietary fiber and protein. However, maize lacks essential amino acids such as lysine and tryptophan should be included in the diet. Notably, maize exhibits significant variation in carotenoid content including beta- carotene, a precursor to vitamin a which is important for vision and antioxidant activity. Maize, a vital cereal crop globally, boasts high productivity and nutritional value serving as human food, poultry feed, and livestock fodder. Primarily utilized as poultry feed (over 90%), also supports the fish sector and human food products (Hasan, 2008).

1.4 Statement of the problem

Maize is a staple crop in Bangladesh's agricultural sector which serves as the primary source of income for many individuals and families. Initially farmers prioritize the basic needs of their households by cultivating various crops. However, they also engage in the cultivation of cash crops such as cotton, jute, tea and maize which not only fulfill domestic demand but also contribute to export earnings. Among these cash crops, maize holds a prominent position globally due to its high productivity and nutritional value, serving as a valuable source of food for humans and feed for poultry and livestock. The cultivation of maize plays a crucial role in Bangladesh's national economy, contributing significantly to agricultural output and rural livelihoods. Despite its importance, there is a noticeable gap in comprehensive studies regarding the economics of maize production. This gap includes a lack of detailed cost analysis and profitability assessment which are essential for farmers to make informed decisions and for policymakers to formulate effective agricultural policies. Understanding the factors that influence the success of maize is paramount for both farmers and planners. By identifying these factors, stakeholders can implement strategies to enhance agricultural productivity and promote sustainable development in the sector. The process of increasing output solely through enhancing efficiency cannot persist indefinitely, as the frontier output level will be attained under ideal technically efficient circumstances. Therefore, these research aims to address this gap by conducting through evaluation of the profitability of maize farming. This assessment will provide valuable information to help support informed policy decisions to effectively manage maize farms and support the long term sustainability of Bangladesh's agricultural sector.

1.5 Key Research Questions

a) What is the level of technical efficiency in maize production?

b) What are the factors that influence the technical efficiency of maize production?

c) Is maize a profitable crop at farm level?

d) What are the problems that faced by the maize farmers?

1.6 Justification of the study

The production of maize can be improved through developing technical efficiency among the farmers. This study will focus on Chuadanga district, which is located in the tropics cancer region and where farmers are becoming more interested in cultivating maize because of its increasing demand as a raw material in the local food industry and as feed for livestock. If some initiatives are taken by the government to produce maize efficiently through proper knowledge sharing with the farmers, then the import gap will be decreased as well as the balance of payment will be increased. The government of Bangladesh is focused on exporting maize products through market expansion and its demand is increasing gradually in domestic and foreign markets besides the government of Bangladesh, which provides subsidies to the farmers for achieving product efficiency by using different inputs such as seeds, fertilizers, irrigation etc. We need to increase maize production to meet the home demand and export it to the foreign market, which will create employment opportunities and reduce poverty. Bangladesh has trouble keeping enough foreign currency on hand, so we should use the agriculture industry and encourage maize production to make up for it.

1.7 Objectives of the study

a. To demonstrate the socio-economic profile of maize farmers;
b. To estimate the profitability from maize production;
c. To assess the level of technical efficiency of maize production;
d. To identify the factors affecting technical efficiency in maize production;
e. To identify the problems that faced by the maize farmers.

1.8 Organization of the study

This thesis is structured into eight chapters, each carefully arranged to provide a systematic exploration of the research topic. Chapter 1 lays the foundation by introducing the study's purpose and objectives. Chapter 2 presents a comprehensive review of existing literature relevant to the research topic. Chapter 3 outlines the methodology employed in conducting the study, detailing research design and data collection methods. Chapter 4 offers a brief review of the socioeconomic profiles of the sampled farmers. Chapter 5 delves into the profitability aspects of Maize production, analyzing its economic viability. Chapter 6 investigates the technical efficiency of maize production methods employed by farmers. Chapter 7 examines the challenges encountered by maize growers, ranging from environmental to market related issues. Finally, chapter 8 summarizes key findings, draws conclusions and provides actionable recommendations based on the study’s outcomes.

CHAPTER 2

REVIEW OF LITERATURE

To obtain facts and data related to the proposed study, it is important to read the literature. Along with the current research, this chapter presents an overview of few associated papers. Maize cultivation in Bangladesh become investigated in a restricted range of socioeconomic studies, which found out that it's miles an extra worthwhile crop than rice (Hussain et al. 1995), (Fokhrul, 1995) and mustard (Haque, 1999). It has been shown that few studies have been performed at the technical efficiency of maize cultivation in Bangladesh. Several of those research won't be completely applicable to the existing study. However the experience and data are useful to provide a roadmap for addressing the upcoming research challenge and proving the new findings. Below are outlined some of the research findings that have been conducted in the past that are relevant to the present research.

Adzawla (2021) investigated the analysis of climate adaptation strategies and their effects on maize farmer's in Northern Ghana's technical efficiency that using cross-sectional data collected from 619 maize farmers in Northern Ghana using a pre-tested questionnaire. In this study, a multi-stage sampling technique was used. For the analysis, descriptive statistics and the Cobb-Douglas stochastic frontier model were used here. The researchers identified several climate adaptation strategies adopted by the farmers including row planting (52.8%), changing planting dates (82.6%), mixed farming (54.8%), refilling (51.4%), and intercropping (43.9%). According to the results of the survey, Climate change strategies have a significant effect on increasing maize production. However, only crop rotation and row planting had a significant effect on maize farmer's technical efficiency. Maize production was influenced by farm size, labor, and seed quality.

Bozoglu (2007) conducted the technical efficiency of sample vegetable farms and identify factors contributing to technical inefficiency in the Samsun province of Turkey using Cobb-Douglas stochastic frontier analysis and collected farm level data from interviews with farm managers from 75 randomly selected farms. The use of the new technology would increase the average yield of vegetable farms ranged from 0.56 to 0.95, with an average of 0.82. Several factors of technical inefficiency have been identified such as education, experience, credit use, women's participation and information values were found to negatively impact to technical efficiency. In contrast, age, family size, off-farm income and farm size were positively correlated with inefficiency.

Abaweira *et al.* (2016) conducted an extensive review of the technical efficiency of maize production in Ghana. Their study used cross-sectional data from 576 maize farmers in the country's four main agro-ecological regions. The data were collected using structured questionnaires and multi-stage sampling techniques. Data analysis involved the use of descriptive statistics and Cobb-Douglas stochastic frontier analysis. According to the results of the survey, Ghana's average technical efficiency rating was 58.1%. This indicated that there is still scope for improvement in terms of improving domestic maize production. The study also identified several factors that influence Ghanaian maize farmer's technical ability. The technical excellence of maize farmer's is influenced by higher education, experience growing maize, knowledge in advancing agricultural skills, use of fertilizers and improved varieties. In addition, male farmers are regarded as being technologically superior to female farmers. Membership in agricultural associations has also a demonstrably positive effect on technical excellence. The maize farmer's technical ability was hampered by an increase in land area and land fragmentation.

Alam *et al.* (2012) estimated the farm level technical efficiency of tilapia farmers in Bangladesh by using Cobb-Douglas stochastic production function and incorporating a technical efficiency effect model. Data from 50 tilapia farmers in the Jashore district were analyzed. The results showed that the average technical efficiency of tilapia farmers was 78% with production levels 22% below marginal production. Key determinants of technical inefficiency include age, education, income, crop height, pond age, pond depth, water color and pond longevity. Achieving maximum technical efficiency could increase tilapia yields from the current 7.36-8.96 tonnes per hectare. The study emphasized the need for improved understanding of technology practices, fisheries extension efforts and ensuring the availability of quality feed and affordable seed to promote tilapia production.

Belete (2020) analyzed the technical efficiency in maize production in Guji Zone by using Cobb-Douglas stochastic frontier model and emphasized the potential for crop production in the region particularly in terms of contributing to the country's food security. Though maize is identified as Ethiopia's largest cereal crop but the farm productivity per hectare in the study area is lower than the national average indicating farming inefficiency. The study collected primary data from 234 maize producing households in two districts using a survey questionnaire. The findings reveal a significant number of inefficient farmers in both districts with a technical efficiency score of 69.03%. Various factors including the gender, age, farm income, access to credit and owned land size significantly influence technical inefficiency.

Philipos (2021) examined the technical efficiency of maize production in Meskanworeda of Gurage Zone by using cross-sectional data from 150 households and employed a multistage sampling technique to collect the data and utilized the Cobb-Douglas stochastic production frontier model with the maximum likelihood method for estimation. Socio-economic variables were also examined for their impact on efficiency employing descriptive statistics for analysis. The findings unveiled the presence of inefficiency within the maize production system with a mean technical efficiency of 49% for the overall sample. The results underscored the positive and significant associations between technical efficiency and factors such as seed usage, extension contact, education, good soil, gender and family size. The study emphasized the potential for enhancing technical efficiency by optimizing the utilization of existing resources.

Rabbany *et al.* (2021) analyzed the effects of partial quantity rationing of credit on the technical efficiency of Boro rice growers in the Pabna district of Bangladesh. Prior to the field investigation the researchers developed a theoretical framework and identified the farm households affected by partial quantity rationing of credit. Data from 174 Boro rice growers was collected and analyzed it in two steps. Firstly, assessing the rice growers technical ability by using stochastic frontier model and the inefficiency effects model was used to investigate the determinants of technical efficiency. The Boro rice growers mean technical efficiency was 78% indicating that their efficiency outperformed the production frontier curve by 22%. The findings revealed that have a major effect on improving actual production levels and improving food security in Bangladesh by using available resources effectively.

Hasan *et al.* (2016) estimated the technical efficiency of Boro rice production in Jhenidah district of Bangladesh. This study aimed to assess the technical efficiency of Boro rice farms and identify the cause of their inefficiency by using multistage random sampling technique and primary data were collected from 112 rice producing farms in the Jhenidah district and estimating the technical efficiency by the Cobb-Douglas stochastic production frontier model while the inefficiency effect model was used to determine the factors. The findings revealed a high average technical efficiency of 0.92 indicating a high Boro rice production efficiency effect model found that age, education, training and access to credit were all important factors that were negatively associated with technical inefficiency.

Sapkota *et al.* (2018) conducted to profitability and resource use efficiency of maize seed production in Palpa district of Nepal. About 260 data were collected from farmers using pre-tested semi-structured questionnaire survey to random selection. Small scale farmers paid more for essential inputs such as labor, seed, tillage and other expenses where the average cost of production per hectare was NRs. 94,195 for small scale farmers and NRs. 64,145 for large scale farmers then the benefit cost ratio was higher for large scale (1.12) farmers than for small scale farmers (0.9) indicated the latter was more profitable.

Rabbany et *al.* (2021) determined the effects of credit constraints on the technical efficiency of Boro rice farmers in Pabna district of Bangladesh where data collected from 570 Boro rice farmers by using a simple random sampling technique. Prior to the field investigation the researchers developed a theoretical framework to distinguish between credit-constrained and non credit-constrained rice farmers. Firstly, used a stochastic frontier model (SFA) to assess the technical efficiency of Boro rice farmers and secondly, used an inefficiency effect model to assess the impact of credit constraints on technical efficiency. The study found that credit-constrained rice farmers had 6.7% lower levels of technical efficiency than non credit-constrained rice farmers. In addition, several other factors were found to have a significant impact on the technical efficiency of both groups of rice farmers including household head education level, family size, availability of certified seed, sowing time, access to extension services, off-farm income, and household savings. Furthermore, the study found that the amount of credit received had a significant impact on technical efficiency, while the interest rate charged on the principal had a significant negative impact.

Khandoker *et al.*(2018) examined the profitability of winter maize cultivation in drought prone areas of Bangladesh. Basically, the study was conducted in Rajshahi, Chuadanga, Cumilla and Rangpur districts to assess the impacts of drought on maize production assess maize farmers technical ability and adaptation strategies and identify the causes. About 200 farmers were randomly selected among which 50 farmers participated from each district. Per hectare the total cost of maize cultivation in drought prone regions were taka 92,582 while the normal conditions were taka 79,594. The average yields per hectare in drought prone and normal areas were 7576 kg and 8729 respectively. The average maize net income per hectare was taka 28,062 and 59,871 taka; Benefit-cost ratios for drought prone and normal areas were 1.31 and 1.75.Maize production in drought prone areas decreased by 22.4% relative to normal environments according to the results of the semi-logarithmic regression technique.

Thabethe *et al.* (2014) evaluated the production efficiency including technical, distribution and economic aspects at 231 small scale sugarcane farmers in South Africa's Mpumalanga province. The researchers selected study participants using a random sampling technique and interviewed 231 farmers. This study showed that sugarcane farmers had deficiencies in technical, allocative and economic efficiency. The average estimates of technical, allocative and economic efficiency were 68.5%, 61.5% and 41.8% respectively. The study also concluded that farmer's education, land size, farming experience and age has a significant and positive impact on production efficiency. However, it is important to note that this study did not provide a clear understanding of the profitability aspect of Sugarcane production in the study area due to its focus on efficiency measures.

Anik *et al.* (2017) examined the drivers of production and technical efficiency of onion cultivation in Bangladesh by interviewing 300 farmers in three major growing regions. To analyze the data, the researchers used a Cobb-Douglas stochastic frontier model. Here, the results showed that land plays a crucial role the most influential factor of production with an elasticity value of 0.33 followed by labor (0.24) and seeds (0.18). Also it was shown that the introduction of modern seed varieties has a clearly positive effect on production and found constant returns to scale in onion production. The average technical efficiency has been estimated at 67% which means that performance can be increased by 49% by eliminating inefficiencies. Several factors were identified as significant contributors to technical efficiency including extension contact, use of recommended fertilizer doses and non agricultural income. Furthermore, higher efficiency levels were observed among owner operators and diversified farms.

