IMPACT OF INCREASED ENERGY PRICES ON INCOME OF STW OWNERS AND WATER BUYERS IN SOME SELECTED AREAS OF GHATAIL UPAZILA IN TANGAIL DISTRICT

A Thesis
By

Examination Roll No. 07 Ag.Econ. (PE) JJ-15 M
Registration No. 29205
Session: 2001-2002
Semester: January-June, 2008

MASTER OF SCIENCE (MS)

IN

AGRICULTURAL ECONOMICS (PRODUCTION ECONOMICS)

Department of Agricultural Economics
Bangladesh Agricultural University
Mymensingh

November 2008

IMPACT OF INCREASED ENERGY PRICES ON INCOME OF STW OWNERS AND WATER BUYERS IN SOME SELECTED AREAS OF GHATAIL UPAZILA IN TANGAIL DISTRICT

A Thesis
By

Examination Roll No. 07 Ag.Econ. (PE) JJ-15 M
Registration No. 29205
Session: 2001-2002
Semester: January-June, 2008

Submitted to the Department of Agricultural Economics
Bangladesh Agricultural University, Mymensingh
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

AGRICULTURAL ECONOMICS (PRODUCTION ECONOMICS)

November 2008

IMPACT OF INCREASED ENERGY PRICES ON INCOME OF STW OWNERS AND WATER BUYERS IN SOME SELECTED AREAS OF GHATAIL UPAZILA IN TANGAIL DISTRICT

A Thesis
By

Examination Roll No. 07 Ag.Econ. (PE) JJ-15 M
Registration No. 29205
Session: 2001-2002
Semester: January-June, 2008

Approved as to style and contents by

(Prof. Tofazzal Hossain Miah)
Supervisor

(Prof. Dr. Md. Habibur Rahman)
Co-supervisor

(Prof. Dr. M. Harun-Ar Rashid)
Chairman
Examination Committee
and
Head, Department of Agricultural Economics
Bangladesh Agricultural University
Mymensingh

November 2008

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENT

First of all, I bow to the grace and mercy of the Almighty Allah without whose desire I could not have materialized my dream to complete this thesis.

I acknowledge my deepest sense of gratitude and immense indebtedness to my reverend teacher and research supervisor Professor Tofazzal Hossain Miah, Department of Agricultural Economics and Dean, Faculty of Agricultural Economics and Rural Sociology, Bangladesh Agricultural University, Mymensingh for his untiring guidance, valuable suggestions, affectionate encouragement, helpful comment, constructive criticisms and continuous supervision during the whole period of the research work and preparation of this thesis.

I would like to pay most sincere and heartfelt gratitude to my Co-supervisor, Dr. Md. Habibur Rahman, Professor, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh for his valuable suggestions in organizing, developing the research work, broad view of discussion and reviewing towards perfection of the entire manuscript.

I express my special gratefulness to Professor Dr. M. A. Sattar Mandal, Department of Agricultural Economics, and Vice-Chancellor of the Bangladesh Agricultural University, Mymensingh for his valuable comments and scholastic suggestions about the thesis.

Heartfelt gratitude are due to Dr. M. Harun-Ar Rashid, Professor and Head, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh for his constructive suggestions and encouragement during the period of this research work.

I would like to express my heartfelt respect to all of the teachers of the Department of Agricultural Economics particularly Professor Dr. S. M. Munzur Murshed, Professor Atiar Rahman Molla, Professor Dr. M. Serajul Islam, Professor Dr. W. M. H. Jaim, Professor Dr. Md. Akteruzzaman for their abundant inspiration and help at the various stages of this research work.

My special thanks and appreciations are due to Md. Wakilur Rahman, Assistant Professor, Department of Rural Sociology, Bangladesh Agricultural University, Mymensingh and Mr. Rayhan Hayat Sarwer, Data Analyst, The World Fish Center, Dhaka, Junior Research Fellows of the project "Shallow Tubewell Irrigation Business in Bangladesh" for their technical advice, inspiration and enormous help in data analysis, preparation of result and constant support without whom the research work could not be carried out successfully.

I owe my dearest friends and well wishers especially Liza, Tanjima, Nasrin, Sathy, who extended their all out help and cooperation during my research work.

I am very much grateful to the STW owners and water buyers in the study area, who helped directly or indirectly by supplying relevant information.

Last but not the least, I reserve my boundless gratitude and immense indebtedness to my most reverend parents and sisters who are not only a constant source of inspiration, but also sacrificed a lot of their happiness in the long process of building my academic career.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF TABLES

Irrigation

LIST OF TABLES (Concluded)

LIST OF FIGURES

LIST OF APPENDIX TABLES

RONYMS AND ABBREVIATIONS

BAU	:	Bangladesh Agricultural University
BADC	:	Bangladesh Agricultural Development Corporation
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit -Cost Ratio
BKB	:	Bangladesh *Krishi* Bank
BPDB	:	Bangladesh Power Development Board
BREB	:	Bangladesh Rural Electrification Board
BWDB	:	Bangladesh Water Development Board
Cm	:	Centimeter
DAE	:	Department of Agricultural Extension
DAP	:	Draught Animal Power
DF	:	Discount Factor
DLRS	:	Department of Land Survey and Records
DOS	:	Diesel operated Shallow Tubewell
DTW	:	Deep Tubewell
et al.	:	Et alia (L.) and others
EOS	:	Electric operated Shallow Tubewell
Etc.	:	Etceteras
FFYP	:	Fifth Five Year Plan
GDP	:	Gross Domestic Products
GOB	:	Government of Bangladesh
Ha	:	Hectare
HSC	:	Higher Secondary Certificate
i.e.	:	That is
IMMI	:	International Irrigation Management Institute
IRR	:	Internal Rate of Return
Kg	:	Kilogram
Km	:	Kilometer
Km^2	:	Square Kilometer

ACRONYMS AND ABBREVIRTIONS (Concluded)

LDC	:	Less Developed Country
LLP	:	Low Lift Pump
MOA	:	Ministry of Agriculture
MOP	:	Muriate of Potash
mm	:	Milimeter
max.	:	Maximum
min.	:	Minimum
mg	:	Miligram
ml	:	Mililiter
MS	:	Master of Science
MV	:	Modern Variety
NGO	:	Non-Government Organization
No/s.	:	Number/s
NPV	:	Net Present Value
O & M	:	Operation and Maintenance
OC	:	Operating Capital
PT	:	Power Tiller
PWB	:	Present Worth of benefit
PWC	:	Present Worth of cost
SSC	:	Secondary School Certificate
STW	:	Shallow Tubewell
Tk	:	Taka (Bangladeshi currerncy)
TSP	:	Triple Super Phosphate
°C	:	Degree Celsius
%	:	Percentage
vs.	:	Versus
&	:	And
<	:	Is less than
>	:	Is greater than
=	:	Is equal to
±	:	plus or mines

ABSTRACT

The present study evaluates the impact of increased energy prices on income of STW owners and water buyers under diesel and electrically operated STWs. Five adjacent villages namely Shekh Shimul, Saitapara, Kurmushi, Kaijalipur and Kagmari Beltail of Dighalkandi union under Ghatail Upazila of Tangail district were purposively selected for the study, where a considerable number of STW owners and water buyers were available. In the study, 30 STW owners and 60 water buyers from 5 villages of Ghatail Upazila were selected randomly. For collecting data, two sets of questionnaire were prepared to record the required information. One set was for the STW owners and the other one was used for the water buyers. The survey covered a whole period of MV Boro production (January to May 2008). Both tabular analyses and project appraisal techniques were used. Three discounting measures such as BCR, NPV, and IRR were chosen. The average life for both the DOS and EOS business was considered as 10 years. The 10 per cent discount rate was chosen for financial analysis.

The major findings of the study are that the water buyers are making profit from MV Boro paddy production, and both DOS and EOS are profitable but MV Boro paddy production under EOS was relatively more profitable than that of DOS. Energy price was the main operating cost of STW business. The DOS owners were anxious about increase of diesel price over time because they were in break-even stage of this business. If diesel price increases this way, it would be very difficult to run STW irrigation business profitably. According to farmers' opinion, the output sharing system is superior to other payment systems for water because the STW owners become more careful about watering the plots regularly. The buyers were also aware about higher profitability of EOS and were not fully satisfied with the prevailing one-fourth water charge and claimed for reduction of water charge.

From the results of the present study it can easily be mentioned that a considerable scope apparently exists in the study areas for the expansion of STWs to enhance the productivity of MV Boro paddy and to increase farm income of the STW owners as well as water buyers. Hence investment in this business can go ahead elsewhere in Bangladesh where topographical and ecological environments similar to those of the study area are found. Since the EOS business are more profitable to their owners than the diesel ones, the expansion of electricity supply to the business area is essential so that tubewells can be operated by electricity.

Finally, based on the findings of the study, some policy implications are suggested and scopes for further studies are indicated.

Chapter 1

INTRODUCTION

1.1 Background

Bangladesh is a home of 140 million people and the most densely populated country in the world suffers from food deficiency for a long time. Moreover, the economy of Bangladesh is dominated by agriculture and the livelihoods of the farmers are largely connected with intensive agriculture production. About 51.69 per cent of its labour force is engaged in agriculture contributing about 21.84 per cent of the Gross Domestic Product (GDP) is derived from crops (GOB 2007). The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security. Despite these improvements, Bangladesh's people remain among the poorest in South Asia, earning only around US$520 each on average per year (BER 2007). Nearly 75 per cent of the country's population depends either directly or indirectly on agriculture. It generates 63 per cent of total national employment and around 25 per cent of national GDP (about 71 per cent of which is derived from crop production) (BBS 2006). So, this sector's performance strongly affects Bangladesh's malnutrition and poverty levels. Rice is the major crop (grown on 80 per cent of the country's irrigated area). The yearly production of rice increased from around 10 million tonnes in the early 1970s to nearly 27 million tonnes in 2006 improving food self-sufficiency and food security nationally (BBS 2006). Such growth has helped to reduce the percentage of poor in the country, from 58.8 per cent in 1992 to 49.8 per cent in 2000 (BBS 2006).