Baree (2012) measured the overall farm specific technical efficiency of onion farms in Bangladesh. Farm level data were used to estimate the parameters of the Cobb-Douglas stochastic production frontier function. This model considered age, experience, education and farm size as factors affecting the impact of technical inefficiency effects in the stochastic frontier. The results showed positive and significant output elasticity for land (0.3026), labor (0.0718) and capital expenditure (0.0442). Conversely, seed (0.0045) and irrigation (0.0007) had a negative and negligible impact on onion yield per hectare. This suggests that increasing the number of seeds and watering hours can lead to a decrease in onion yield. Coefficients for age, experience and farm size were significant and showed expected negative signs, suggesting that the impact of inefficiencies in onion production decreased with farm age, experience and size. The study found the technical efficiency of onion farms to range from 58 to 99% with an average value of 83%. This means that onion production can be increased by 17% per hectare at no additional cost through the efficient use of production technology.

Rahman (2014) conducted a comprehensive study on maize cultivation focusing on its profitability and cost-effectiveness. According to the report, maize outperformed rice and wheat in yield (7.98 t/ha) and profitability (BCR=1.63). These results demonstrate the versatility of maize as a high yielding crop. The study also found that the economic success of maize cultivation was 87%. However, significant improvement has been identified by eliminating organizational and sales inefficiencies which could result in a 15% cost reduction while maintaining current production levels. According to the report, education played a crucial role in increasing efficiency but larger farmers were less efficient. The efficiency has been found to be affected by geographic conditions with Bogra region showing a lower level of efficiency than Dinajpur and Kushtia. The report provides several policy implications based on these findings such as investment of education, implementing appropriate price controls to stabilize prices and facilitating input markets to ensure timely delivery of required inputs. Overall, this report provides valuable insights into maize productions profitability and economic success, stressing the importance of education, farm size, geography and policy interventions in maximizing the crops potential.

Chiona *et al.* (2014) estimated the technical efficiency of smallholder maize farmers in central province, Jambia and identify the factors that influence maize production efficiency by using Cobb-Douglas Stochastic frontier analysis. This study used primary data from 400 households. The results indicated that there is an opportunity to improve technical efficiency beyond current input levels. The average technical efficiency was

50% and varied between a minimum of 2% and a maximum of 84%. The distribution of technical efficiency scores showed that 14% of farmers scored below 30% and 46% of farmers scored above 50%. Additionally, 14% of farmers achieved a technical efficiency value of 70% or higher. Maximum likelihood analysis revealed that factors such as farmer's age, use of certified hybrid seeds, access to credit, renewal advice and off farm income significantly affect technical efficiency.

Baree *et al.* (2011) conducted a comparative analysis of farm specific technical efficiency among different categories of onion producing farms in Bangladesh. The researchers employed the Cobb-Douglas stochastic frontier production function and utilized farm level data to estimate the relevant parameters. Socio economic factors such as age, education, experiences and plot size were taken into consideration in the technical inefficiency effects model. The study found that the elasticity of output in relation to land and labor varied across farm categories. Additionally, the coefficients of age, experience, education and plot size exhibited specific patterns in different sizes. Farm specific technical efficiency ranged from 55% to 99% for small farms, 57% to 99% for medium farms and 56% to 99% for large farms with average technical efficiency of 77%, 87% and 84% and these data suggest onion production per hectare can be increased by 23%, 13% and 16% respectively for small, medium and large farms through the effective use of existing production technology.

Hossain et *al.* (2008) conducted to measure the technical efficiency and economic performance of potato production in three distinct areas viz. Munshiganj, Bogra, and Jessore. Seventy-five potato farmers were included in the study and they achieved an average tuber yield of 24.90 t/ha, surpassing the national average yield of Bangladesh (14.90 t/ha) and approaching the potential yield range of 25-30 t/ha for diamante and cardinal varieties. The findings indicated that potato cultivation resulted in a gross margin of tk. 174,319/ha and a benefit-cost ratio of 2.40. The study also revealed that the average technical efficiency among the sampled farmers was 75%, suggesting that the current technology and input levels could be improved to increase output by 25%.

Sampa *et al.* (2022) analyzed the technical efficiency on maize cultivation in selected areas of Bangladesh. The factors that influence maize production and resource utilization in selected areas of Bangladesh particularly in dairy and poultry industries which were booming. Using a pretested questionnaire and a simple random sampling, data from 130 maize farmers in Manikgonj and Rajshahi districts was collected. To investigate the effect of various factors on maize production, the Cobb-Douglas production method was used. The results demonstrated the positive effect of seed quality, soil preparation, fertilizer application and water management on maize production. The report also revealed that inefficient resources were being used with seed and fertilizer underutilization and excessive labor consumption. Although farmers made good profits, challenges such as high seed prices, natural disasters and low grain prices were deemed as potential threats to future maize cultivation.

Bapari *et al.* (2016) investigated the economic analysis (productivity, profitability and resource use efficiency) of onion production in Sujanagar and Santhia areas of Pabna, Bangladesh. Primary data were collected from a random sample of 100 onion farmers from his four villages in the study area using a multistage sampling technique. The results highlighted the importance of socioeconomic characteristics in onion production with the majority of male farmers being middle aged (age 41-60) with varying level of experience and no formal education. Applying the Cobb-Douglas production function revealed positive and significant elasticity of output concerning seed, cultivation, fertilizer, insecticide, labor and irrigation. The study also showed that onion production in the study were profitable with average yield of 1535.6 kg, production cost of taka 26,329.63 and net profit of taka 26,883.48 per bigha. However, onion growers face several challenges such as inadequate storage facilities, limited technical knowledge, a shortage of efficient labor at higher costs, unavailability of high yielding seeds and increased input expenses.

Rahman et al. (2013) aimed to estimate the profitability and technical efficiency of maize farmers using Cobb-Douglas production function through purposively selected from 60 maize farmers in Natore district that comprising three villages of Gurudaspur upzila. Maize production was found profitable as benefit-cost ration (BCR) was 1.54 that represented the average level of technical efficiency was very high (96.90%) for existing technology and input levels so that output can be increased only 3.10% where some factors like farmer's age, education and training facilities etc. had significant positive effect on maize production.

Begum *et al.* (2016) conducted the determinants of technical efficiency of freshwater prawn farming in southwestern Bangladesh that using a translog stochastic production model and primary data was collected from 90 randomly selected farmers in that areas. The results revealed a wide variety of technological efficiency in prawn farming ranging from 9.50% to 99.94% with an average efficiency of 65% which suggested 35% of potential output can be increased by reducing inefficiency. Additionally, the results also showed that farmer's education and non-farm income have a positive effect on productivity while factors such as farmer's education, farm distance from water canals and membership in fish farm associations had a negative effect.

Ayinde *et al.* (2015) investigated the technical efficiency of maize production in Ogun state, Nigeria. Primary data were collected from 100 maize farmers using a multistage sampling technique and descriptive statistics, gross margin analysis and stochastic production frontier were used to collect data. The majority of the respondents were married males with an average age of 50.1 years and a median household size of 6 people according to the socioeconomic characteristics of the respondents. The majority of farmers had no prior experience with secondary schooling and were involved in full time farming with significant portion of them involved in inter cropping activities like seeds, herbicides, labor and farm size were identified as key factors in maize production while the household size and education level played an inefficiency role.

Backman *et al.* (2011) estimated the determinants of technical efficiency of rice farms in North central and North western regions in Bangladesh that used a quadratic stochastic frontier production model and data were collected from twelve villages in Bangladesh north central and north western regions using the computer frontier program 4.1. The results revealed significant differences in the degree of technical efficiency among rice cultivation ranging from 0.16 to 0.94 with a mean technical efficiency of 0.83. The researchers revealed several factors as contributing to efficiency disparities among the farm households studied including age and education of household heads, off farm incomes, land fragmentation, access to microfinance, extension visits and regional variations.

Hoque *et al.* (2021) conducted to measure the technical efficiency of cauliflower cultivation on Dhaka district in Bangladesh. Using the stochastic production frontier model the technical efficiency of Cauliflower production in Savar and Keraniganj upazila of Dhaka distict in Bangladesh and primary data were collected from 120 households by face-to-face interviews using a structured questionnaire. The results revealed that the mean of technical efficiency was expected to be 85%. According to the results, the households engaged in cauliflower cultivation had the ability to raise their income by 15% while maintaining their current resources.

Ferdausi *et al.* (2011) aimed to estimate the profitability and resource use efficiency under different farm size groups of maize production. From five villages in the Bogra district, total 65 farmers were randomly selected among them 30 were small, 30 were medium and 5 were large farmers and tabular and statistical method were used. The average cost of maize production per hectare was estimated at taka 46,278 for all farmers, with taka 41,263 taka 53,554 and taka 48,715 for small, medium and large farmers respectively. For small, medium and large farmers the net returns per hectare were calculated at taka 57,823, taka 53,895 and taka 64,138. The small farmers had the highest benefit-cost ration (BCR) followed by medium farmers (2.01) and large farmers (2.32).The effectiveness study revealed that most farmers inefficiently used the inputs.

Roy et al. (2017) measured the growing popularity of maize cultivation in Rangpur district of Bangladesh : An evidence from Gangachara upazila. The study aimed to explore the reasons behind the growing popularity and assess the future viability of maize cultivation in the Gangachara upazila (Sub-district) of Rangpur district. Three stage cluster sampling method was employed to select 110 experienced farmers who had been cultivating maize for at least 10 years replacing traditional crops such as Tobacco and Boro rice. Two types of crop pattern were found and they are Potato-Maize-Aman and Maize-Aus-Aman between of these Potato-Maize-Aman was found to be the most. The Benefit-cost ratio for maize, boro rice and tobacco cultivation was 1.40, 0.68 and 0.75 respectively. If the production cost of maize is tk 1 then it used to bring taka 1.40 from the market, thereby creating a profit of taka 0.40.

Hasan (2008) conducted a study on economic efficiency and constraints maize production in the northern region of Bangladesh using 100 sample sizes from each district. All farmers in the study used hybrid seeds for maize cultivation resulting in an average yield of 6.27 ton/ha which was higher in Dinajpur (6.35 ton/ha) compared to Panchagarh district (6.18 ton/ha). Returns of scale for the selected inputs were 0.72 and 0.68 for Dinajpur and Panchagarh respectively and the average technical efficiency was 0.84 at Dinajpur and 0.80 at Panchagarh. Furthermore, it was discovered that farmers in the study area had the potential to increase maize productivity by achieving full efficiency through resource reallocation. Economic analysis comparing maize and maize- based cropping patterns with Boro rice and Boro based cropping patterns highlighted the higher profitability of the maize production system.

Khatun et al. (2014) conducted the study aimed to assess the profitability and resource use efficiency of maize production among different farm size groups by using Cobb-Douglas production function analysis. A sample of 65 farmers (30 small, 30 medium and 5 large) were randomly selected from five villages in Bogra district where tabular and statistical analyses both were applied. Average total cost of maize production per hectare was estimated at taka 46,278 for all farmers with varying costs and gross margins were found to be taka 67,592, taka 64,694 and taka 74,089 and net returns were calculated at taka 57,823, taka 53,895 and 64,138 per hectare for small, medium and large scale farmers respectively. However, BCR was the highest (2.40) for the small farmers followed by medium (2.01) and large (2.32) farmers respectively. The findings of this study revealed that large farmers earned higher profit than those of small and medium farmers.

Rahman et al. (2013) aimed to estimate the profitability and technical efficiency of maize growers using Cobb-Douglas production function through purposively selected from 60 maize growers in Natore district that comprising three villages of Gurudaspur upazila. Maize production was found profitable as benefit-cost ratio (BCR) was 1.54 that represented the average level of technical efficiency was very high (96.90%) for existing technology and input levels so that output can be increased only 3.10% where some factors like farmer's age, education and training facilities etc. had significant positive effect on maize production.

Adnan et al. (2021) focused on assessing profit efficiency and influencing factors for the inefficiency of maize production among 350 hybrid maize growers in selected areas of Bangladesh. The researchers employed the profit frontier function and inefficiency effects model and conducted data collection using a multistage stratified random sampling procedure and age, education level, extension experience and non-farm income as the main factors contributing to profit inefficiency. Findings of the study confirmed the profitability of maize production with an average net return of 32392 BDT/acre and a benefit-cost ration exceeding 2. The study revealed a profit efficiency score of 0.71 indicating 29% profit inefficiency. The average net benefit was estimated at 32392.40 BDT/acre with a profit-loss of 16975.99 BDT/acre. Further analysis showed a potential benefit of 49,368.39 BDT/acre through improvements in allocation efficiency, technical efficiency and scale efficiency.

CHAPTER III

METHODOLOGY

3.1 Introduction

Chapter 3, "Methodology," of this thesis delves into the intricate framework established to assess the technical efficiency of maize cultivation in the Chuadanga district of Bangladesh. As the cornerstone of empirical research, the methodology section meticulously outlines the procedures, techniques, and analytical tools employed to achieve the research objectives. With a focus on robustness and precision, this chapter elucidates the selection criteria for the study sample, the collection of primary data through structured interviews and surveys, and the utilization of advanced econometric models such as stochastic frontier analysis (SFA) to measure technical efficiency. Furthermore, it expounds upon the theoretical underpinnings guiding the research design, ensuring a comprehensive understanding of the methodological approach adopted to investigate the intricacies of maize cultivation in the context of Chuadanga district.

3.2 Selection of the study area

The selection of Chuadanga district for examining the technical efficiency of maize cultivation in Bangladesh, specifically focusing on Chuadanga Sadar and Jibannagar Upazilas, is strategically grounded in several key factors. Firstly, Chuadanga district presents a pertinent case study due to its significant contribution to maize production within the country. Being situated in the southwestern region of Bangladesh, Chuadanga is emblematic of the broader agricultural landscape in the country, characterized by its reliance on maize cultivation as a staple crop for both subsistence and commercial purposes. Furthermore, the choice of Chuadanga Sadar and Jibannagar Upazilas within the district is deliberate, as these areas encapsulate diverse socio-economic and agro-ecological dynamics representative of maize cultivation practices in Bangladesh. Their selection allows for a nuanced exploration of technical efficiency across different contexts, including variations in landholding sizes, access to resources, and agricultural practices. By focusing on these specific locales, this study aims to offer insights that are not only applicable within the Chuadanga district but also hold relevance for broader agricultural policy formulation and intervention strategies aimed at enhancing the efficiency and sustainability of maize cultivation practices in

Bangladesh.

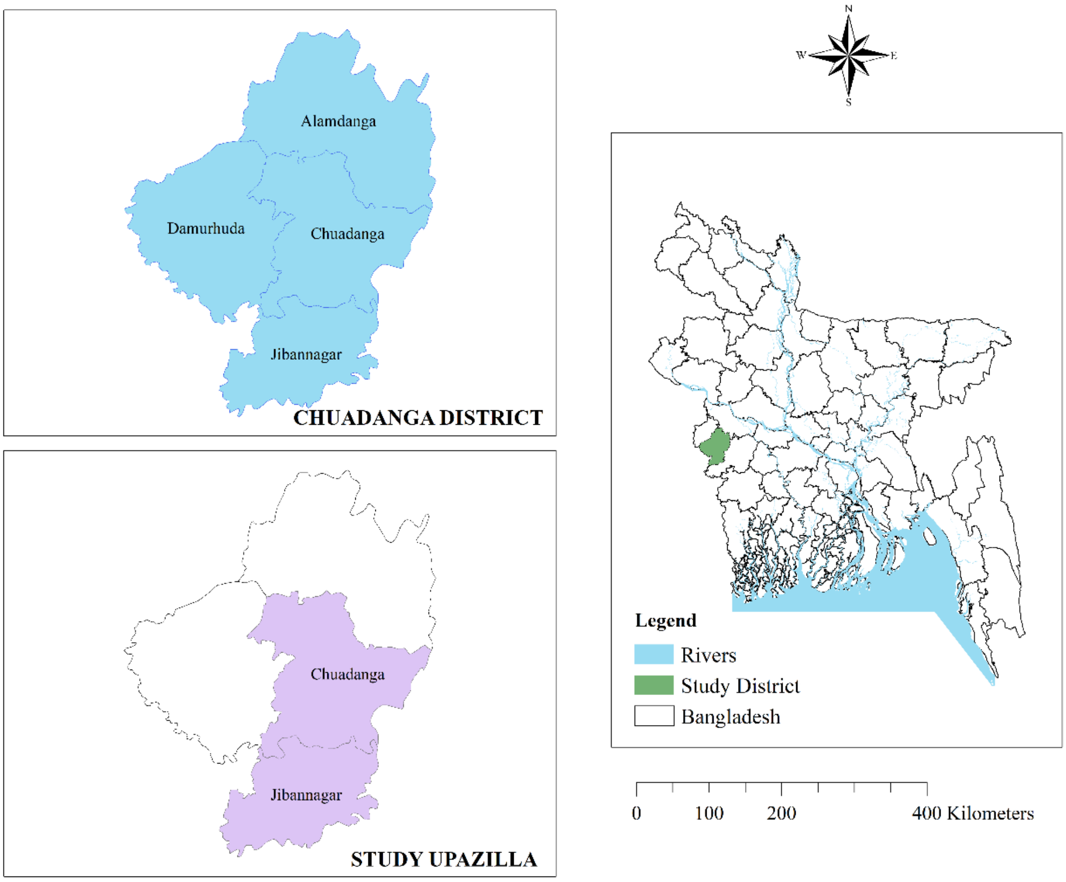

Figure 3.1: Study Area

3.3 Method of investigation

Survey research is a method used in quantitative research to collect data from a predefined group of respondents through standardized questionnaires or interviews (Ponto, 2015). This method involves asking specific questions to gather information about people's preferences, behaviors, attitudes, or opinions (Check & Schutt, 2011). Survey methods can include various techniques such as online surveys, paper surveys, telephone interviews, or face-to-face interviews. It's a widely used approach for gathering data efficiently and systematically (Singleton Jr et al., 1988).

In this study, the methodology employed to gather pertinent information involved utilizing surveys as the primary data collection tool. The researcher, driven by the understanding that the approach to studying and the objectives at hand significantly influence the information gathering process, opted for this method. Personally, engaging with individuals involved in maize farming within the targeted areas, the researcher distributed questionnaires and conducted interviews. By directly interacting with the proprietors of maize farms, valuable insights and perspectives were obtained, enriching the study's dataset with firsthand experiences and knowledge from those deeply involved in the subject matter.

3.4 Sampling methodology and sample size

In conducting a study on maize farming, a multi-sampling technique was employed to select a representative sample of 60 maize farmers. This sampling methodology was chosen to ensure diversity across various regions and farming practices, providing a comprehensive understanding of maize cultivation techniques and challenges. The sample size of 60 was determined to strike a balance between statistical significance and practical feasibility, aiming to capture a broad spectrum of perspectives while maintaining manageable data collection efforts. By employing this approach, the study aims to yield insights that can inform agricultural policies, improve farming practices, and enhance the overall productivity and sustainability of maize farming operations. The utilization of multi-sampling techniques is pivotal in effectively measuring both maize farming information due to several reasons

. Firstly, it ensures a representative sample by selecting participants from different stages of the production process, enhancing the generalizability of the findings (Andaregie & Astatkie, 2020). Secondly, it allows for the inclusion of diverse farm sizes and conditions, capturing variations in practices and resources among smallholder farmers (Fikadu & Kerorsa, 2023). Thirdly, employing such a technique aid in reducing selection bias, as it involves a systematic approach to selecting participants, minimizing the risk of over or under-representing certain groups (Shavgulidze et al., 2017). Moreover, it enhances the precision of estimates by capturing the heterogeneity present in the population, leading to more accurate assessments of technical efficiency (Mengui et al., 2019). Overall, employing a multi-stage sampling technique is crucial for obtaining robust and reliable insights into the technical efficiency of maize farming practices. Overall, the adoption of multi-sampling techniques is indispensable for acquiring comprehensive and actionable insights into maize farming practices. Equation (1) shows that a total of 200 farmer samples were randomly selected using Cochran's proportional allocation sampling technique (Cochran, 1977).

$$ni = n^{*} \left(\frac{Ni}{N}\right) \qquad (1)$$

where;

ni = Number of sampled farms in ith;

n* = Total sample size;

Ni = Total number of farms in ith district;

N = Total number of farms in the study area.

3.5 Preparation of the survey schedule

The preparation of a survey schedule is a crucial step in ensuring effective data collection. To create a robust schedule, define the survey's purpose, craft concise and relevant questions, and maintain simplicity to enhance participant comprehension. Striking a balance between question types and avoiding bias contributes to the survey's validity (Krosnick, 2018; Owens, 2002). Additionally, planning for field data collection involves clear protocols for each component, optimizing survey response rates and feedback opportunities further improve survey quality (Aguinis et al., 2021).

An effective interview schedule is essential to the research and survey's effectiveness. A schedule of interviews was created with the study's aims in mind in order to get the necessary data. The study's objectives guided the preparation of the draft schedule, which was created prior to the final schedule. After then, a pre-test of the schedule was conducted to confirm the questions' applicability and the type of answer. Following pre-testing and any required modifications, the final survey schedule was created. The information listed below was included in the final survey schedule, which was created in logical order:

1. The socioeconomic status of maize farmers;
2. Information about maize farms;
3. Farm families' sources of revenue;
4. Seed costs;
5. Labor costs for humans;
6. Machineries use costs;
7. Equipment and tool costs;
8. Revenue from the maize;
9. Issues that maize farmers confront and;
10. Solutions that maize farm operators recommend.

In-person interviews with respondents were conducted from December 2023 to January 2024 in order to gather data for the current study. Throughout that time, the researcher performed several field excursions in order to gather data.

3.6 Collection of data

The collection of data is vital for maize-related studies due to several reasons. Firstly, data provides empirical evidence and insights into various aspects of maize cultivation, consumption, and its impact on society, economy, and health (Salmensuu, 2021). Secondly, thorough data collection enables researchers to analyze trends in maize prices, consumption patterns, and market participation, aiding in understanding market dynamics and informing policy decisions (Demisse et al., 2022). Additionally, data on the nutritional content of maizes and their role in human diet and health help in promoting awareness about the nutritional benefits of maize consumption (Beals, 2019). Moreover, historical data on maize cultivation and its contribution to population growth and urbanization provide valuable insights into the historical significance of this crop (Nunn & Qian, 2011). Overall, the collection of data facilitates comprehensive analyses, informed decision-making, and advancements in maize-related research, ultimately contributing to the sustainable development of maize agriculture and its positive impact on various sectors.

Getting accurate and reliable information out in the field is tough. How a study turns out depends a lot on how good the data is and how consistent it is. How researcher gather the data really affects how reliable it is. We need clear schedules to make sure our surveys are right. We got data straight from the people we were studying using interviews made just for this study. This helped us make sure the data was dependable. We used schedules to get info from maize farmers too. Before the interviews, we explained what we were doing so everyone felt comfortable speaking up. We didn't ask unnecessary questions to save time for both the people we talked to and ourselves. We were careful when we collected the data to make sure it was right and dependable. We also thought about how the people we were talking to preferred to communicate, and we kept things friendly. We also looked at info from other sources like books, journals, and agencies including the Bangladesh Economic Review (BER) and the Bangladesh Bureau of Statistics (BBS), Sher-e-Bangla Agricultural University Archive.

3.7 Problems faced in collecting data

The researcher encountered the following issues and challenges when gathering primary data:

1. The majority of farmers in the chosen regions were hesitant to provide accurate information regarding their sources of income. Because they were reluctant to provide true information because they believed the researcher to be a government agent.
2. The fact that the respondents in the chosen areas did not maintain written records meant that the researcher in charge of data collection had to rely entirely on the respondents' recollection. This presented another significant challenge.
3. The majority of respondents in the research areas lacked any information of research studies. Thus, it was challenging to persuade them of the significance of the findings.
4. Occasionally, the farmers refused to work with the researcher voluntarily. They could not see any need to provide the researcher with information.
5. The researcher frequently had to spend more time and effort gathering information from farm respondents who were not available at home.

3.8 Processing and tabulation of data

Data processing has many parts, and one important step is tabulation. Tabulation means putting data in tables, making it easier to compare and analyze. First, raw data is turned into numbers. Then, numbers are given to different categories in a process called coding. Tabulation helps summarize data neatly, making it easier to understand and study. It's a key part of processing data, helping organize numbers so we can find patterns and understand what they mean (Christanto et al., 2012; Habibi & Machdi, 2014). Researcher needed to process data to reach the study's goals. After collecting data, researcher organized and summarized it. Then, we put the interview data into a special computer program called STATA and measured the technical efficiency.

3.9 Analysis of data

3.9.1 Analytical techniques

Data were analyzed to achieve the objectives of the study. For this study, the following techniques were used.

a) Tabular Technique and

b) Functional Technique

3.9.1.1 Tabular technique

Tabular technique of data analysis involves presenting and organizing data in a structured format using rows and columns. This method simplifies the comprehension of information, making it easy to identify patterns, trends, and relationships within the dataset. Tabular presentation is widely employed in exploratory data analysis (EDA) for tabular data, aiding in quantitative and qualitative analysis as well as temporal and spatial assessments (Behrens & Yu, 2003; Wainer, 1993). By systematically arranging data, the tabular technique enhances the accessibility and clarity of information, serving as a foundational tool for various analytical processes (Li et al., 2020). Typically, the tabular technique is employed to determine the unrefined correlation or fluctuations among variables. The tabular technique was employed in this study since it was commonly utilized, simple to calculate, and easy to comprehend. The study used a number of statistical measures, including sum, average, percentage, and so forth. Both total cost and variable cost were included in the profitability study.

To evaluate the profitability of potato farms, the following profitability equation was developed.

$$\Pi = PbQb + PLQL - \Sigma(Pxi.Xi) - TFC$$

Where,

Π =Profit (Tk.);

P_b = Per unit price (Tk./kg);

Q_b = Quantity (Kg.);

P_L= Per unit price of used materials and excreta (Tk./kg);

Q_L= Quantity of waste (Kg.);

P_{xi} = Per unit price of ith (variable) inputs used in the potato farm (Tk.);

X_i= Quantity of ith (variables) inputs used in Kg;

i= (1,2, 3, … 200) and

TFC = Total fixed cost

3.9.1.2 Statistical Technique

Technical efficiency refers to how well a farm can make the most stuff with what it has and the tools it uses. If a farm is technically good, it does its job well compared to other farms. Basically, a company is technically efficient if it uses its production method to make the most stuff possible with the technology it has. In simpler terms, a company is efficient if it operates at the best point possible, rather than inside that point. To make stuff well, the ingredients used must be the same. The amount of stuff made from certain ingredients shows how efficient the process is, but it's not always clear if the ingredients used are the same as the best ones for that process. When different companies use different quality ingredients, their efficiency depends on both the quality of what they use and how well they manage it. But if differences in ingredients are the same across all companies, it doesn't affect efficiency (Coelli et al., 2005).