Irrigation has revolutionized rice production in Bangladesh. However, limited irrigation is used for non-rice crops. The rice crop alone occupies 90-95 per cent of the irrigated area and only 5-10 per cent is left for other crops. Cultivation of modern variety (MV) of rice during the *Boro* season is almost entirely dependent on irrigation water. Irrigation has been practiced for thousand of years, chiefly in regions with annual rainfall of less than 500 mm, including many countries of

Africa, Asia and America. Irrigation means artificial water supply for dry agricultural land by means of dams, barrages, channels, or other devices. Irrigation frequency means the recurrence of the artificial application of water to land to assist in the production of crops. Grain crops reveal their need for water by wilting temporarily. It is better to base the irrigation schedule on observations made of the moisture status of the soil. The time and frequency of irrigation for some of the important field crops as recommended by the Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI) are mentioned here:

Continuous standing water in rice field is not necessary. A good yield can be obtained if the soil is in saturated condition from the time of transplanting. The number of tillers increases sufficiently if the field is in saturated condition up to 30-45 days after transplanting. Per hectare yield of rice is not hampered if the fields remain dry for 3 days after disappearing of standing water in between each irrigation. Water requirements of rice are maximum at booting and flowering stages. During this period sufficient water should be maintained in the plot to get a good yield. For rice a single excessive irrigation should be avoided. Frequent small irrigation is preferable. The depth of water in each irrigation should be 5-7 cm. Frequency of irrigation can be determined by dividing the depth of irrigation by the water to be depleted from the soil per day.

In Bangladesh, about 95 per cent of the rainfall occurs during April to October, leaving the winter months, (i.e., November to March) very dry. Therefore, irrigation is a prerequisite for obtaining stable high yields during the dry season.

It is also used in wetter areas to grow certain crops, such as rice. Estimates of total irrigated land in the world range from 220 to 250 million hectares, almost half of them in India, Bangladesh, Pakistan, and China (Sarwer *et al*. 2008). However, the use of canals, dams, weirs, and reservoirs (as like as tank made by bricks) for the distribution, control, and storage of water was probably initiated in ancient Egypt (Sarwer *et al*. 2008).

1.2 Irrigation Technology in Bangladesh

Different types of irrigation technologies are being used in Bangladesh but the extent of success varies due to geographic location, climatic condition, economic status, soil texture, land elevation, and availability of groundwater. Both small and minor scale irrigation systems play the dominant role in MV *Boro* rice cultivation. Minor irrigation comparatively smaller, easier and cheaper means of the artificial application of water to land to assist in the production of crops. It is difficult to utilize fully the huge water resources for the benefit of the country due to social, economical, financial and technical constraints. Though efforts have been made to develop some major irrigation, flood control and drainage projects, desired results from these projects are yet to be achieved. To meet the need for increased food production, minor irrigation is being widely used.

Table1.1 Irrigation under Different Plan Periods

Plan Period	Irrigated area (million ha)			Percentage of total irrigated area under minor irrigation
	Minor irrigation	Major irrigation	Total	
Bench mark (1972-73)	0.89	0.05	0.94	94.68
First Five Year Plan (1973-78)	1.10	0.06	1.16	94.82
Two Year Plan (1978-80)	1.33	0.08	1.41	94.32
Second Five Year Plan (1980-85)	2.28	0.19	2.47	92.30
Third Five Year Plan (1985-90)	2.89	0.21	3.10	93.22
Fourth Five Year Plan (1990-95)	2.95	0.17	3.12	94.55
Fifth Five Year Plan (1996-2001)	2.81	0.04	2.85	98.59

Source: Planning Commission (1999).

1.3 Evolution of Groundwater Technology in Bangladesh

Bangladesh is a small country in the South Asian region with an area of 147,570 square kilometers. Geographically it is situated between 20°34′ and 26°38′ North latitude and 88°01′ to 92°41′ East longitude (BBS 2006). The nation, largely a flat delta, is transacted by numerous rivers and their tributaries. It has fertile cultivable land and abundant water in the wet season, but limited water in dry season. There are two major sources of irrigation water in Bangladesh: (i) Surface; and (ii) Groundwater. In 1970s, irrigation was mainly dependent on surface water, but during the last two decades the area irrigated by groundwater increased significantly. Up to 1992, there was a tubewell siting regulation that required obtaining government permission for sinking irrigation wells. Up to 1992 there was 0.389 million Shallow tubewells (STWs) used for irrigating 1.392 million ha land, but in 1992 when government suspended the siting regulations and selling of STW was handed over to the private sector. As a result in 2006, 1.129 million STWs were used to irrigate 3.160 million ha of land. During the last 13 years the irrigation scenario in Bangladesh has changed with more use of groundwater and the number of STW has increased many times (MOA 2006). *Boro* rice alone contributed the highest proportion of total rice production in 2007 (BER 2007). Increase of *Boro* rice production remains a significant way to increase total food production and ensure food security in the country. Groundwater covers 75 percent of total irrigated area. About 80 percent of groundwater used for crop production, where *Boro* paddy alone used 73 percent of total irrigation (BBS 2007). STW covered 60 percent of total irrigated area (BBS 2006).

Table 1.2 Summary of Change in Use of Irrigation Technologies

Mode of irrigation	1996/97	2006/07
Groundwater		
Shallow tubewell (%)	56.55	65.56
Deep tubewell (%)	13.00	14.72
Surface water		
Low-lift pump (%)	14.50	16.87
Traditional (%)	4.25	0.60
Gravity flow (%)	10	2.25
Total	100	100

Source: Sarwer *et al.* (2008) and the Fifth Five Year Plan (1998).

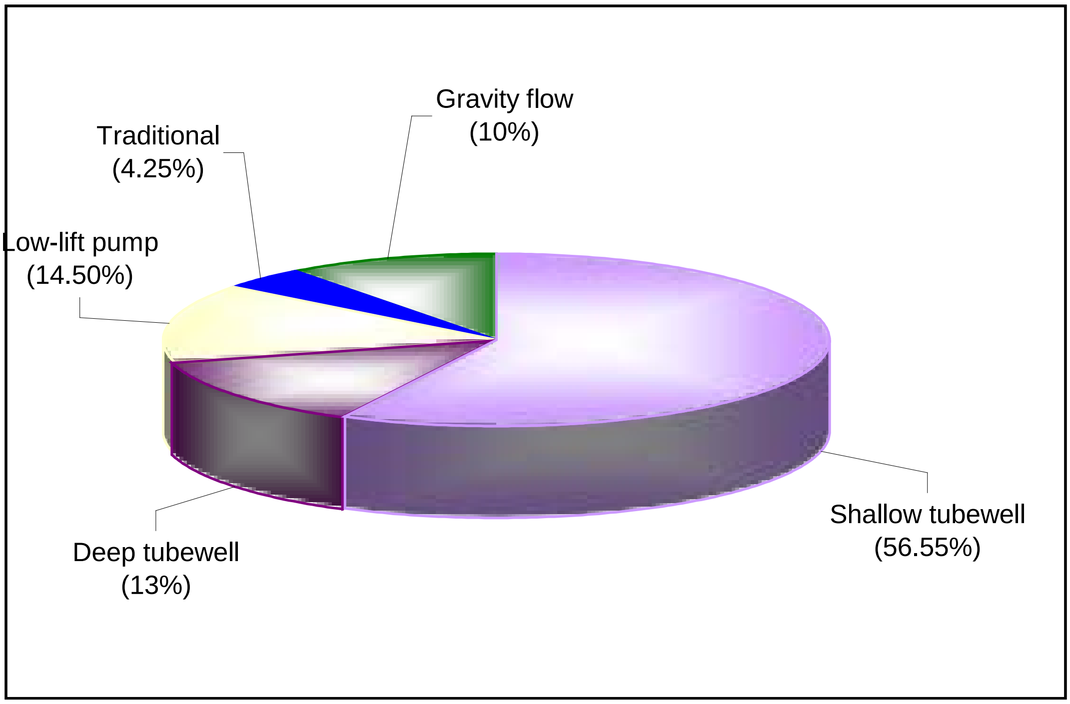

Figure 1.1 Shares of Irrigation Technologies in Utilizing Groundwater in 1996/97

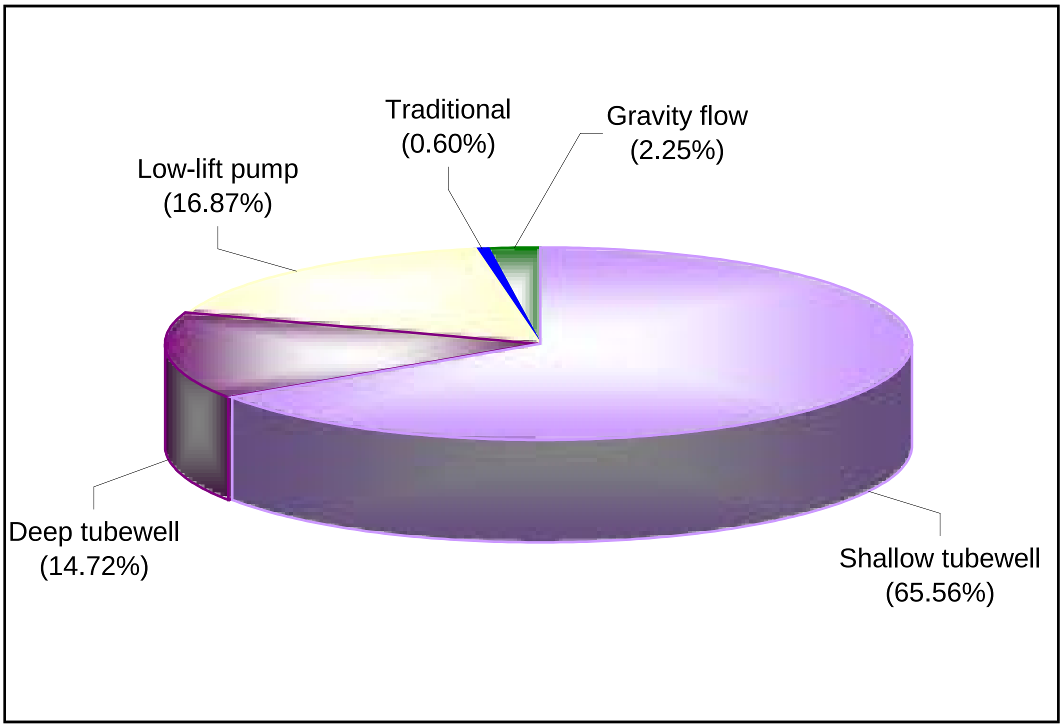

Figure 1.2 Shares of Irrigation Technologies in Utilizing Groundwater in 2006/07

1.4 Irrigation Devices

Irrigation devices specially designed mechanical appliances used for lifting water either from surface or sub-surface sources for irrigation and domestic purposes. In Bangladesh, 7.56 million hectares are suitable for irrigation. But according to the present estimate of available water resources, only about 6.8 million hectares can be irrigated. At present, only about 3.12 million ha have been brought under irrigation. This indicates that additional 3.68 million ha of rainfed lands can be covered with irrigation. With proper utilization and management, 4.5 - 5.0 million hectares of land can be irrigated by using groundwater. In Bangladesh, about 94 per cent of the irrigated land is under small and minor irrigation. In 2005/06, three types of irrigation equipment were found in operation as shown in Table 1.3.