3.9.1.3 The stochastic frontier models

The best way to figure out how well something works is by using the stochastic frontier model. This method is better than other methods because it looks at both sides of the error – the one we know about and the one we don't. It also considers things like mistakes in measurement and random events that affect how well a business operates. This means the model can be different for each business. Jondrow et al. (1982) first introduced this model, which is often called the stochastic frontier model made it even better. Other methods assume that all businesses work the same way, ignoring the fact that some things can affect how well a business does, like broken equipment or bad weather. But the stochastic frontier model looks at all the different factors that can affect a business and separates out what the business can control from what it can't. This means the results it gives are fair.

3.9.1.4 The stochastic frontier with cobb-Douglas production function

Cobb-Douglas production function, a formula in economics that calculates output based on inputs developed by Douglas (1928). The Cobb-Douglas way of figuring out how much stuff farms make is really popular because it's easy to do the math for it and understand it (Heady et al., 1960). This technique plays a crucial role in assessing the relationship between production outputs and inputs like labor and capital. By employing output elasticity measures, it gauges the responsiveness of output to changes in these input levels. Real-world applications include estimating average production levels in manufacturing, cost minimization strategies, and assessing the overall productivity of industries. This statistical approach provides valuable insights into resource allocation and production optimization, contributing to informed decision-making in various economic sectors (Bounthavong, 2019; Dritsaki & Stamatiou, 2018). Even though it makes curved lines on graphs, it can't handle things that don't rely on each other or compete, and it can't show all the different stages of production well because it's limited in how it can switch between different inputs. Basically, if we assume that one thing is usually smaller than another (which is usually the case), then how much stuff farms make from each worker or acre keeps going down as they use more workers or acres. But for some kinds of making things, where everything sort of works the same no matter what, the Cobb-Douglas can still give a pretty good guess. Also, it's easy to figure out the numbers for it because they're simple and straightforward (Beattie & Taylor, 1985).

The formula for a Stochastic frontier with Cobb-Douglas Production is:

$$Yi = f\ (Xi, \beta)\ exp.(Vi - Ui)\ i = 1, 2, 3, \dots\dots\dots\dots, N$$

The stochastic production frontier is represented by the expression $f\ (Xi, \beta)$ exp.(Vi), where Vi has a symmetric distribution to reflect the random effects of measurement error and external shocks that cause the placement of the deterministic core $f\ (Xi, \beta)$ to differ among firms.

The one-sided error component $Ui > 0$ thus captures the technological inefficiency compared to the stochastic production frontier.

The following model was used in this study:

$$Y = aX_1^{b1} aX_2^{b2} aX_3^{b3} aX_4^{b4} aX_5^{b5} aX_6^{b6} e^{Ui}$$

Where Y is the frontier output, X is physical input, b the elasticity of Y with respect to X, α is intercept and $\mathcal{E} = V - U$ is a composed error term as defined earlier. For simplicity, we have ignored the subscript.

The function was estimated as follows:

$$\begin{aligned} ln\, Y = Ina + b_1 In\, X_1 + b_2 In\, X_2 + b_3 In\, X_3 + b_4 In\, X_4 + b_5 In\, X_5 \\ + b_6 In\, X_6 + b_7 In\, X_7 + b_8 In\, X_8 + b_9 In\, X_9 + b_{10} In\, X_{10} \\ + Ui \end{aligned}$$

Where,

Y = Gross return (Tk./kg);

a = Constant or intercept value;

X_1= Cost of hired labor for ith farm (Tk./ha);

X_2 = Cost of irrigation for ith farm (Tk./ha);

X_3 = Cost of insecticide/pesticides for ith farm (Tk./ha)

X_4 = Tillage cost for ith farm (Tk./ha)

X_5 = Cost of urea for ith farm (Tk./ha)

X_6 = Cost of TSP for ith farm (Tk./ha)

X_7 = Cost of DAP for ith farm (Tk./ha)

X_8 = Cost of biofertilizer for ith farm (Tk./ha)

X_9 = Cost of manure for ith farm (Tk./ha)

Ui = Error term;

i= 2,3,...60;

b1, b2, b3, b4, b5, b6 = Regression co-efficient of respective variables, and ln =Natural log.

The model of the technical inefficiency effects in the stochastic production frontier equation is defined by:

$$Ui = \delta 0 + \delta 1Z1 + \delta 2Z2 + \delta 3Z3 + \delta 4Z4 + \delta 5Z5 + \delta 6Z6 + \delta 7Z7 + Wi$$

Where,

Z1……………..Z7 are explanatory variables.

The equation can be written as:

$$\begin{aligned} Ui = \delta 0 &+ \delta 1\, Age + \delta 2\, Education + \delta 3\, Family\ Size + \delta 4\, Training \\ &+ \delta 5\, Experience + \delta 6\, Social\ member + \delta 7\, Market\ Distance \\ &+ Wi \end{aligned}$$

V is a two-sided uniform random variable that is independent of the farmer and has a distribution of $N\ (0, \sigma 2), U$ is a one-sided technical inefficiency effect that is controlled by the farmer and has a distribution of $Vi|N\ (0, u2)$, and Wi is a two-sided uniform random variable. W is a random variable that cannot be seen and has a positive half-normal distribution. STATA and R studio were both used at the same time to estimate the model.

3.10 Process for calculating benefits and costs

All cost items must be computed in order to determine profit or loss. In order to assess costs and advantages, the market price at which goods or services are actually exchanged for has been taken into consideration. The cost components were divided into two major groups: (1) Fixed costs and (2) Variable costs. For a year, the expenses and profits were calculated per hectare maize production. The following headings were used to group the cost items.

CHAPTER IV

SOCIOECONOMIC STATUS OF THE MAIZE FARMERS

4.1 Introduction

Understanding the socioeconomic status of maize farmers is pivotal in comprehending the broader context within which maize cultivation operates in Chuadanga District, Bangladesh. This chapter delves into various socioeconomic factors that influence and are influenced by maize farming practices, shedding light on the intricate interplay between agriculture and livelihoods in the region.

4.2 Age profile

Maize farming demographics are structured into three distinct age categories: younger, middle-aged, and older farmers. Each group brings unique perspectives and experiences to the agricultural landscape. Younger farmers often infuse the industry with innovation, embracing modern techniques and technologies to enhance efficiency and sustainability. Middle-aged farmers, with their blend of youthful energy and seasoned wisdom, serve as the backbone of the sector, leveraging years of practical knowledge to navigate challenges and seize opportunities.

Table 4.1: Age profile of the respondents

Age category	Frequency	Percentage
Younger Age	4	6.7
Middle Age	30	50.0
Older Age	26	43.3

Source: Field Survey 2023

Among the respondents, 6.7% fell into the Younger Age category, comprising 4 individuals. The middle age group constituted the majority, comprising 50.0% of the respondents, with a total of 30 individuals falling into this category. The older age category consisted of 26 individuals, accounting for 43.3% of the respondents (table 4.1).

4.3 Educational profile

The educational categorization of maize farmers encompasses six distinct tiers, reflecting a spectrum of academic attainment. At the foundational level, there are those classified as 'Illiterate', lacking formal schooling. Moving forward, 'Signature' denotes individuals with minimal literacy, able to sign their names but lacking substantial educational background. Progressing through the ranks, 'Primary' denotes completion of classes one through five, while 'Secondary' signifies education up to the S.S.C level, encompassing classes six through ten. 'Higher Secondary' marks those who have completed classes eleven and twelve, representing a higher academic echelon. Finally, the 'Degree and above' category encapsulates maize farmers with tertiary education, indicating a comprehensive academic foundation that may offer diverse perspectives and skill sets in agricultural practices and beyond.

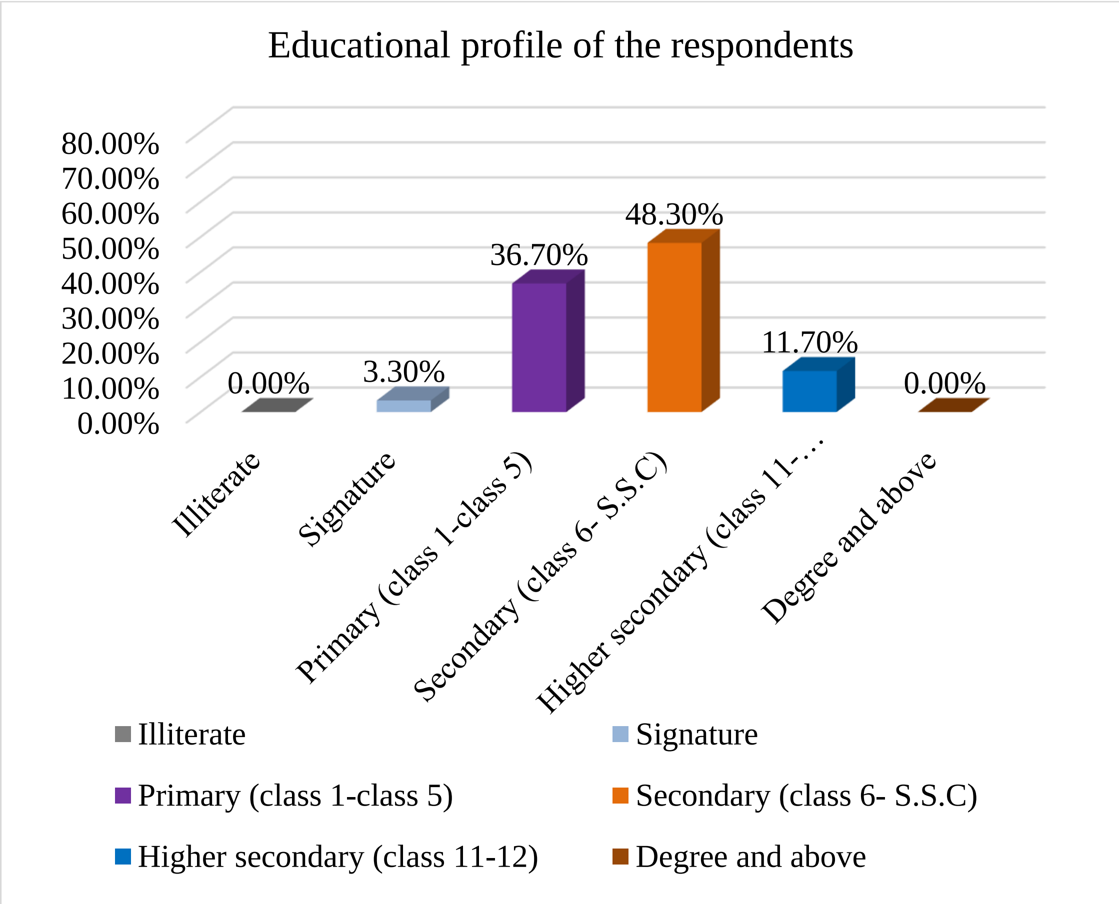

Figure 4.1: Educational profile of the respondents

Source: Field Survey 2023

Among the respondents 0.00% were classified as illiterate, indicating no formal education. A small proportion, 3.30%, were able to sign their names, suggesting basic literacy skills. The largest segment, comprising 36.7% of the respondents, had completed primary education, ranging from class 1 to class 5. Nearly half of the respondents, 48.30%, had attained a secondary level of education, spanning from class 6 to S.S.C. Furthermore, 11.70% had completed higher secondary education, covering class 11 to class 12. Notably, none of the respondents reported possessing a degree or higher qualification (figure 4.1).

4.4 Experience profile

Maize farmers' experiences are segmented into three distinct categories based on their tenure in the industry. The first category encompasses those with less than five years of experience, representing a group marked by fresh perspectives and potentially innovative approaches. The second category, spanning from five to ten years of experience, likely indicates a phase where farmers have gained a foothold in the industry, honing their skills and strategies. Finally, the third category, comprising farmers with over ten years of experience, represents a seasoned cohort who have weathered various challenges and accrued substantial knowledge.

Table 4.2: Experience profile of the respondents

Experience category	Frequency	Percentage
Bellow 5 Year	21	35.00
5-10 Year	14	23.33
Above 10 Year	25	41.67

Source: Field Survey 2023

According to the table 4.2, 35.00% of the respondents fell under the category of below 5 years of experience. The majority, constituting 41.67% of the respondents, had more than 10 years of experience. On the other hand, 23.33% of the respondents reported having between 5 to 10 years of experience. This distribution highlighting a significant proportion with extensive professional backgrounds exceeding a decade, while also acknowledging a notable portion with moderate experience ranging from 5 to 10 years.

4.5 Occupation status

Maize farmers' occupational statuses are typically categorized into two main groups. Firstly, there are those for whom agriculture serves as the primary occupation, indicating that their livelihood primarily relies on cultivating maize and possibly other crops. Secondly, there are farmers who engage in agriculture as a secondary occupation, meaning that while they may have other primary sources of income, they still dedicate a portion of their time and resources to maize farming.

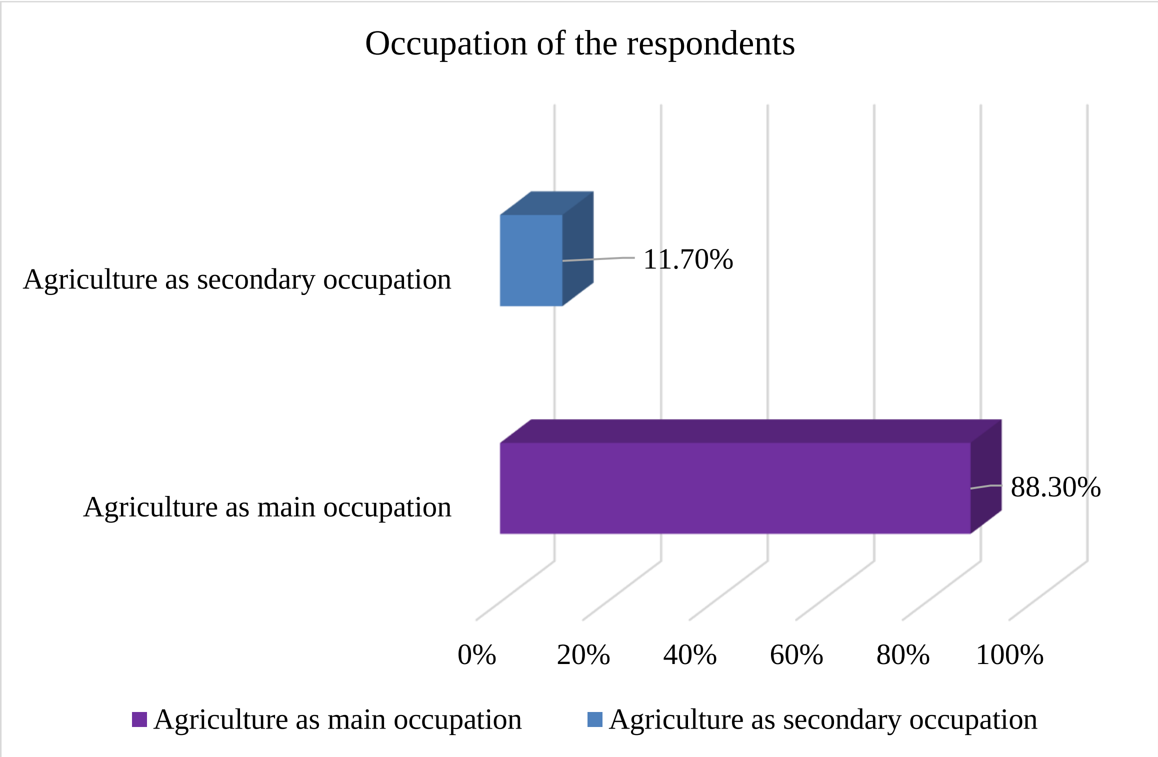

Figure 4.2: Occupation of the respondents

Source: Field Survey 2023

The occupation distribution among the respondents illustrated in figure 4.2. The majority, comprising 88.30%, list agriculture as their main occupation, indicating a significant reliance on agricultural activities for livelihoods. Interestingly, a notable portion, 11.70%, also engage in agriculture as a secondary occupation, suggesting either diversification of income sources or a multifaceted approach to livelihood strategies within the surveyed population.

4.6 Family information

The information concerning maize farmer families is meticulously categorized into five distinct segments, providing valuable insights into their demographics. These categories include the average family member count, delineating the typical size of these agricultural households. Furthermore, there's a breakdown into the average number of males and females within these families, elucidating gender dynamics. Additionally, the statistics extend to the average count of working members, shedding light on the labor force participation within these communities. Moreover, within this framework, there's a specific focus on delineating the average number of working males, highlighting the predominant role men play in the agricultural activities of maize farming households. This comprehensive categorization offers a nuanced understanding of the familial structures and labor dynamics within maize farming communities, facilitating targeted interventions and policies to support their livelihoods.

Table 4.3: Family information of the respondents

Items	Frequency	Average
Average Family Member	60	4.93
Average Male	60	2.38
Average Female	60	2.55
Average working member	60	1.45
Average working male	60	1.45

Source: Field Survey 2023

The table 4.3 indicates frequencies and averages across various categories. On average, each family consisted of approximately 4.93 members. In terms of gender distribution, the average number of male members per family was 2.38, while the average number of female members was slightly higher at 2.55. Additionally, the data reveals that, on average, 1.45 members per family were employed. This figure remained consistent when specifically considering male members who were working, indicating that the average number of working males mirrored the overall average of working members per family.

4.7 Farmer's category

In the realm of maize farming, land sizes are delineated into three distinct categories, each bearing its own significance in agricultural dynamics. The first category encompasses plots of land up to 2 hectares, characterized as small holdings. These modest-sized farms often require intense and meticulous management, as every inch of land must be utilized efficiently. Moving up the scale, the medium category spans from 2 to 5 hectares, offering a slightly broader canvas for cultivation. Here, farmers navigate the terrain with a balance of precision and scalability, leveraging their resources to optimize yields. Finally, the domain of large-scale maize farming extends beyond 5 hectares, representing vast expanses of agricultural enterprise.

Table 4.4: Farmers' farm category based on land size

Farmers Category	Frequency	Percentage
Up to 2 ha (Small)	6	10.0
2 - 5 ha (Medium)	27	45.0
Above 5 ha (large)	27	45.0

Source: Field Survey 2023

Among the surveyed farmers farm category form table 4.4 its evident that, 10.0% are categorized as "Small," with land holdings of up to 2 hectares. The majority of farmers, constituting 45.0% each, fall into the "Medium" category, possessing land sizes ranging from 2 to 5 hectares, and the "Large" category, encompassing land holdings above 5 hectares.

4.8 Irrigation system

Maize farmers rely on irrigation systems to ensure consistent and efficient water distribution for their crops, with machinery playing a crucial role in this process. These irrigation systems are typically categorized into two main types: motor-based and selo machines. Motor-based systems utilize electric or fuel-powered motors to pump water through the irrigation network, offering reliable and customizable water delivery to maize fields. On the other hand, selo machines, likely named after their inventor or specific technology, represent a different approach, possibly employing innovative mechanisms for water dispersal, which may include traditional or more advanced techniques tailored to the needs of maize cultivation.

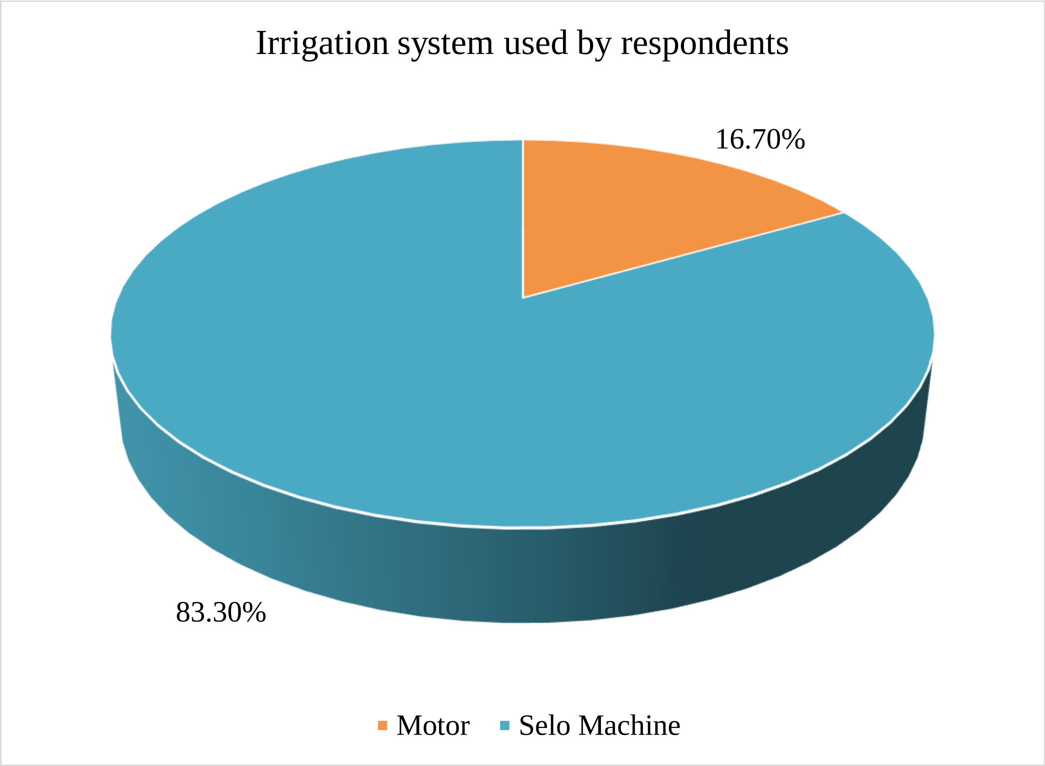

Figure 4.3: Irrigation system used by respondents

Source: Field Survey 2023

The distribution of irrigation systems utilized by respondents illustrated in figure 4.3. Among the respondents surveyed, 16.70% reported using a motor for irrigation purposes, while a significant majority of 83.30% indicated the utilization of a Selo Machine for irrigation.

4.9 Own machinery

The opinions among maize farmers regarding the utilization of their own machinery can be broadly categorized into two distinct groups: those in favor and those opposed. For those in the affirmative camp, owning machinery presents an opportunity for greater control over their farming operations, offering flexibility in scheduling tasks and potentially reducing dependence on external resources.

Table 4.5: Respondents response on using own machinery

Response	Frequency	Percentage
No	28	46.7
Yes	32	53.3

Source: Field Survey 2023

In Table 4.5, the respondents' feedback regarding the utilization of their own machinery is presented. Out of the total respondents surveyed, 53.3% indicated affirmatively that they do utilize their own machinery, while 46.7% responded negatively.

4.10 Training information

The training information of maize farmers' respondents is segmented into two distinct categories: those who have received training and those who have not. This division delineates the varying levels of knowledge and skill acquisition among maize farmers. The "Yes" category comprises farmers who have undergone training sessions, likely equipped with insights into modern agricultural practices, pest management techniques, and enhanced cultivation methods. Conversely, the "No" category denotes farmers who haven't received formal training, potentially lacking access to crucial resources and information necessary for optimizing maize production.

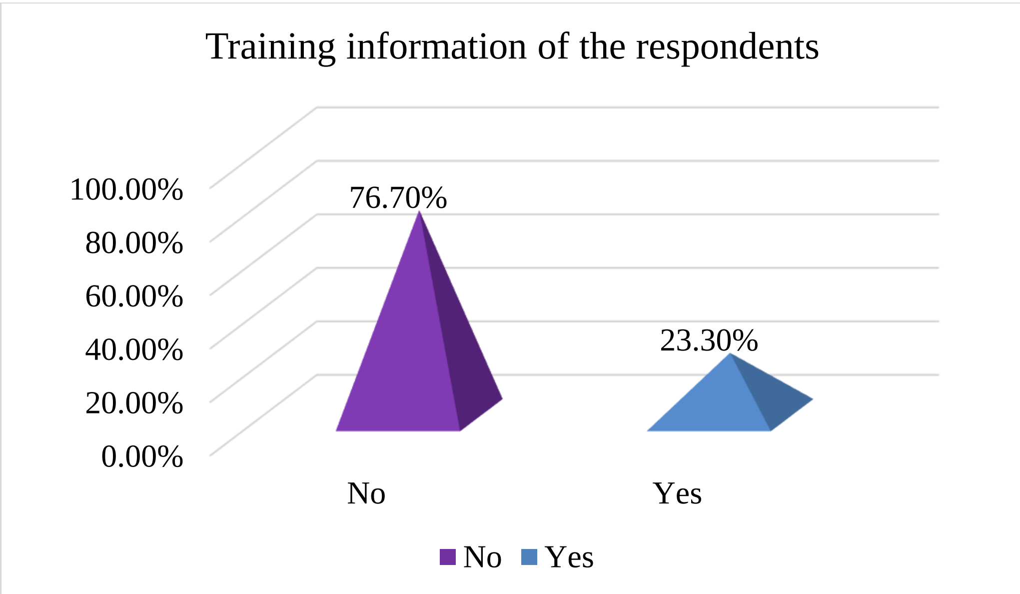

Figure 4.4: Training information of the respondents

Source: Field Survey 2023

The data presented in Figure 4.4 illustrates the training information of the respondents. The majority, comprising 76.70% of the respondents, indicated that they have not undergone training. Conversely, 23.30% of the respondents stated that they have received training.

4.11 Distance of agricultural extension office

Maize farmers' accessibility to agricultural extension services is vital for their success, with the distance to extension offices being a crucial factor. In a recent study, respondents' proximity to these offices was categorized into three distinct ranges. For farmers residing within 5 kilometers of the extension office, access to support and guidance is readily available, enabling timely interventions and advice. Those situated between 5 and 10 kilometers away may experience slightly reduced accessibility, potentially impacting their ability to promptly address agricultural challenges. Meanwhile, farmers residing over 10 kilometers away face the greatest distance barrier, potentially hindering their access to vital extension services.

Table 4.6: Distance of agricultural extension office

Distance category	Frequency	Percentage
Bellow 5 Km	5	8.3
5 - 10 Km	45	75.0
Above 10 Km	10	16.7

Source: Field Survey 2023

The data presented in Table 4.6 illustrates the distribution of distances to agricultural extension offices. Among the respondents surveyed, 8.3% reported a distance of less than 5 kilometers, indicating relatively close proximity to these offices. The majority, constituting 75.0% of the respondents, reported distances ranging from 5 to 10 kilometers, suggesting that a significant portion of the sample resides within this moderate range of accessibility to extension services. However, 16.7% of respondents indicated distances exceeding 10 kilometers, highlighting a considerable proportion facing greater travel distances to access agricultural extension resources.

4.12 Credit information

Maize farmers' credit receiving information is organized into two distinct categories: those who have received credit and those who have not. The affirmative category, labeled "Yes," indicates farmers who have successfully obtained credit to support their farming endeavors, potentially enhancing their ability to invest in resources and improve yields. On the other hand, the "No" category encompasses farmers who have not accessed credit, highlighted potential barriers or challenged they may face in securing financial support for their agricultural activities.