Table 1.3 Number of Irrigation Equipment by Different Types in 2005/06

Name of irrigation equipment	Number of operated equipment
Shallow tubewells (STWs)	11,82,525
Deep tubewells (DTWs)	28,289
Low lift pumps (LLPs)	1,19,135

Source: Adapted from Sarwer *et al.* (2008).

The irrigation efficiency is only about 30 per cent. With proper utilization and improved management, 4.0 to 5.0 million hectares of land can be irrigated easily by using the same number of irrigation devices instead of the present 3.12 million hectares. Devices for irrigation water lifting range from age-old indigenous water lifts to highly efficient pumps. Pumps operated by electric motors or engines have come into prominence in all large scale lift irrigation schemes. Selection of a suitable water lifting device for a particular situation depends on the characteristics of the source of water and the lifting device, the amount of water to be lifted, the depth to the pumping water level, the type and amount of power available and the economic status of the farmers. The irrigation devices commonly used in Bangladesh may be classified in the following ways.

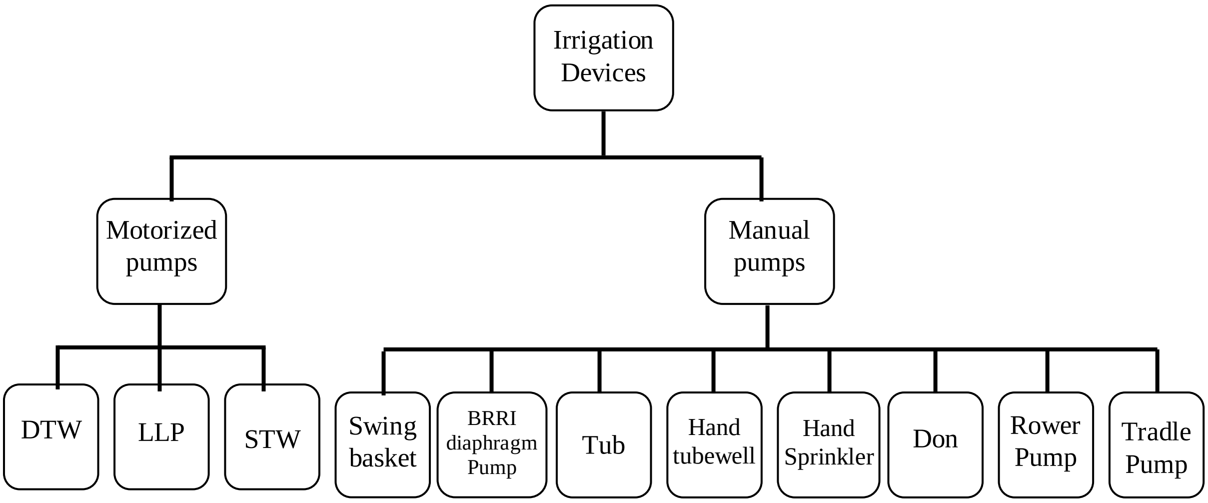

Figure1.3 Classification of Irrigation Devices Used in Bangladesh

1.5 Groundwater for Irrigation Purposes

Groundwater in Bangladesh occurs at a very shallow depth. Groundwater contributes largely to irrigation (about 80 per cent of the total coverage was provided by groundwater in 2006/07). Mainly irrigation was used for crops grown in *Rabi* (dry) season in Bangladesh. In the absence of adequate surface water in the dry season, irrigation becomes heavily dependent on groundwater. Two types of irrigation equipment such as DTW and STW were mainly used for groundwater irrigation. About 60 per cent areas are covered by STW (BBS 2006). Coverage of STWs irrigation areas has increased by about 17 per cent during the last 6 years (2000/01-2005/06) (BBS 2006). The STWs are operated by diesel and electricity. Electricity operated STWs have been increasing due to upward trend of diesel price. Mainly Crop share and cash payment systems have widely been used to irrigate rice field in Bangladesh.

During the last decade and a half, irrigation coverage has been increased significantly to raise food production levels. The cropping patterns have also changed by the installation of different types of irrigation wells, particularly STWs (Table 1.4).

Table 1.4 Changes in Cropping Patterns

Before situation (1985/86)		Present situation (2007)	
Cropping patterns	% under different patterns	Cropping patterns	% under different patterns
Fallow-*Aman-Boro*	23	Aus- *Aman –Boro*	64
Aus-*Aman*-Fallow	23	Aus- *Aman*-Vegetables	16
Aus-Fallow-Fallow	10	Vegetables-Vegetables-Vegetables	2
Aus-*Aman*-Pulse	10	Jute-*Aman*-Fallow	1
Fallow-*Aman*-Fallow	6	Aus-*Aman*-Jute	2
Jute –*Aman*-Fallow	5	Jute-*Aman-Boro*	1
Jute –*Aman*-Pulse	4	Jute-*Aman*-Vegetables	1
Aus-*Aman*-Wheat	4	Fallow-*Aman-Boro*	2
Jute/Fallow-Fallow/*Aman*-Tomato/Potato/Chilli	4	Jute-Vegetable-Fallow	1
Others	11	Others	10
Total	100	Total	100

Source: Sarwer *et al. (*2008).

In changing situation over the time some existing issues regarding groundwater irrigation by STWs are essential to study to improve the irrigation business in Bangladesh.

1.6 Irrigation Market in Bangladesh

The demand for irrigation water has been increasing day by day and the cost is also increasing accordingly. By minimizing losses of irrigation water, more area can be irrigated with the same volume of water. If proper water management is practiced agricultural production can be increased through either higher yield or larger irrigated areas. Therefore, the importance of proper water management has widely been accepted by those concerned with irrigation and crop production.

To plan and implement water resource use, Bangladesh government has established a number of organizations, from the national to the local level. But, these organizations remain inefficient: they lack coordination and their functions tend to overlap. Moreover, these efforts have tended to concentrate on reorganization at the national level. Not enough attention has been paid to organizational development at the lower levels. To address this, participatory irrigation management (PIM) was begun in 1995, with the introduction of a three-tier management structure for irrigation systems. As a result, it is observed that the farmers singly or jointly used STW to irrigate their land. Although farmers basically install STW to irrigate their own land, but they also sell water to other farmers. This is assumed that they sell water commercially to earn profit like in other businesses. Following the process of STW irrigation development a form of business has been established in rural Bangladesh.

There are generally two major forms of payment for water under STWs. The first is the traditional system of fixed cash payment per unit of land or time usually based approximately on the average cost of supplying water, which includes depreciation of STWs, fuel, management and supervision. Payment is made partly at the beginning and partly after the harvest of paddy. The other system, which is widely practiced, is the payment for water in the form of a 25 percent share of the harvested paddy. Water buyers, who purchased water from STW owners, paid one fourth of total production of paddy from irrigated plots.

1.7 Objectives of the Study

The present study has been designed to fulfill the following specific objectives:

i. to identify socioeconomic status of STW owners and water buyers;

ii. to assess the impact of increased energy prices on command areas under diesel and electrically operated STWs;

iii. to estimate the relative profitability of farmers producing irrigated MV *Boro* paddy under diesel and electrically operated STWs and its contribution to household income;

iv. to estimate the profitability of STW irrigation business and its contribution to household income;

v. to estimate contribution of key inputs to the production processes of irrigated MV *Boro* paddy production; and

vi. to suggest some policy guidelines/recommendations.

1.8 Hypotheses of the Study

The following hypotheses were set for the study:

(a) There is no variation in socioeconomic characteristics between the owners of STW and water buyers producing MV *Boro* paddy.

(b) There is no impact of increased energy prices on command areas under diesel and electrically operated STWs.

(c) There is no difference in profitability of farmers producing irrigated MV *Boro* paddy under diesel and electrically operated STWs and its contribution to household income.

(d) STW irrigation business is unprofitable and its contribution to household income is almost nil, and

(e) Contribution of key inputs to the production process of MV *Boro* Paddy is negligible.

1.9 Justification of the Study

Bangladesh is a land of mighty rivers and innumerable tributaries, heavy rainfall and recurring floods. Yet, irrigation plays a vital role in this country for half of the year (mainly in dry season) when water scarcity seriously handicaps farming operation. In Bangladesh, optimum use of irrigation water should play an important role in increasing agricultural production. Overall development of the country's agricultural sector will require year-round use of irrigation facilities. The country will benefit substantially through improvements in the allocation and distribution of the available water. It is observed from the survey data that the people singly or jointly used STW to irrigate their own land. Although people primarily install STW to irrigate their own land, but they also sell water to other neighboring farmers to earn money like in other businesses. Following the process of STW irrigation development a form of business has been established in rural Bangladesh. These STWs are operated by diesel and electricity. Electricity operated STWs have been increasing due to upward trend of diesel price. In changing situation over time some existing issues regarding groundwater irrigation extracting by STWs is essential to study to improve the irrigation business in Bangladesh.