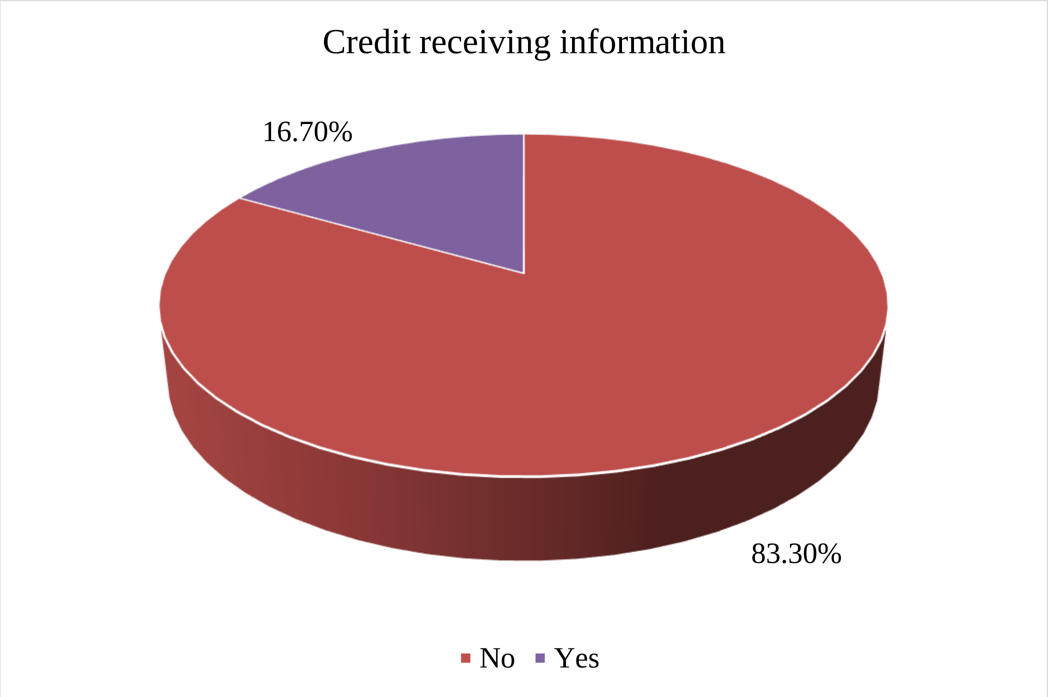

Figure 4.5: Credit receiving information of the respondents

Source: Field Survey 2023

In Figure 4.5, the data illustrates the credit receiving information of the respondents. It reveals that the majority, accounting for 83.3%, responded negatively, indicating that they did not receive credit. Conversely, a minority of respondents, constituting 16.7%, affirmed that they did receive credit.

CHAPTER V

PROFITABILITY OF MAIZE PRODUCTION

5.1 Introduction

In the preceding chapters, we delved into various aspects of maize cultivation in Bangladesh, particularly focusing on the technical efficiency of production. Our examination provided valuable insights into the factors influencing productivity and efficiency at the farm level. However, understanding the profitability of maize production is essential for both farmers and policymakers to make informed decisions regarding resource allocation, investment, and policy formulation. This chapter aims to assess the profitability of maize cultivation in the context of Chuadanga District, Bangladesh. Profitability analysis involves evaluating the financial returns and costs associated with maize production, providing a comprehensive picture of the economic viability of this agricultural activity. By scrutinizing the profitability aspects, we can identify areas of strength and weakness within the maize production system, offering recommendations for enhancing economic outcomes and sustainability.

5.2 Variable cost

Variable costs are essential in maize production due to their direct impact on profitability and efficiency. These costs, including seeds, fertilizers, pesticides, and labor, directly correspond to the amount of maize produced. By carefully managing variable costs, farmers can optimize their inputs to achieve higher yields while controlling expenses. This strategic approach ensures a competitive edge in the market while maximizing returns on investment in maize cultivation. In Table 5.1 the Variable Cost amounts to 118039.63Tk, representing 57.41% of the total cost.

5.2.1 Land preparation cost

Efficient land preparation ensures proper soil aeration, nutrient availability, and weed control, optimizing conditions for maize growth. Investing in quality land preparation minimizes crop stress, enhances water retention, and promotes uniform plant emergence. Ultimately, it contributes significantly to achieving optimal maize yields and maximizing returns on investment for farmers. Land preparation emerges as a significant cost factor, totaling Tk. 8569.59, which accounts for 4.17% of the total production cost.

Table 5.1: Total cost of per hectare maize production

Cost Items	Unit	Per hectare cost of maize production			
		Unit Price	Quantity (Kg)	Total Cost	Percentage Of Total Cost
A. Variable Cost				118039.63	57.41
Land Preparation				8569.59	4.17
Seed	Kg	1917.68	7.48	14344.26	6.98
Hired Labor	Man Day	420.83	59.57	25067.64	12.19
Irrigation	Tk			13208.33	6.42
Pesticide	Tk			2483.33	1.21
Cow-dung	Tk	12	2900	34800.00	16.92
Urea	Tk	28	167.5	4690.00	2.28
MOP	Tk	18	67.62	1217.10	0.59
DAP	Tk	16	157.5	2520.00	1.23
Zinc	Tk	300	7.48	2245.00	1.09
TSP	Tk	25	160.25	4006.25	1.95
Borax	Tk	250	2.61	651.96	0.32
Gypsum	Tk	48	81.5	3912.00	1.90
Other	Tk			324.17	0.16
B. Fixed Cost	Tk			87574.50	42.59
Family Labor	Man Day	400	25	10000.00	4.86
Land Use Cost	Tk			42574.50	20.71
Interest on Operating Capital	Tk			35000.00	17.02
Total Cost (A+B)	Tk			205614.13	100.00

Source: Author owns calculation

5.2.2 Seed cost

High-quality seeds ensure robust crops with improved resistance to pests, diseases, and adverse environmental conditions, leading to higher yields. However, excessive seed costs can significantly inflate production expenses, diminishing overall profitability. Balancing seed quality with affordability is essential for maximizing returns and sustaining a successful maize farming enterprise. The unit price of the seed is listed as Tk. 1917.68 per kg, with a quantity of 7.48 kg. Consequently, the total cost for seed procurement amounts to Tk. 14344.26 . This seed cost represents approximately 6.98% of the total production cost per hectare of maize.

5.2.3 Hired labor

Maize cultivation involves labor-intensive tasks such as planting, harvesting, and post-harvest activities. Fluctuations in hired labor costs directly influence production expenses, affecting the economic viability of maize farming. Efficient management of labor expenses ensures competitive pricing, maximizing returns for farmers and sustaining the maize industry's growth and stability. Hired labor is measured in man-days, with a unit price of Tk. 420.83 per man-day. The quantity of labor utilized is 59.57 man-days per hectare, resulting in a total cost of Tk. 25067.64. Notably, hired labor costs account for 12.19% of the overall total cost of maize production per hectare.

5.2.4 Irrigation cost

Efficient irrigation practices ensure consistent water supply, crucial for maize's growth and development, particularly during critical stages like germination and tasseling. High irrigation costs can significantly inflate production expenses, affecting the economic viability of maize farming operations and ultimately influencing market competitiveness and food security. The irrigation cost is detailed as Tk. 13208.33, representing 6.42% of the total cost.

5.2.5 Pesticide cost

Maize, being susceptible to various pests and diseases, requires consistent protection, which often entails significant expenses on pesticides. Balancing the cost of these chemical inputs with potential yield losses from pest damage is essential for farmers to maximize profitability and sustain their livelihoods. The total cost attributed to pesticides is Tk. 2483.33, which constitutes approximately 1.21% of the overall total cost of maize production per hectare.

5.2.6 Cow-dung cost

Cow dung cost is crucial in maize production due to its role as a potent organic fertilizer. Rich in essential nutrients like nitrogen, phosphorus, and potassium, cow dung enhances soil fertility, promotes healthy plant growth, and boosts maize yields. Additionally, its use reduces dependency on chemical fertilizers, thereby promoting sustainable agricultural practices while also minimizing production costs for farmers. Cow-dung unit price is Tk 12. The quantity required is 2900 kg, resulting in a total cost of Tk. 34,800. This item accounts for approximately 16.92% of the total production cost.

5.2.7 Urea cost

The cost of urea is pivotal in maize production due to its significant role as a primary nitrogen fertilizer. Maize requires ample nitrogen for optimal growth and yield. Urea, being a widely used nitrogen source, directly impacts production expenses. Fluctuations in urea prices directly influence farmers' input costs, affecting profitability and the affordability of maize production. Hence, monitoring urea costs is essential for sustainable maize cultivation and agricultural economics. The cost urea cost stand with a unit price of Tk. 28. The quantity listed is 167.5 kg, resulting in a total cost of Tk. 4690. Additionally, this cost accounts for approximately 2.28% of the total cost of maize production per hectare.

5.2.8 MOP cost

The MOP (Muriate of Potash) cost is pivotal in maize production due to its direct impact on yield and quality. Maize requires potassium for robust growth and development, with MOP being a primary source of this essential nutrient. Managing MOP costs effectively ensures optimal potassium levels in the soil, fostering healthy plant growth, increased resistance to diseases, and ultimately higher yields, thus underlining its crucial role in maize production. Muriate of Potash, came with a unit price of Tk. 18 per kilogram. The quantity utilized is 67.62 kg, resulting in a total cost of Tk. 1217.10. This MOP Cost constitutes approximately 0.59% of the overall total cost of maize production per hectare.

5.2.9 DAP cost

The cost of DAP (Diammonium phosphate) holds significant importance in maize production due to its role as a primary source of phosphorus, vital for plant growth and development. DAP cost directly impacts the overall budget of maize cultivation, influencing farmers' decisions on input selection and profitability. Efficient management of DAP expenses ensures optimal nutrient provision, enhancing crop yield and quality while maintaining economic sustainability in maize farming practices. DAP came with a unit price of Tk. 16 per kilogram. The quantity utilized is 157.5 kg, resulting in a total cost of Tk. 2520. This MOP Cost constitutes approximately 1.23% of the overall total cost of maize production per hectare.

5.2.10 Zinc cost

Zinc is an essential micronutrient necessary for enzyme activity and protein synthesis, crucial processes for maize plants. Insufficient zinc levels can lead to stunted growth, reduced yields, and poor grain quality. Thus, managing zinc costs effectively ensures optimal nutrient uptake and overall maize crop health, directly impacting agricultural productivity and profitability. Zinc cost came with a unit price of Tk. 300. The quantity utilized is 7.48 kg, resulting in a total cost of Tk. 2245. Additionally, the zinc cost constitutes approximately 1.09% of the total cost of maize production per hectare.

5.2.11 TSP cost

The cost of Triple Super Phosphate (TSP) is pivotal in maize production due to its significant role in enhancing crop yields. As a primary source of phosphorus, TSP directly impacts plant growth, root development, and overall yield. Maize, being a high-demand crop, requires sufficient phosphorus for optimal growth and productivity. Therefore, managing the cost of TSP effectively becomes essential for ensuring economical yet efficient maize production practices. The unit price of TSP is Tk. 25 per kilogram, with a total quantity of 160.25 kg. Consequently, the total cost incurred for TSP amounts to Tk. 4006.25. This cost item represents approximately 1.95% of the total cost of maize production per hectare.

5.2.12 Borax cost

The cost of borax is crucial in maize production due to its indispensable role in enhancing crop yields and quality. Borax acts as a micronutrient supplement, aiding in the metabolism of carbohydrates and proteins crucial for plant growth. Additionally, it promotes better absorption of essential nutrients from the soil, thus maximizing maize productivity. Keeping the cost of borax affordable ensures accessibility to this vital resource for farmers, facilitating optimal maize cultivation. The unit price of borax is

Tk. 250 per kg, with a total quantity of 2.61 kg. Consequently, the total cost incurred for borax amounts to Tk. 651.96. This cost item represents approximately 0.32% of the total cost of maize production per hectare.

5.2.13 Gypsum cost

The cost of gypsum holds paramount importance in maize production due to its pivotal role in soil management. Gypsum enhances soil structure by reducing compaction and improving water infiltration, fostering optimal root development crucial for maize growth. Additionally, it aids in mitigating soil acidity, facilitating better nutrient uptake by maize plants. Thus, the affordability and availability of gypsum directly impact maize yield and overall production efficiency. The unit price of gypsum is Tk. 48 per kg, with a total quantity of 81.5 kg. Consequently, the total cost incurred for gypsum amounts to Tk. 3912. This cost item represents approximately 1.9% of the total cost of maize production per hectare.

5.2.14 Other cost

These costs encompass various factors such as labor, equipment, utilities, and maintenance, all of which directly impact the bottom line. By meticulously analyzing other costs, farmers can make informed decisions regarding resource allocation, pricing strategies, and efficiency improvements, ultimately optimizing their maize production processes for long-term success. The total cost attributed to other cost is Tk. 324.17, which constitutes approximately 016% of the overall total cost of maize production per hectare.

5.3 Fixed cost

The expenses like land, machinery, and infrastructure, which are constant regardless of output levels. These costs provide the foundation for operations, enabling efficient planning and resource allocation. Understanding fixed costs is critical for farmers to determine break-even points, assess profitability, and make informed decisions about production scale and investment in the maize farming business. The total cost of per hectare maize production, with a focus on fixed costs. The total fixed cost is Tk. 87,574.5, representing 42.59% of the overall expenditure (table 5.1).

5.3.1 Family labor

Unlike hired labor, family members often contribute their time without direct payment, reducing production expenses. This cost-saving measure enhances the competitiveness of maize farming operations, allowing for greater efficiency in resource allocation. Furthermore, the reliance on family labor fosters a sense of unity and shared responsibility within farming households, strengthening familial bonds and community ties. Family labor is measured in man-days, with a unit price of Tk. 400.00 per man-day. The quantity of labor utilized is 25.00 man-days per hectare, resulting in a total cost of Tk. 10000. Notably, hired labor costs account for 4.86% of the overall total cost of maize production per hectare.

5.3.2 Land use cost

Efficient land allocation directly influences production capacity, affecting stocking densities and infrastructure development. Higher land costs can escalate operational expenses, potentially reducing margins. Moreover, strategic land use planning ensures optimal resource utilization, minimizing environmental footprint and promoting long-term viability in the aquaculture industry. Land use cost stands out, amounting to Tk. 42574.5, representing approximately 20.71% of the total production cost.

5.3.3 Interest on operating capital

Interest on operating capital is crucial in maize farming due to its impact on profitability and sustainability. Maize farming requires upfront investment in lands, equipment, and stocking, all of which incur ongoing operating expenses. Interest on capital affects the overall cost structure, influencing pricing decisions and profitability margins. Efficient management of interest ensures financial stability, enabling farmers to maintain optimal conditions for maize and maximize returns. The total IOC attributed to this item is Tk. 35000, representing 17.02% of the overall expenses.

5.4 Total cost (A+B)

The table 5.1 presents the total cost of maize production per hectare, amounting to Tk. 205614. This figure encompasses various cost items involved in the production process, including expenses related to labor, materials, equipment, and other operational costs.

5.5 Returns from maize farming

Maize production offers substantial returns to farmers due to its versatility and high demand in various industries. With efficient cultivation methods and suitable climate conditions, farmers can achieve impressive yields, translating into significant profits. Additionally, maize by-products such as animal feed, ethanol, and food additives further enhance the economic viability of maize farming, making it a lucrative venture for agricultural entrepreneurs.

5.5.1 Gross return

The data presented in Table 5.2 illustrates the gross return of per hectare maize production, detailing the associated costs. Maize production entails a return of Tk/ha 328,333.33, while the by-product incurs an additional Tk/ha 1,250. The total return per hectare for maize production sums up to Tk/ha 329,583.33. This information provides a clear overview of the financial aspects involved in maize cultivation, outlining both the primary expenditure on maize itself and the supplementary cost related to its by-product.

Table 5.2: Gross return of per hectare maize production

Per hectare gross return of maize production	
Items	**Tk/ha**
Maize	328333.33
By Product	1250.00
Total	329583.33

Source: Author owns calculation

5.5.2 Gross margin

The gap between how much money maize farmer make and how much it costs to produce things is called gross margin. Farmers like to focus on making more money than it costs to produce stuff, which is why they use gross margin analysis. This helps them plan and make decisions for the farm in the short term. In Table 5.3, the gross margin for maize production per hectare stands at 211543.70 Tk. This figure reflects the financial returns generated from the production maize within a specified area.

5.5.3 Net return

The financial metrics associated with maize production per hectare showed in table 5.3. Specifically, it highlights a net return of 123969.20 Tk for each hectare of maize production. This figure represents the overall profit generated from maize farming after factoring in all costs and expenses.

Table 5.3: Gross margin, net return, and benefit cost ratio per hectare maize production

Margins & Returns	Per hectare maize production
A. Gross return	329583.33
B. Total variable cost	118039.63
C. Total cost	205614.13
D. Gross margin (A-B)	211543.70
E. Net return (A-C)	123969.20
F. Return per taka invested (Total cost basis) A/C	1.60

Source: Author owns calculation

5.5.4 Benefit cost ratio

The benefit-cost ratio in maize farming measures the cost efficiency of the venture by comparing the total benefits derived from the operation to the total costs incurred. It accounts for factors such as revenue from maize sales, reduced feed costs, and potential environmental benefits against expenses like initial investment, operational costs, and maintenance. A higher ratio indicates a more financially viable and sustainable maize farming operation. The return per taka invested, calculated on a total cost basis, is noted as 1.60. This figure indicates the efficiency of investment in maize production, suggesting that for every unit of currency invested, there's a return of 1.60 units, reflecting a potentially favorable economic outcome from this venture.

CHAPTER VI

TECHNICAL EFFICIENCY OF MAIZE PRODUCTION

6.1 Introduction

For a long time, economists have used a method called applied econometrics to figure out how well farmers are doing in using their resources effectively. One way they do this is by looking at something called the production function. This helps them see how efficient a farmer is in getting the most crops they can with the resources they have and the methods they use. Imagine each farmer has a goal to get as many crops as possible with what they have. We compare each farmer's actual performance to this ideal goal. If a farmer isn't getting the most crops, they can with what they've got, we say they're not being efficient. We can measure how far off they are from being as good as they could be by looking at how much they're willing to stray from the best methods. This chapter's main goal is to find out how efficient maize growers are and how many of them fall into different efficiency categories. They used a special method called the stochastic frontier production function to do this. This method is useful because it helps us estimate how efficient or inefficient farmers are, and it's controlled by the farmers themselves.

6.2 Interpretation of stochastic frontier production function

The first thing to do when making a maximum likelihood guess is to come up with a math equation called the Likelihood Function for the sample information. This equation helps figure out how likely it is to get a certain set of data, based on a chosen probability model. We don't know the exact values for certain parts of this model. The maximum likelihood guesses, called MLEs, are the values for these parts that make the sample data the most likely.

For the production of maize by farmers, the maximum likelihood estimates for the parameters of the Cobb-Douglas production function with stochastic frontier and the technological inefficiency impact model are shown in Table 6.1.

Table 6.1: Parameters of Stochastic Frontier Production Function for maize production

Independent variables	**Coefficient**	**Standard Error**	**p-value**
Stochastic Frontier			
Land Preparation Cost (X_1)	0.369***	0.046	0.000
Seed Cost (X_2)	-0.029**	0.015	0.048
Urea Cost (X_3)	-0.077***	0.022	0.000
TSP Cost (X_4)	0.02	0.019	0.288
MOP Cost (X_5)	-0.004	0.021	0.841
Cow-dung Cost (X_6)	0.317***	0.104	0.002
DAP Cost (X_7)	0.031*	0.018	0.087
Gypsum Cost (X_8)	0.045**	0.021	0.034
Zinc Cost (X_9)	-0.072**	0.034	0.035
Pesticide Cost (X_{10})	0.11***	0.025	0.000
Irrigation Cost (X_{11})	-0.449***	0.037	0.000
Human Labor Cost (X_{12})	0.205***	0.018	0.000
Constant (X_0)	7.598***	1.225	0.000
Inefficiency Model			
Age (Z_1)	0.068	.171	0.693
Education (Z_2)	1.976	4.897	0.687
Experience (Z_3)	0.372	.519	0.473
Total Family Member (Z_4)	-4.403	11.504	0.702
Total Land (Z_5)	5.432	8.709	0.533
Distance of Agriculture Office (Z_6)	0.102	.552	0.854
Training Received (Z_7)	-9.385	16.123	0.561
Credit Received (Z_8)	14.557	22.261	0.513

Constant (Z_0)	-6.917***	.186	0.000

6.2.1 Land Preparation Cost (X_1)

The regression coefficient of land preparation cost (X_1) of maize production was positive and significant at 1% level of significance which indicates that if expenditure on land preparation was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.029%.

6.2.2 Seed Cost (X_2)

The regression coefficient of seed cost (X_2) of maize production was negative and significant at 5% level of significance which indicates that if expenditure on seed was increased by 1% keeping other factors constant, revenue of maize would be decreased by 0.029%.

6.2.3 Urea Cost (X_3)

The regression coefficient of urea cost (X_3) of maize production was negative and significant at 1% level of significance which indicates that if expenditure on urea was increased by 1% keeping other factors constant, revenue of maize would be decreased by 0.077%.

6.2.4 Cow-dung Cost (X_6)

The regression coefficient of cow-dung cost (X_6) of maize production was positive and significant at 1% level of significance which indicates that if expenditure on cow-dung was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.317%.

6.2.5 DAP Cost (X_7)

The regression coefficient of DAP cost (X_7) of maize production was positive and significant at 10% level of significance which indicates that if expenditure on DAP was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.031%.

6.2.6 Gypsum Cost (X_8)

The regression coefficient of gypsum cost (X_8) of maize production was positive and significant at 5% level of significance which indicates that if expenditure on gypsum was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.045%.

6.2.7 Zinc Cost (X_9)

The regression coefficient of zinc cost (X_9) of maize production was negative and significant at 5% level of significance which indicates that if expenditure on zinc was increased by 1% keeping other factors constant, revenue of maize would be decreased by 0.072%.

6.2.8 Pesticide Cost (X_{10})

The regression coefficient of pesticide cost (X_{10}) of maize production was positive and significant at 1% level of significance which indicates that if expenditure on pesticide was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.11%.

6.2.9 Irrigation Cost (X_{11})

The regression coefficient of irrigation cost (X_{11}) of maize production was negative and significant at 1% level of significance which indicates that if expenditure on irrigation was increased by 1% keeping other factors constant, revenue of maize would be decreased by 0.449%.

6.2.10 Human Labor Cost (X_{12})

The regression coefficient of human labor cost (X_{12}) of maize production was positive and significant at 1% level of significance which indicates that if expenditure on human labor was increased by 1% keeping other factors constant, revenue of maize would be increase by 0.205%.

6.3 Interpretation of technical inefficiency model for maize farmer

6.3.1 Age (Z_1)

The positive but insignificant coefficient of age implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.2 Education (Z_2)

The positive but insignificant coefficient of education implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.3 Experience (Z_3)

The positive but insignificant coefficient of experience implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.4 Total Family Member (Z_4)

The negative but insignificant coefficient of total family member implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.5 Total Land (Z_5)

The positive but insignificant coefficient of total land size implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.6 Distance of Agriculture Office (Z_6)

The positive but insignificant coefficient of distance of agriculture office implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.7 Training Received (Z_7)

The negative but insignificant coefficient of training received implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.3.8 Credit Received (Z_8)

The positive but insignificant coefficient of credit received implies that this factor has no impact on technical inefficiency. This factor does not reduce or increase technical inefficiency of maize farming.

6.4 Distribution of technical efficiency

The distribution of technical efficiency among maize farmers presented in table 6.2. The efficiency levels are categorized into three ranges: 50-80%, 81-90%, and 91-100%. Within these ranges, there are respective counts of farmers and their percentages. For the 50-80% efficiency range, there are 17 farmers, constituting 28.3% of the total. In the 81-90% range, there are 23 farmers, accounting for 38.3% of the total. The highest efficiency range, 91-100%, comprises 20 farmers, making up 33.3% of the total. The minimum value recorded is 68.00, while the maximum value reaches 99.00. On average, the efficiency stands at 86.99. Additionally, the standard deviation (SD) is calculated to be 8.29.

Table 6.2: Difference between Frequency Distribution of Technical Efficiency of maize farmer

Efficiency (%)	No. of Farmers	Percentage of Farmers
50-80	17	28.3
81-90	23	38.3
91-100	20	33.3
Total	60	100
Minimum	68.00	
Maximum	99.00	
Average	86.99	
SD	8.29	

Source: Author owns calculation

(Sadiq et al., 2009) found that the positive and significant value for education reveals that education increase inefficiency in maize production. Small-scale farmers who grow maize typically work at about 83% of their maximum potential efficiency. This means they're only getting 83% of the highest possible harvest from the resources they use. The findings suggest there's room to boost output by 17% without needing more resources. Also, the analysis of yield gaps shows that small-scale maize farmers could increase their average yield by 4.8 quintals per hectare by using their inputs more effectively (Tsega et al., 2022). The average skill level of maize farmers is about 69.03%. This means there's a chance to raise maize production by 31.07% without using more inputs. Some farmers are as low as 40.26% efficient, while others are as high as 99.9% efficient (Belete, 2020). Technical efficiency varied between 0.71 and 0.99, averaging 0.93. Factors like experience, extension service, and farm size were found to have negative coefficients, suggesting they contribute to reducing inefficiency among maize farmers (Yeasmin Sampa, 2018). The technical efficiency of different production units varies widely, with some operating at levels as low as 18% and others as high as 99%. The lowest efficiency, at 18%, falls significantly below the most efficient level, which is 99%. This means that the least efficient production units are not operating effectively. On the other hand, the most efficient units, operating at 99% efficiency, are just 1% away from the highest possible efficiency. These units can be considered efficient because it's rare for any production unit to reach 100% efficiency in practice. When looking at the combined data, the average technical efficiency across all units is 49.11%. This figure compares well with similar studies done in different agricultural areas, suggesting that the production units in this study are performing reasonably efficiently (Borko & Ameda, 2021).

CHAPTER VII

PROBLEMS FACED BY THE MAIZE FARMERS

7.1 Introduction

In this chapter, we delve into the intricate challenges confronted by maize farmers within the Chuadanga District of Bangladesh. Despite the promising potential of maize cultivation in addressing food security and economic prosperity, farmers encounter a multitude of obstacles that hinder their productivity and overall well-being. Understanding these challenges is crucial for devising effective strategies to enhance the technical efficiency and sustainability of maize farming practices in the region.

7.2 Problems faced by the maize farmers

The data presented in Table 7.1 outlines the primary challenges encountered by maize farmers, along with the corresponding percentages and ranks:

7.2.1 Lack of high-yielding hybrid maize

Maize farmers encounter difficulties due to the unavailability or inadequate access to high-yielding hybrid maize varieties, impacting their yield and overall productivity, contributing to food insecurity and economic instability in agricultural communities.

7.2.2 Lack of labor

Maize farming operations suffer from manpower shortages, hindering timely and efficient tasks such as planting, weeding, and harvesting, leading to decreased productivity, increased production costs, and potential crop losses, exacerbating livelihood challenges for farmers and their families.

7.2.3 Salinity, drought, and floods

Maize cultivation faces adverse effects from environmental factors such as soil salinity, prolonged droughts, and sudden floods, which disrupt crop growth cycles, reduce yield quality and quantity, threaten food security, and amplify socio-economic vulnerabilities among farming communities, necessitating adaptive strategies and sustainable resilience measures.