The agriculture sector is the single largest contributor to income and employment generation and a vital element in the country's challenge to achieve self-sufficiency in food production, reduce rural poverty and foster sustainable economic development. The government has, therefore, accorded the highest priority to this sector to meet these challenges and to make this sector commercially profitable. In producing MV *Boro* paddy, irrigation is the lifeline of agriculture in Bangladesh.

It is reported that under the existing system of water charge STW irrigation is not profitable from the viewpoints of STW owners. It is often argued that with increased fuel prices and low command area, profitability of the owners of STWs has decreased substantially. In this context, the profitability of STWs needs to be re-examined both from STW owners' point of view as well as water buyers' point of view.

With the above background, this study may be useful both at micro and macro levels. It is expected that the study will provide some valuable information to the farmers and the owners of the STWs. It is also expected that this study will give some guidelines to the researchers and to the policy makers. Farmers may use the result of the study in making decision with respect to irrigation management. This analysis would also help in making decisions as to the choice of technology and systems of payment for water which will contribute most to increasing society's welfare. Better selection of project is helpful for a low income country like Bangladesh by removing wastage of scarce resources. This study should improve understanding on the performance of STWs irrigation business. The study will also be helpful for policy makers reviewing the policy options for irrigation in general.

1.10 Outline of the Study

This study consists of eight chapters. The present chapter is followed by chapter 2, which furnishes a brief review of empirical investigation related to the present study. Chapter 3 presents research methodology followed in this study. In Chapter 4, description of the study area is presented. Socioeconomic characteristics of STW owners and water buyers are discussed in Chapter 5. Profitability of MV *Boro* paddy and its contribution to household income is presented in Chapter 6. In Chapter 7, profitability of STW irrigation business and its contribution to household income are discussed. Summary, conclusion and policy implications are given in the final chapter.

Chapter 2

REVIEW OF LITERATURE

The aim of this chapter is to review the previous studies, which are related to the present one. Although a good number of researchers of various agencies and organizations have shown their interest in conducting research on the economics of tubewell irrigation business in Bangladesh as well as in other developing countries, but it was found that only a few works were conducted in Bangladesh, which were related to this study. Review of some research works relevant to the present study are briefly discussed below:

Sarwer *et al.* (2008) conducted a study on Shallow Tubewell Irrigation Business in Bangladesh. They investigated the profitability of STW irrigation business in increasing energy price regime. The STW business was profitable in current normal situation but the business will unprofitable for diesel operated STW while electrically operated STW will not be unprofitable but will stay in a break-even stage during uncertain situation considering 10% increase of cost or 10% decrease of benefit only. But it would be fairly unable to sustain the STWs, particularly diesel operated STW business in severe uncertain situations.

Intizar (2007) examined evidence on poverty-reducing impacts of irrigation in local settings as well as at broader regional levels, and also looks into key factors influencing these impacts, and attempts to answer the following key questions: (i) what is the magnitude of impact of irrigation on poverty reduction; (ii) what is the response of poverty reduction to irrigation or irrigation-induced expansion in agricultural output across various settings; (iii) do poverty-reducing impacts of irrigation vary across systems, and if so, why? Or what are the conditioning factors that determine the anti-poverty impacts of irrigation? The paper offers insights into these questions with analyses and findings from his studies and with review and referencing of other related topical studies on the subject.

Chakravorty (2004) conducted the experiment to compare the practice of cost recovery from irrigation farmers, with the derived economic cost of water per unit volume. The pricing framework is based on two major scenarios: (i) pricing for those who use critical volume of water under a production regime; (ii) pricing for those who waste water under the same production regime. It allowed shifts in social preferences of water use and changed volume of water under different agro-ecological situations. Prices could be adjusted to the circumstances where waste of water is discouraged and incentives offered to relatively poor farmers for more efficient use of water. Three sets of alternative uses were used: (i) winter rice, (ii) fish cultivation and (iii) industry and domestic. The exercise was aimed at introducing water pricing under a uniform and socially acceptable framework. The concept of water market in this paper implies rationalization of the use of this scarce resource and possible reallocation of water both within agriculture sector, and from agricultural use to non-agricultural ones. Even within agricultural sector, an additional unit of water to those who can afford to produce crops with higher value added (other than traditional paddy or wheat) would be a welcome venture (i.e., for farmers growing fruit and vegetables).

Rahman and Takeda (2004) conducted the study to examine the cost of rice production with reference to irrigation water. It was found that the cost of irrigation water was 33 per cent of the total production cost in the surveyed villages. In those two villages almost all large households had irrigation devices. Farmers who had no irrigation device purchased water for irrigation from those who had. It was also observed that selling irrigation water was a profitable business among irrigation device holders.

Miah (2004) conducted a study on profitability analysis of Shallow Tubewell Owners under crop sharing arrangement in some selected areas of Bogra district. He showed that the farmers/water users can make a reasonable profit from HYV *Boro* by purchasing water from STW owners, but the profit of STW owners is not so high.

Kumar (2003) presented a theoretical model to analyze farmers' response to changes in power tariff and water allocation regimes vis-a-vis energy and groundwater use. It validates the model by analyzing water productivity in groundwater irrigation under different electricity pricing structures and water allocation regimes. Water productivity was estimated using primary data of gross crop inputs, cost of all inputs, and volumetric water inputs. The analysis shows that unit pricing of electricity influences groundwater use efficiency and productivity positively. It also shows that the levels of pricing at which demand for electricity and groundwater becomes elastic to tariff are socio-economically viable. Further, water productivity impacts of pricing would be the highest when water is volumetrically allocated with rationing. Therefore, an effective power tariff policy followed by enforcement of volumetric water allocation could address the issue of efficiency, sustainability and equity in groundwater use in India.

Fujita *et al.* (2003) tried to show that the rapid agricultural growth in West Bengal, India, since the 1980s is mainly attributable to the development of private shallow tubewell irrigation, rather than the agrarian reforms. Data are based on an intensive field survey conducted in September 2000. Large farmers mainly invested in tubewells, but it does not mean that they monopolize agricultural profit as the so-called 'waterlords'. On the contrary, water sales business became less profitable as the number of tubewells increased in the village, and the real water charge declined through the changes of contractual arrangement in the groundwater market. It also comments on the current situation of irrigation subsidy relating to state-operated deep tubewells and power subsidy given to electrified tubewells, as well as their effects to irrigated farming. Lastly, it points out the large difference in factor shares in rice production between West Bengal and Bangladesh, arguing that West Bengal agriculture is much more equitable in favour of landless labourers.

Tushaar *et al.* (2003) reported aims to reevaluate the entire debate on the system of charging water extraction mechanisms for electricity consumption in South Asia, from the perspective of the energy-irrigation nexus. It outlines the simple logic of what might be a win-win strategy for an energy-irrigation nexus in South Asia, at least in the short-run. Metered and flat tariff regimes are explored not just as alternative pricing policies but as alternate business philosophies.

Herath (2002) stated that irrigation and water management are indispensable elements in increasing agricultural production and productivity in the developing countries. However, evaluation of the heavy investments made in irrigation by developing country governments and development banks reveals that the potential of these investments has not been realized. There is widespread recognition of the need to improve the performance of irrigation, particularly in the area of governance. The 'New Institutional Economics' has much to offer the study of institutional arrangements in water use. The basic concepts of the New Institutional Economics are summarized in this paper, and a review of the performance of irrigation institutions in a number of countries (India, Sri Lanka, Nepal, Japan and China, Philippines, Malaysia, Haiti and other countries) is presented. It is argued that heavy government involvement at the farm level, and bureaucratic interference, have been instrumental in the demise of effective institutional mechanisms in irrigation in many countries. It is clear that new thinking and practices are needed, particularly to develop institutions that are structurally suited for water management and protection at the local level.

Sarker and Lingard (2001) conducted the study in an area of Bangladesh to assess the impact of minor irrigation on different farm sizes and to determine the optimum allocation of resources of large and small farmers among different crops in a STW irrigation system. Data were collected through a survey of 114 farms in Bogra District in 1999 in order to develop linear programming representative farm models. The analysis takes into account crop activities, inputs used, farm size and soil types. Optimal plans show misallocation of existing resources and indicated considerable scope for increasing farm income by reallocating existing resources. The misallocation of resources on large farms was greater than on small farms. The analysis suggests that, by reallocating existing resources, large farms can increase farm income and employment more significantly than small farms. The research supports the view that the government should maintain a policy that favours private sector investment and operation of STW irrigation and that the extension workers may direct farmers to allocate their resources in a better way.

Jaim and Akteruzzaman (1999) stated that privatization and deregulation policies adopted by the government in the last few years had a significant effect on the groundwater irrigation market. Recent studies have confirmed that privatization and deregulation policies have speeded up groundwater irrigation development particularly through rapid expansion of small-scale cheaper STWs. In many cases, the command areas of hitherto monopolized Deep Tube-wells (DTWs) have been encroached by the STWs which caused a decrease in water price. Thus, the groundwater market has been transformed from a monopolistic to an oligopolistic structure after introduction of STW. Further development of groundwater irrigation is also expected by more investment in STW, the technology which is cost effective and easy to manage compared to DTW.

Asad (1998) observed that Bangladesh's Barind Project was initiated to benefit a relatively poor, underdeveloped and environmentally fragile area (of nearly 7500 km) with a population of over 5.5 million. The area has low rainfall and difficult access to groundwater. The main purpose of the project is for irrigated agriculture, but many other elements have been successful in increasing prosperity and arresting desertification. The project has managed to achieve progress in specific technical activities and also in wider social and environmental benefits. The project is financially sustainable since its revenue income covers its operating costs.