Table 7.1: Problems faced by the maize farmers

Problems	Percentage	Rank
Lack of high-yielding hybrid maize	87	1st
Lack of labor	80	2nd
Salinity, drought, and floods	78	3rd
Diseases caused by various organisms	72	4th
Limited awareness among farmers about benefits and best practices of maize cultivation	65	5th
Inadequate irrigation facilities	60	6th
Challenges accessing institutional credit	55	7th

Source : Field survey 2023

7.2.4 Diseases caused by various organisms

Maize crops are susceptible to a range of diseases caused by pathogens, pests, and other harmful organisms, leading to yield losses, decreased crop quality, increased reliance on pesticides and fungicides, elevated production costs, and heightened risks to food security and farmer livelihoods, necessitating integrated pest management approaches and disease-resistant crop varieties.

7.2.5 Limited awareness among farmers about benefits and best practices of maize cultivation

Maize farmers lack sufficient knowledge and information about the advantages and optimal techniques of maize cultivation, resulting in suboptimal agronomic practices, reduced yields, missed opportunities for yield improvement and income generation, and limited adoption of sustainable agricultural technologies, highlighting the importance of farmer education and extension services.

7.2.6 Inadequate irrigation facilities

Maize farming suffers from inadequate access to reliable irrigation infrastructure, leading to water scarcity, uneven moisture distribution, reduced crop yields, increased susceptibility to drought stress, and compromised resilience to climate variability, underscoring the urgent need for investments in irrigation development and water management strategies to support sustainable agricultural production.

7.2.7 Challenges accessing institutional credit

Maize farmers face difficulties in obtaining financial support and credit facilities from institutional sources, limiting their ability to invest in inputs, equipment, and technology, constraining farm expansion and modernization efforts, impeding productivity enhancements, and exacerbating poverty and inequality in rural farming communities, necessitating improved access to inclusive and affordable financial services and supportive policy interventions.

CHAPTER VIII

SUMMARY AND CONCLUSION

8.1 Summary

Bangladesh, an emerging nation with a population of 165.2 million, relies heavily on agriculture for its economic growth. The country's agricultural sector contributed 13.02% to the national GDP in 2021-22, with over 70% of the population and 40.6% of the labor force dependent on agriculture. However, the agricultural sector experienced a slowdown in 2021-22, with a sectoral share of broad agriculture, industry, and service at 11.50%, 37.07%, and 51.44 percent, respectively. The region is also vulnerable to the consequences of global warming and climate change due to its unique geographic location, floodplains, low elevation, high population density, and heavy reliance on nature for resources and services. This study examines the technical efficiency of maize cultivation in Chuadanga district, focusing on Chuadanga Sadar and Jibannagar Upazillas, to offer insights for broader agricultural policy formulation and intervention strategies. The methodology used for data collection included surveys and interviews with maize farming proprietors, providing valuable insights and perspectives.

This study was conducted using a multi-sampling technique to select a representative sample of 60 farmers. This method ensures diversity across regions and farming practices, providing a comprehensive understanding of maize cultivation techniques and challenges. The sample size of 60 was chosen to balance statistical significance and practical feasibility, aiming to capture a broad spectrum of perspectives while maintaining manageable data collection efforts. The study aims to yield insights that can inform agricultural policies, improve farming practices, and enhance productivity and sustainability of maize farming operations. In-person interviews were conducted from December 2023 to January 2024, followed by field excursions. The data was organized and summarized using STATA, a computer program for measuring technical efficiency. The stochastic frontier model is used to measure the effectiveness of businesses, considering both known and unknown factors. The Cobb-Douglas production function is used to calculate output based on inputs, providing valuable insights into resource allocation and production optimization. To determine profit or loss, all cost items must be computed, considering the market price at which goods or services are actually exchanged for. The expenses and profits were calculated per hectare maize production for a year. The study reveals that the majority of respondents, including 6.7% of the younger age group and 43.3% of the older age group, have completed primary education. A small percentage, 3.30%, have basic literacy skills. The majority of respondents have completed secondary education, with 48.30% having attained a secondary level and 11.70% having completed higher secondary education. The majority of respondents have less than 5 years of experience, with 41.67% having more than 10 years of experience. The majority of respondents list agriculture as their main occupation, indicating a significant reliance on agricultural activities for livelihoods. A notable portion also engage in agriculture as a secondary occupation, suggesting diversification of income sources or a multifaceted approach to livelihood strategies. Family sizes are approximately 4.93, with an average number of male members per family being 2.38. On average, 1.45 members per family are employed. Farmers farm categories are categorized into "Small," "Medium," and "Large." Irrigation systems used by respondents vary, with 16.70% using motors and 83.30% using Selo Machines. Training information is presented, with 76.70% not having undergone training, while 23.30% have received training. Distances to agricultural extension offices are distributed, with 8.3% reporting less than 5 kilometers, 75.0% ranging from 5 to 10 kilometers, and 16.7% exceeding 10 kilometers. Credit receiving information is also presented, with 83.3% of respondents reporting negative responses and 16.7% affirming they do receive credit.

The cost of maize cultivation is a significant factor in achieving optimal yields and returns on investment. Land preparation, seed quality, hired labor, irrigation, pesticides, cow-dung, urea, Muriate of Potash (MOP), DAP, zinc, and other costs contribute to the overall cost. Land preparation costs account for 4.17% of the total production cost, while seed procurement costs account for 6.98%. High irrigation costs can inflate production expenses, affecting market competitiveness and food security. Pesticides account for 1.21% of the total cost, while cow-dung costs account for 16.92%. Zinc costs account for 2.28% of the total cost. Muriate of Potash costs ensure optimal soil potassium levels, while DAP costs ensure optimal nutrient provision. Zinc costs impact agricultural productivity and profitability, with zinc costs accounting for 1.09% of the total cost. Efficient management of these costs ensures a competitive edge in the market and maximizes returns on investment in maize cultivation. The cost of maize production per hectare is a significant factor in the overall economic success of the farming industry. The unit price of phosphorus (TSP) is Tk 25 per kilogram, which is approximately 1.95% of the total cost of maize production per hectare. The cost of borax is Tk 250 per kg, which is 0.32% of the total cost of maize production per hectare. Gypsum, a vital resource for maize growth, is Tk 48 per kg, which is 1.9% of the total cost of maize production per hectare. Other costs include maintenance, planning and resource allocation, community ties, land use cost, and capital. The gross return of maize production per hectare is Tk/ha 328,333.33, with a net return of 123969.20 Tk for each hectare of maize production. The benefit-cost ratio in maize farming measures the economic efficiency of the venture by comparing the total benefits derived from the operation to the total costs incurred. A higher ratio indicates a more financially viable and sustainable maize farming operation. The cost of maize production per hectare is a critical factor in the overall economic success of the farming industry. By analyzing these costs, farmers can make informed decisions about resource allocation, pricing strategies, and efficiency improvements, ultimately leading to long-term success.

The study examines the maximum likelihood estimates for the parameters of the Cobb-Douglas production function with stochastic frontier and the technological inefficiency impact model for maize production. The parameters include land preparation cost, seed cost, urea cost, cow-dung cost, DAP cost, gypsum cost, zinc cost, pesticide cost, irrigation cost, and human labor cost. The regression coefficients show that increasing land preparation by 1% would increase maize production revenue by 0.029%. However, increasing seed cost by 1% would decrease maize production revenue by 0.029%. Increased urea cost by 1% would decrease maize production revenue by 0.077%. Increased cow-dung cost by 1% would increase maize production revenue by 0.317%. Increased DAP cost by 1% would increase maize production revenue by 0.031%. Increased gypsum cost by 1% would increase maize production revenue by 0.045%. Increased zinc cost by 1% would decrease maize production revenue by 0.072%. Increased pesticide cost by 1% would increase maize production revenue by 0.11%. Increased irrigation cost by 1% would decrease maize production revenue by 0.449%. Increased human labor cost by 1% would increase maize production revenue by 0.205%. The technical inefficiency model for maize farmers shows that factors such as age, education, experience, total family members, total land size, distance of agriculture office, training received, and credit received do not significantly impact technical inefficiency. Therefore, the study suggests that improving these factors could potentially reduce or increase technical inefficiency in maize farming. The technical efficiency of maize farmers is categorized into three ranges: 50-80%, 81-90%, and 91-100%. The majority of farmers in these ranges are farmers, with an average efficiency of 86.99. However, maize farmers face several challenges, including the lack of high-yielding hybrid maize, labor shortages, and environmental factors like soil salinity, drought, and floods. These issues lead to food insecurity, economic instability, and increased reliance on pesticides and fungicides. Limited awareness among farmers about the benefits and best practices of maize cultivation, inadequate irrigation facilities, and challenges accessing institutional credit are also significant issues. Diseases caused by various organisms, limited knowledge about the benefits of maize cultivation, and inadequate irrigation facilities further exacerbate these issues. Accessing institutional credit is also a challenge, as it limits farmers' ability to invest in inputs, equipment, and technology, limiting farm expansion and modernization efforts. These challenges highlight the need for improved access to financial services and supportive policy interventions.

8.2 Conclusion

In conclusion, this study has provided a comprehensive analysis of the technical efficiency of maize cultivation in Chuadanga District, Bangladesh, addressing each of the stated objectives. The socio-economic profile of maize farmers revealed crucial insights into their demographic characteristics, landholding sizes, access to credit, and education levels, offering a nuanced understanding of the context within which maize production occurs. Through data envelopment analysis (DEA), the level of technical efficiency was rigorously evaluated, highlighting variations in efficiency levels among farmers and uncovering potential areas for improvement in resource utilization. Factors influencing technical efficiency, such as farm size, access to extension services, use of modern agricultural inputs, and training, were identified, providing policymakers with actionable insights to formulate targeted interventions aimed at enhancing productivity and sustainability in maize production. Additionally, the profitability analysis underscored the economic viability of maize cultivation, offering incentives for both existing farmers and potential investors. This study serves as a valuable resource for policymakers, enabling evidence-based decision-making to support the agricultural sector's growth and development in Bangladesh. By leveraging the findings of this study, policymakers can design policies and programs tailored to address the specific needs and challenges faced by maize farmers, ultimately contributing to improve livelihoods, food security, and rural development in the region.

8.3 Recommendations

Based on the study's findings, maize farming is viewed as a lucrative investment opportunity in Bangladesh, offering significant income and employment prospects. Despite its profitability, farmers encounter challenges in maximizing profits, necessitating intervention from policymakers. Specific recommendations are proposed to enhance maize production, urging policymakers to take necessary measures.

(a) Since most maize farmers already operate efficiently with existing farming systems and released maize varieties, the development of new varieties is crucial to further increase maize productivity.

(b) Prioritize investment in labor-saving technologies to reduce manual labor in maize production by implementing machinery and specialized equipment for planting, harvesting, irrigation and pest control.

(c) Develop maize varieties tolerant to drought, heat and salinity to enhance production in challenging environments.

(d) Effective maize disease management involves implementing crop rotation, using disease-resistant varieties and employing integrated pest management techniques, alongside maintaining field cleanliness, proper irrigation and early planting schedules.

(e) To improve farmer awareness and adoption of best practices in maize production, prioritize educational outreach initiatives, offering tailored training programs covering topics like crop rotation, disease management and high-yield maize varieties. Utilize various communication channels to disseminate educational materials and collaborate with local agricultural experts for up-to-date information and practical demonstrations.

(f) Address inadequate irrigation in Bangladeshi maize production through infrastructure upgrades and system expansion, introducing water-efficient technologies, providing irrigation management training and exploring alternative water sources.

(g) Encourage small and marginal farmers to invest in maize cultivation by offering institutional credit at lower interest rates along with easy loan disbursement policies and collateral-free loans.

As a result, it is suggested that both government agencies and non-governmental organizations take proactive steps to implement intervention activities aimed at boosting farmer's productivity and improving their technical efficiency. These interventions have the potential to bring about significant changes in the livelihoods of farmers, leading to improved incomes and overall well-being.

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APPENDIX

Appendix I: Stoc. frontier normal/half-normal model

trvtest	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
landprepcostha	.369	.046	8.06	0	.279	.458	***
SeedCostha	-.029	.015	-1.98	.048	-.059	0	**
Ureacostha	-.077	.022	-3.50	0	-.121	-.034	***
TSPCostha	.02	.019	1.06	.288	-.017	.058	
MOPCostha	-.004	.021	-0.20	.841	-.045	.037	
CowdungCostha	.317	.104	3.04	.002	.113	.522	***
DAPCostha	.031	.018	1.71	.087	-.004	.066	*
GypsumCoatha	.045	.021	2.12	.034	.003	.087	**
zincCostha	-.072	.034	-2.10	.035	-.139	-.005	**
PesticteCostha	.11	.025	4.42	0	.061	.159	***
IrrigationCostha	-.449	.037	-12.01	0	-.522	-.375	***
totalhumanlaborcos~a	.205	.018	11.55	0	.17	.24	***
Constant	7.598	1.225	6.20	0	5.196	9.999	***
Constant	-6.917	.186	-37.20	0	-7.282	-6.553	***
age	.068	.171	0.39	.693	-.268	.403	
Education012345	1.976	4.897	0.40	.687	-7.623	11.574	
Experience	.372	.519	0.72	.473	-.645	1.388	
Totalfamilymember	-4.403	11.504	-0.38	.702	-26.951	18.145	
Totallandha	5.432	8.709	0.62	.533	-11.638	22.502	
Distanceofagricult~e	.102	.552	0.18	.854	-.981	1.184	
trainingreceived	-9.385	16.123	-0.58	.561	-40.986	22.216	
Creditreceived	14.557	22.261	0.65	.513	-29.075	58.188	

Constant	-42.626	51.517	-0.83	.408	-143.598	58.347	
Mean dependent var	12.702	SD dependent var	0.116				
Number of obs	60	Chi-square	654.407				
Prob > chi2	0.000	Akaike crit. (AIC)	-197.646				
*** p<.01, ** p<.05, * p<.1							