Ghani (1998) found that the present irrigated area 90 per cent is irrigated using DTW, STW, manually operated and low lift pumps. Through irrigation management and effective operation of the flood control and drainage projects, agricultural production of the country can be increased substantially. The country could produce enough food grains to support the increasing population and to export fresh vegetables and fruits provided there is an improved processing, storage, packaging and transportation programme. To create suitable conditions for this improvement, mistrust between, public, government and private business has to be removed. Other constraints include low productivity per unit of land and water, poor access to marketing and transportation, poor access to credit and changing government policy which should be resolved for sustainable development of agriculture in Bangladesh.

Rahman (1997) undertook a study on optimization of STW owner income in a selected area of Tangail District. He showed that the investment in both diesel and electrically operated STWs were profitable but ensured supply of electricity would make this business more profitable than diesel engine.

Mannan (1996) conducted a study entitled, "Economics of shallow tubewells in an area of Bangladesh". He estimated per hectare cost and return of STW irrigation on income and employment and to make an appraisal of investment on STWs. In this study, 30 STW owner (15 diesel operated and 15 electrically operated STWs) were selected from four villages of Shahzadpur Thana of Sirajganj district. The results of the analysis indicated that there were significant differences between the per hectare costs and returns of crop production in irrigated and non irrigated plots. The findings of the study also reveal that the annual income of STW owners were Tk 39,610.87 and 18,362.38. The analysis reveals that the investments in electrically operated STWs were more profitable rather than diesel operated STWs.

Rao (1996) conducted a study on economics of Shallow Tubewells in an area of Bangladesh. He found that there was a significant difference existed between per hectare costs and returns of crops production in irrigated and non irrigated plots. He also found that investment in electrically operated STWs were more profitable than that of diesel operated STWs.

Manndal and Parker (1995) performed a study on privatization of minor irrigation in Bangladesh. They found that the average net returns per STW were Tk 6,859 in the case of STW owners. It reveals from their study that electrically operated STW had higher returns than that of diesel operated STWs. When an inter districts comparison was made, they found that the average net returns of STWs were higher in more advanced districts (Tk 6,220 in Bogra and Tk 7,874 in Comilla) than those in less advanced districts (Tk 2,501 in Hobiganj and Tk 3,708 in Nilphamari).

Uddin (1992) conducted a study entitled, "An evalution of minor irrigation projects of Tangail district considering different systems of payment for water". He found that participating farmers are making profit under tubewell projects considering different systems of payment for water. All STWs and DTWs with the exception of electrically operated DTWs under cash payment systems are profitable. Electrically operated DTW projects under cash payment system are making losses, since the managers are required to pay a huge amount of bribes to the officials of BPDB for electricity connection. The results of sensitivity analysis suggest that the profitability of the projects is positively related to water charges.

Miah (1989) conducted another study on comparative performance of diesel and electrically operated STW irrigation project in Taingail District. He found that the participating farmers were earning profits from HYV *Boro* cultivation and both electrically and diesel operated STW projects were profitable from the view point of managers as well as the economy as a whole.

World Bank (1989) made an attempt to highlight the groundwater market situation. It was found that the market for the groundwater technologies was highly imperfect because of the discrimination between technologies with respect to acquisition price and subsidies. The deep tubewells were heavily subsidized and distributed with subsidized bank credit to the large farmers while their had been little or no direct subsidies on STW, most of which were bought by small and medium farmers and the rate of cash purchase of STWs was higher than in the case of DTWs. No doubt there were considerable, "hidden" subsidies for all types of technologies in terms of huge loan defaults, but this was a reflection of the failure of the credit market, and inefficiency of bureaucracy and politics. The report also made an attempt of observe the share crop system.

Shah (1989) conducted a research on efficiency and equity impacts on groundwater markets. He showed groundwater markets had far reaching social effects. Some 5-7 millions well owning rural families in India were likely to be involved as water sellers; some 15 - 25 million or more were be water buyers. There was substantial skewness in private ownership of energized wells; as a result, water buyers were normally resource poor families. He observed that this number would be no doubt increased as the remaining 2/3rd of the unutilized groundwater potential in the country get developed over the next 20 years or so.

Mandal (1987) found in his study that there were two forms of payment for water under DTW and STW. The first one was the traditional system of cash payment, usually based approximately on the average cost of supplying water for irrigation including fuel, management and supervision. Payment was made partly at the beginning and partly after the harvest of paddy. The other system was in the form of a 25 per cent share of the produced crops.

Petty *et al.* (1978) stated that the aquifer underlying the High Plains and many of the alluvium aquifers underlying the Trans Pecos are exhaustible; i.e., there is a negligible recharge from percolation and other sources. Therefore, even with unchanged natural gas prices, these groundwater supplies are being "economically" exhausted over time as pumping depth increases. Increases in fuel prices will lead to reduced groundwater pumpage and result in less groundwater being economically recoverable. Although life of the physical supply will be exhausted, a greater quantity of groundwater will be economically unrecoverable for irrigation without significant product price increases.

The present study is a modest attempt in this direction. It has been designed to evaluate the impact of increasing energy price on incomes of STW owners and water buyers in an area of Bangladesh, where intensive STW irrigation business has gradually been developed. A decorous attempt has been undertaken to find out not only the relative profitability of water buyers, who are virtually using irrigation water for MV *Boro* paddy production under diesel and electrically operated STWs, but also to assess the profitability of the STWs owners, who are investing in STWs for the purpose of supplying irrigation water to MV *Boro* fields in exchange of water charges that are received by tubewell owners in the form of either some fixed amount of crop-share of the harvested paddy or a certain amount of cash money (per unit of crop field).

Chapter 3

METHODOLOGY OF THE STUDY

3.1 Introduction

Methodology is an integral part of any research. Methodology can highlight the situation of a research. The reliability of a scientific research depends to a great extent on the appropriate methodology used in the research. This chapter deals with a brief description of methodological steps and procedures followed in the study. A farm management study involves collection of data from individual farmers. There are several methods of data collection of which farm business survey is important. The farm business survey method was used in the present study. This method has two major advantages: i) Survey enables quick investigation of large number of cases, and ii) its results have wider applicability (Miah 2004). The design of the survey involves several steps, such as: selection of the study area, selection of the sample, preparation of survey schedule, period of survey, conducting interview, etc.

3.2 Selection of the Study Area

The study area has been chosen from an intensively irrigated area of Bangladesh, which falls under the Indo-Gangetic basin region. The study area comprises of five adjacent Mauzas/villages namely Sheikh Shimul, Saitapara, Kurmushi, Kaijalipur and Kagmari Beltail of Dighalkandi union under Ghatail Upazila in Tangail district. The entire irrigation system of the area mainly depends on groundwater lifting device like STW.

The main considerations in selecting the study area were as follows:

i. A large number of STW owners and water buyers were found in the area; and
ii. The study areas also have easy access from the Bangladesh Agricultural University (BAU) and local language of these areas was quite familiar to the researcher.

Another significant advantage of selecting this area was that the study area had a good history of irrigation business over the past decades. So, the study area has been chosen keeping in mind the basic objectives of the study.

3.3 Selection of Samples, Sampling Techniques and Sample Size

Early in the planning of any survey the researcher needs to choose the sampling method to be employed. For the selection of samples for a study two things need to be taken into considerations. The sample size should be as large as to allow for adequate degrees of freedom in the statistical analysis. In other words, administrations of field research, processing and analyzing of data should be manageable within the limits imposed by physical, human and financial resources. It is not possible to study all the owners of STW and water buyers of the study area. Two-stage stratified random sampling technique was used to collect data from water buyers. Firstly, 30 STW owners were selected randomly from all and then two water buyers were also randomly chosen from each of the selected 30 STWs. During the selection of 30 STW owners, equal weight was given to diesel operated STWs and electricity operated STWs to assess business in both cases. Thus 30 water buyers from Diesel Operated STW (DOS) and 30 water buyers from Electrically Operated STW (EOS) were selected for the study. So a total of 90 samples (30 STW owners, 30 DOS water buyers and 30 EOS water buyers) were used for this study.

3.4 Preparation of Survey Schedule

In conformity with the objectives of the study, a preliminary survey schedule was designed for recording the data. The schedule included questions on the socio economic characteristics of the STW owners and it contained the detailed information about initial investments and operating expense of STWs, and input-output data of MV *Boro* paddy production. The schedule was first pre-tested and then it was finalized.

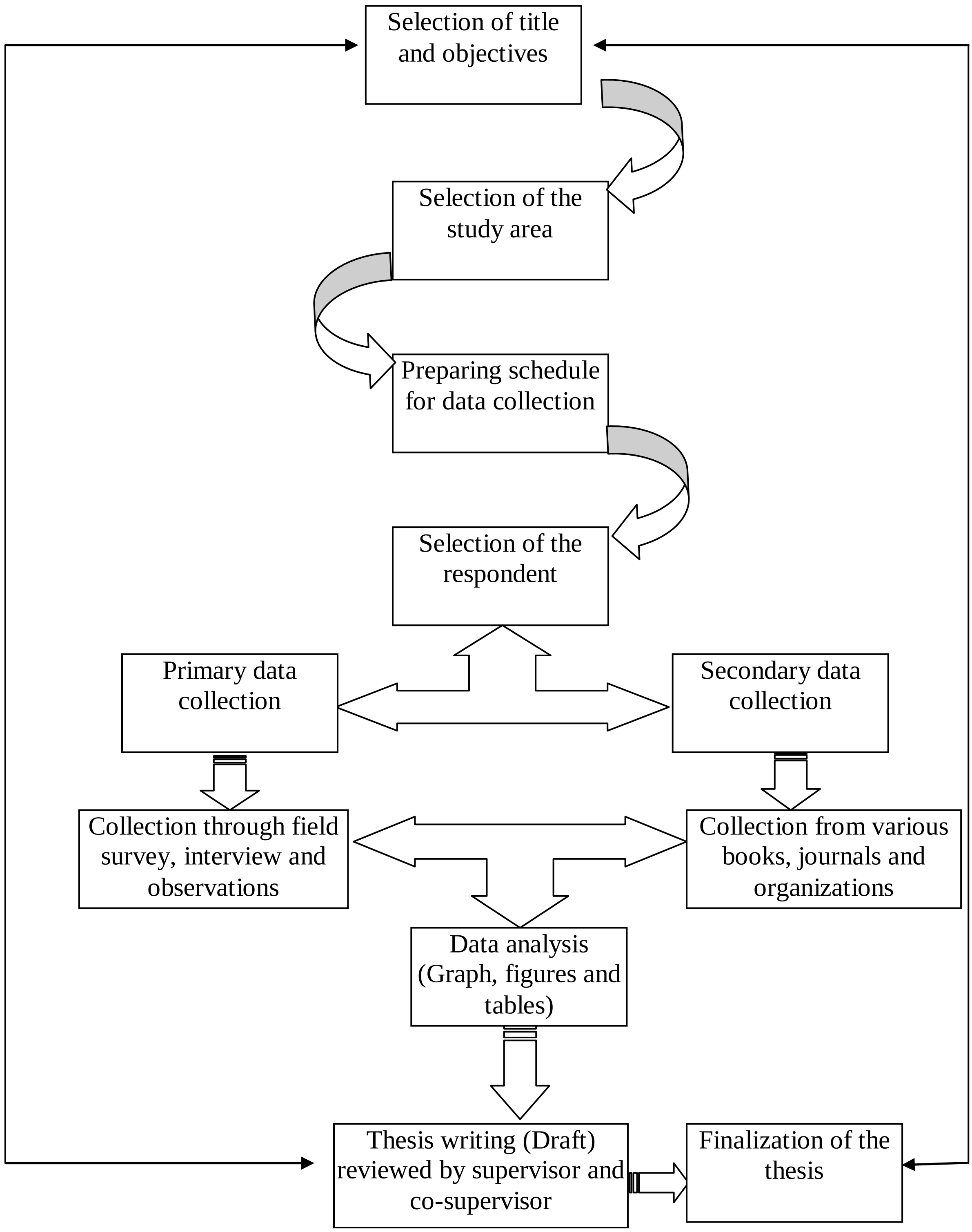

Figure 3.1 Steps Followed in Preparing the Thesis

3.5 Period of the Study

Boro paddy is generally transplanted in January-February and harvested at April-May. Since STWs are usually used to a great extent in *Boro* season, the author collected data during the *Boro* season of 2008. However, the formal data was collected during the period from January to April 2008.

3.6 Collection of Data

After the preparation of final schedule the researcher herself collected data. According to Dillon and Hardaker (1993) there are three main methods by which farm survey data can be gathered. These are: (1) direct observation; (2) interviewing respondents; and (3) record kept by respondents. In this study "interviewing respondents" method i.e., farm survey method was used for data collection, as it is less costly and less time consuming. Moreover, survey enables quick investigations of large number of cases and its results have wider applicability. Before going to make an actual interview, the author explained the aims and objectives of the study to all the respondents. The researcher also assured them that all information would be kept confidential so that there was no hesitation in the minds of the respondents to answer the relevant questions correctly.

Both primary and secondary data were collected for this study. The primary data were collected through two sets of interview schedule: one for STW owners and another for water buyers. The secondary data were mainly collected from Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), Bangladesh Water Development Board (BWDB), Center for Environmental and Geographic Information Services (CEGIS) and Department of Land Survey and Records (DLRS). Having interviewed a respondent, it was necessary to check and cross-check the interview schedule to verify whether all include items were recorded properly. If found any item that was left out or inconsistent or contradictory, the missing information were collected from respondent. It may be noted here that all the information were collected in local unit, which were converted into standard international units while processing and analyzing data. Apart from these two sets of questionnaire, four sets of checklist were prepared for conducting focused group discussions (FGD) with rural STW/motor mechanics, spare parts sellers, installation mechanics and local workshop owners.

3.7 Problems Faced in Collecting Data

During the period of data collection, the following problems were encountered:

i. Most of the respondents initially hesitated to answer questions because they had no previous idea about such type of research. To overcome this situation a good deal of time was spent to gain their confidence.

ii. It was difficult to convince the respondents on the utility of this study because most of them were illiterate and did not have any idea about farm management study.

iii. The respondent were mostly afraid of imposition of new taxes and therefore, they were reluctant to provide information relating to their land holdings, others assets, etc. Even, some of them were asking the researcher whether they would get any benefit from this interview, or not.

iv. Sometimes the respondents were not available at their residence and in such cases, more than one visit were required to conduct a single interview.

3.8 Analytical Techniques

The collected data were analyzed with the purpose of achieving the objectives of the study. Both tabular and regression analysis were done to achieve the main objectives. The tabular method has been widely used in farm management research, because it is convenient and easy to understand. The tabular method of analysis includes classification of data in the forms of tables. In this study, simple and weighted average, percentages etc., were used.

To find out the factors influencing the farmers to participate in STW irrigation business, the following probit regression function was specified as follows:

$$Y = a + ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_6X_6 + u_i$$

Where,

Y = Types of farmers (0=Participatory farmer and 1=water seller);

X_1 = education level (year);

X_2 = income (Tk in lac);

X_3 = cultivable land (hectare);

X_4 =occupation-sub (1=yes, 2=otherwise);

X_5 = age (year); and

X_6 = family size (no.).

a = intercept, ß = Coefficients of the key variables.

To examine the performance of STW irrigation business, profitability analysis of STW business and *Boro* rice were done. Production period of *Boro* rice was about four months and due to such short production period the following profit function was fitted.

$$\pi = P_y.Y + P_b.B - \sum_{i-1}^{n} (Pxi.Xi) - TFC$$

Where,

π = Per hectare net return or profit of MV *Boro* paddy (Tk/ha);

Y = total quantities of main product (i.e., paddy) per hectare (kg/ha);

P_y= per unit price of paddy (Tk/kg);

B= total quantities of by-product (i.e., straw) per hectare (Kg/ha);

P_b= per unit price of by-product;

X_i= quantity of the ith inputs used for producing per hectare MV *Boro* paddy;

P_{xi}= per unit price of the concerned inputs used for MV *Boro* paddy production;

TFC= total fixed cost involved in producing MV *Boro* paddy; and

i = 1, 2, 3.........................., n (number of inputs).

Three discounting measures have been employed in this study. These are:

(a) Benifit-cost ratio (BCR);

(b) Net present value (NPV); and

(c) Internal rate of return (IRR).

(a) Benefit cost ratio (BCR)

The BCR is a relative measure, which is used to compare present worth of benefits with costs. The BCR is estimated by dividing the sum of present worth of gross benefits by the sum of the present worth of gross costs .Accept all projects when BCR is greater than 1 or more when discounted at the opportunity cost of capital. BCR may be illustrated as:

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

Where,

BCR = Benefit cost Ratio

B_t = present worth of benefit in each year

C_t = present worth of cost in each year

n = number of years

i = Discount rate

(b) Net present value (NPV)

The NPV is an absolute measure, which estimates the project net present worth. NPV is obtained by deducting the present worth of cost from the present worth of benefits. Accept all projects when NPV is greater than zero (0) when discounted at opportunity cost of capital. The net present value may be expressed as:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+t)^t}$$

(c) Internal rate of return (IRR)

The Internal rate of return (IRR) is defined, as the average earning power of the money invested in a project over the project life. The IRR is that discount rate, which makes the NPV of project equal to zero (Miah 1987and Siddique 1999). IRR may be expressed as.

$$IRR = \sum_{t=1}^{n} \frac{B_t - C}{(1+t)^t} = 0$$

3.9 Benefit and Cost Streams of Owners of STWs

In financial analysis, all costs and benefits of STW irrigation business were determined by using farmgate prices and /or market prices.

3.9.1 Benefits of STWs

The items included under the benefits of STWs are:

Water charge: The water charge implies that the fixed payment, which has been made to the owners of STWs by individual client farmers under the concerned projects. The farmers made payment in kind by giving one-fourth share of produced paddy as irrigation charge.

Salvage value: In project analysis it is generally expected that the capital assets do not used up during the project life. As a result, the projects have residual assets after its life. The value of residual assets is treated as benefits of the projects in the last year.

3.9.2 Costs of STWs

The cost of STWs irrigation business from the viewpoint of individual investors can broadly be classified under the following two heads:

a) Investment costs; and

b) O & M costs.

Investment costs. Capital cost (i.e., initial purchasing price of the concerned equipment) was the main of investment costs. The cost of engine (in case of diesel operated STWs), cost of motor (in case of electrically operated STWs), pump, filter, pipe, installation cost, cost of electricity connection, were the other investment costs of STW is operated by electricity.

O & M costs. These costs involve the cost of mobil (in case of diesel operated STWs), cost of electricity (in case of electrically operated STWs), cost of spare parts and mechanic fees, salaries for the lineman and/or operator, drain maintenance cost, etc.

3.10 Discount Rate

Since the result of benefit-cost analysis is highly sensitive to the discount rate; the choice of an appropriate discount rate plays a vital role in the appraisal of the concerned projects. To select an appropriate discount rate is very difficult task in less developed countries (LDCs). However, the available literatures (Miah and Hardaker 1988 and Gittinger 1994) suggest that in most developing counties the opportunity cost of capital varies between 8 to 12 percent. According to the manager of the BKB, Banagladesh Agricultural University (BAU) Branch, the lending rate of agriculture (production) loan was 10 per cent in 2007. Thus, 10 per cent discount rate has been chosen for the financial analysis of irrigation business.

Chapter 4
DESCRIPTION OF THE STUDY AREA

4.1 Introduction

A brief description of the study area is presented in this chapter to know the basic characteristics of the study area which includes location of the study area, topography and soil, land type, climate, temperature and rainfall, area and population, education, occupation, agriculture, irrigation facilities, roads, communication, transport, marketing facilities, etc. These are discussed below:

4.2 Location of the Study Area

Keeping in view the main objectives of the study, five adjacent villages of Dighalkandi union namely, Saitapara, Kurmushi, Kagmari Beltail, Kaijalipur and Shekh Shimul under Ghatail Upazila of Tangail district were selected purposively for the study. The area is situated between latitude 24^0 25'17.5" longitude 89^0 57' 26.84" and latitude 89^0 59' 10.10" longitude 24^0 24' 08.55". The location and other information of the study area are shown in the Figure 4.1.

4.3 Topography and Soil

The selected five villages, like most low-lying areas of Bangladesh, have a more or less flat alluvial topography, Dighalkandi union of Ghatail Upazila in Tangail district, which falls under the Old Brahmaputra Flood Plain. The soils in the eastern part of the Upazila fall under the category of Madhupur Tract. The texture of the soil ranges from clay loam to sandy clay loam. However, the western part is formed by the alluvial flood plains of the Jamuna, where the texture of the soils ranges from sandy loam to loam. The whole area except this higher land goes under water for five to six months a year between late June and November but is dry for the remaining period.

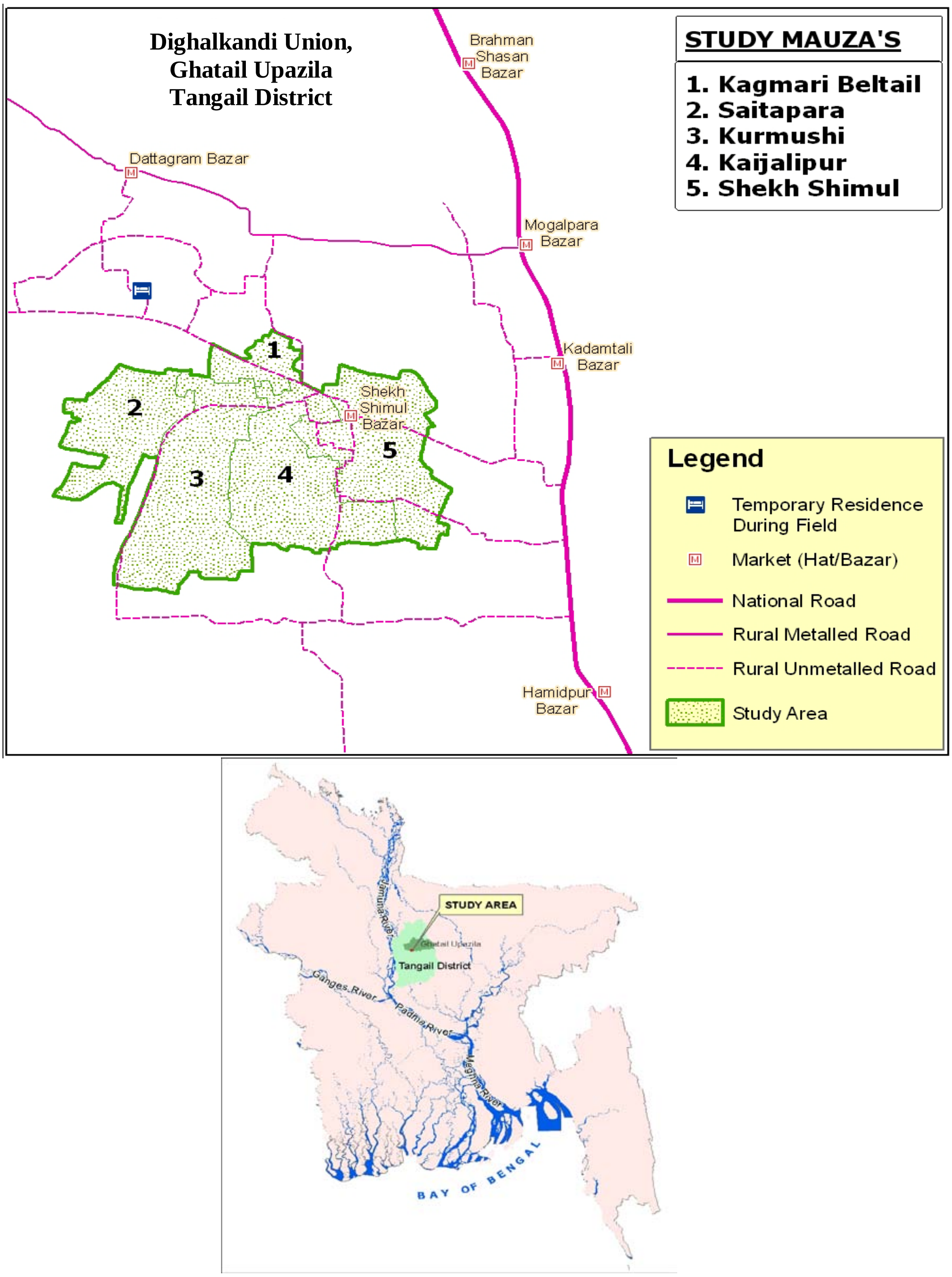

Figure 4.1 Location of the Study Area

All the villages have soil of similar texture and structure which is very fertile. The surface soil of the area is composed of clay-loam to sandy-loam and receives a small deposit of silt carried down by the flood waters every year. To classify the study area as settlements with homestead vegetation, water bodies and agricultural lands. About 77 per cent of the study area is covered by agricultural land (Table 4.1). The settlement class includes household, surrounding homestead vegetations, few surrounding homestead agricultural lands, etc. Table 4.1 presents different topographical features and their coverage areas of the study area.

Table 4.1 Different Types of Topographic Features of the Selected Five Villages

FEATURE	AREA (HA)	PERCENTAGE
Agricultural Land	288	77.0
Settlement	73	19.0
Waterbodies	15	4.0
Total	376	100

Source: Sarwer *et al.* (2008).

4.4 Climate, Temperature and Rainfall

There was no arrangement for recording temperature and rainfall in the study area. As a result, exact climatic data are not known. However, the climate of the area is similar to that in other parts of Tangail as well as in the neighbouring Mymensingh district. The Mymensingh Meteorological office keeps records of temperature and rainfall. The distance from this Meteorological office to the study area is around 40 km.

The climate of the study area is warmed and humid; but moderately cold and dry weather prevails in winter. Maximum and minimum temperature in the study area varies from 12.6 °C to 32.2 °C. Cold weather persisted from November to February and hot temperature prevailed during March to October. However, the extremely low temperature is observed during the period from December to January, while the extremely high temperature exists in April. The rainy season generally was found to begin from May and continued up to October. In the study district, 95 per cent of the annual rainfall occurs in the monsoon. The average monthly rainfall throughout the year was 226 mm in 2005 (BBS 2006). The highest rainfall occurred in October and this was the lowest in January and December 2005. The average humidity percentage of this area was 80.67 per cent. The highest humidity percentage was recorded as 87 per cent in August to September and lowest was 71 per cent in February (BBS 2006).

Table 4.2 Monthly Temperature, Humidity and Rainfall of Mymensingh District in 2005

Name of months	Maximum temperature (°C)	Minimum temperature (°C)	Average humidity (%)	Rainfall (mm)
January	23.8	12.6	82	003
February	27.3	16.8	71	027
March	29.6	20.4	76	084
April	31.6	22.3	74	153
May	30.6	22.7	79	454
June	32.4	25.9	82	257
July	31.0	25.9	84	454
August	31.5	26.3	87	511
September	32.4	25.7	83	408
October	30.1	23.7	87	361
November	29.1	17.9	84	000
December	27.0	13.6	79	000
Average (monthly)	29.7	21.15	80.67	226

Source: BBS (2006).

4.5 Area and Population

The most recent statistics on the population of the study area is not available. The surrounding total area of Ghatail Upazila was 475.05 km^2 and total population was 22,399 of which, male was 11,579 and female was 10,820. The total number of households was 4,985.

Table 4.3 Area and Population of Ghatail Upazila

Area (km^2)	Total population (No.)	Male (No.)	Female (No.)	Sex ratio (M/F)	Households (No.)
475.05	22,399	11,579	10,820	103:100	4,985

Source: BBS (2006).

4.6 Occupation of the Villagers

Agriculture was the main occupation and major source of income of the people in the study area. A few people of the selected villages were engaged in small trading and government, semi-government or private services, and they had agriculture as the secondary occupation. The main occupations of the landless and marginal farmers were wage labourer.

4.7 Agriculture

Agriculture is the main source of income and occupation of livelihood of most of the people in the selected areas. Almost all homestead area are used for agriculture directly or indirectly. The agricultural practices are relatively intensive in this area due to the expansion of the irrigation facilities, use of modern varieties of *Boro* seed increasingly and expansion of power tiller uses. Generally two or three crops are grown from a plot of land in one year. Proportion of single cropped area is very low. Most of the areas under double cropped area and the rest is under triple cropped area. Most of the land is under irrigated condition except fallow land and water logging areas. Even from the low lying lands the farmers harvest two crops in a year. But the medium and moderate high land under irrigation facilities are used intensively for producing rice and non-rice crops. The cropping patterns of the study areas are mainly rice based. Transplanted *Aman* and MV *Boro* are the main rice crops. The winter crops like wheat, potato, mustard, pulses and vegetables like brinjal, tomato, bean, cucumber, lalshak etc., are also grown in the study areas.

4.8 Irrigation facilities

There is no observation well in the study area to monitor and record the static groundwater table. Two nearby observation wells are present, which are maintained by Bangladesh Water Development Board and thus used for this study, which are under Ghatail Upazila. The static GW table hydrograph (Figure 4.2) shows that the maximum drop of static water level occurs during the month of March and April. This is the period of the flowering stage of *Boro* crop when it requires maximum water and thus the highest pumping occurs at that time.

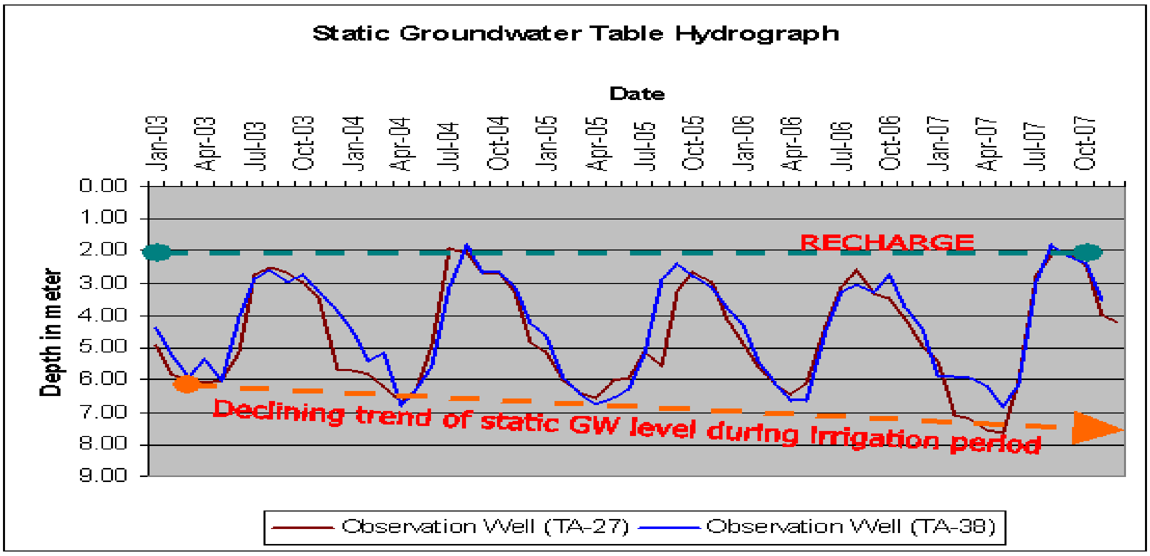

Figure 4.2 Static Groundwater Table Hydrograph in Ghatail Upazila, Tangail (BWDB)
Source: Sarwer *et al.* (2008).

There is a declining trend of the static groundwater table observed during the irrigation period (Figure 4.2) and it is probably due to the increasing trend of irrigated area and also increasing number of electric driven tubewells of the Ghatail Upazila.

4.9 Road, Communication, Transport and Marketing Facilities

Communication, transport and marketing facilities are the main agricultural infrastructure and they play a vital role in agricultural development. The villagers in the study area enjoyed good communication facilities with the district town since these villages were either situated around the paved roads or connected by kutcha road with the paved roads. The marketing facilities of the selected areas are good. Generally farmers buy and sell their daily necessaries in different markets (Hat/Bazar). They usually carry their products by vans, Tempoes, By-cycles etc.

Chapter 5

SOCIOECONOMIC CHARACTERISTICS OF STW OWNERS AND WATER BUYERS

5.1 Introduction

The main purpose of this chapter is to examine the socioeconomic characteristics of the selected STW owners as well as water buyers. In order to get a complete picture about the owners of STW and water buyers, it is essential to know their socioeconomic characteristics. This is crucial because socioeconomic characteristics of the sample farmers are likely to affect their production decision and technology use. In other words, this chapter has been designed to test the set hypotheses (a) and (b), as stated in Section 1.9. However, some of the important characteristics were considered in this study, which included age distribution, family size and composition, educational level, occupational status, distribution of tubewell owners and farmers according to the farm size, STW ownership formation, electric connection and billing systems, sharing arrangement, command area formation, ownership type and energy uses, conflict and mitigation are discussed below:

5.2 Age Distribution

In this study, all the selected STW owners and water buyers in the study area were classified into different age groups such as: 30.01 to 40.0 years, 40.01 to 50.0 years, 50.01 to 60.0 years, 60.01 to 70.0 years and 70.01 to 80.0 years. Table 5.1 shows that most of the STW owners (40.00 per cent) belonged to 50.01 to 60 years age group while most of the buyers (36.67 per cent) belonged to 40.01 to 50 years age group. From this table it was found that most of the selected farmers were within the age group of potential labour force.

Table 5.1 Age Distribution of the Selected STW Owners and Water Buyers

Age group (Years)	STW Owners		Water buyers	
	No.	%	No.	%
30.01 to 40.00	4	13.33	16	26.67
40.01 to 50.00	7	23.33	22	36.67
50.01 to 60.00	12	40.00	16	26.67
60.01 to 70.00	2	6.67	4	6.67
70.01 to 80.00	5	16.67	2	3.33
All	30	100	60	100

Source: Field survey (2008).

5.3 Family Size and Composition

A family is known as the smallest fundamental unit of the society and also the country as a whole. In the present study, a family has been defined as total number of persons living together and taking meals from the same kitchen under the administration of the same head of the family. Here, family members include the respondent himself and his wife, sons, daughters and old parents. Again, persons, who have been employed for household works of a family, i.e., servants, caretakers etc., are excluded from the family members in the present study. The number of persons of all families under different age groups were divided into four categories: (i) less than 6.0 years (ii) 6.01 to 18.0 years (iii) 18.01 to 54.0 years and (iv) above 54 years (Miah 2004).

The size and composition of family are shown in Table 5.2. The Table shows that the average family size of STW owners was at 3.48, of whom 1.78 were males and 1.70 were females. The majority (48.85 per cent) of the family members were in the age group of 18.01 to 54.0 years. The male-female ratio was 1.05:1.

The Table also shows that the average family size of water buyers was at 4.90, of whom 2.66 were males and 2.24 were females. The majority (46.94 per cent) of the family members were in the age group of 18.01 to 54.0 years. The male-female ratio was 1.18:1.

Table 5.2 Size and Composition of STW Owners and Buyers According to Age and Sex

Age group (years)	Owner			Buyer		
	Male	Female	Total	Male	Female	Total
Less than 6.0	17 (9.77)	15 (8.62)	32 (18.39)	25 (10.20)	18 (7.35)	43 (17.55)
6.01 – 18.0	15 (8.62)	12 (6.90)	27 (15.52)	30 (12.24)	17 (6.94)	47 (19.18)
18.01 – 54.0	45 (25.86)	40 (22.98)	85 (48.85)	58 (23.67)	57 (23.26)	115 (46.94)
54.0 and above	12 (6.89)	18 (10.34)	30 (17.24)	20 (8.16)	20 (8.16)	40 (16.33)
All	89 (51.15)	85 (48.85)	174 (100)	133 (54.28)	112 (45.71)	245 (100)
Average family size	1.78	1.70	3.48	2.66	2.24	4.90

Source: Field survey (2008).

Note: The figures in the parentheses indicate percentage.

5.4 Education Level

The level of education is generally considered as an index of social advancement of a community. It is also consider as an important measuring rod for progressive attitude of the farmers towards the adoption of modern technology. Literate farmers can have better access of the update technical information regarding the improved farming system and can make rational economic decision. It helps a person to have day-to-day information about the modern technology together with technological change in various agricultural production processes. It makes a man more capable to manage and coordinate scarce resources and hence to earn maximum profit (Miah 1990).

It is generally expected that the educated STW owners would do better in their business through better management and control of resources. The average year of schooling was low for both single and partner owners in the study areas (Table 5.3).

Only a few STW owners were highly educated. Single STW owners were more or less equally educated as in the case of STW partners (Table 5.3).

Again the majority (70 per cent) of the STW owners did not have adequate technical knowledge. However, a few owners had technical knowledge for repairing or maintaining diesel engines but none of them was able to repair electric motors.

Rural mechanics repaired diesel engines only. They provided services to STWs by visiting the STWs physically. But in the case of repairing of electric motors, such home services were not available in the study areas. Therefore electric motors had to be taken to nearby mechanics shop at Hamidpur Bazar for repairing services. Since STW owners had easy access to repairing services, their own technical knowledge seems to be low.

Table 5.3 Literacy Level of the Selected STW Owners and Water Buyers

Literacy level	Owners		Buyers	
	No.	%	No.	%
Illiterate	10	33.33	27	45
Up to V	8	26.67	16	26.67
VI to X	3	10	4	6.67
S.S.C	3	10	6	10
H.S.C	3	10	4	6.67
Graduate and above	3	10	3	5
All	30	100	60	100

Source: Field survey (2008).

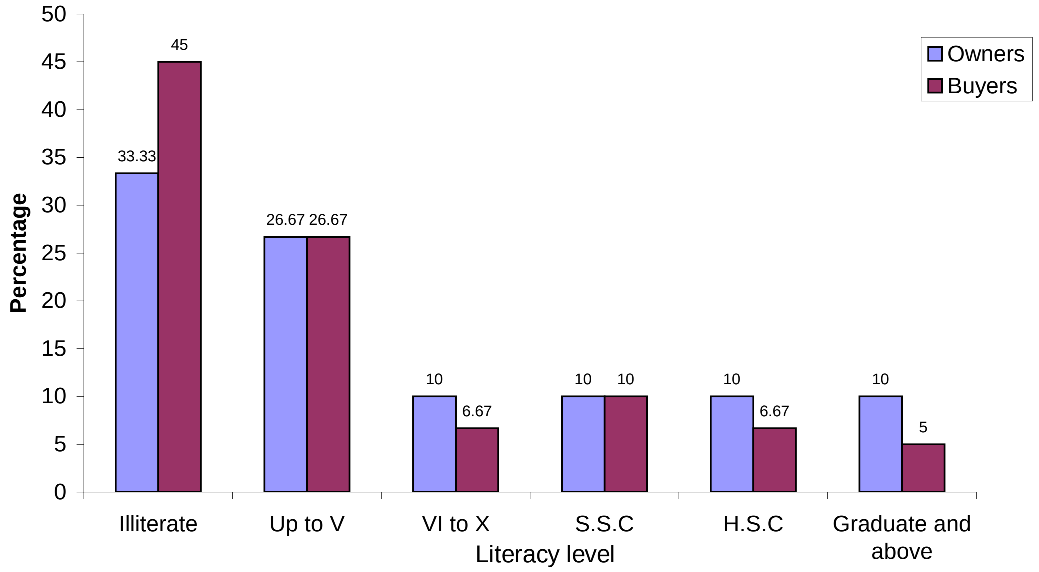

Figure 5.1 Bar Diagram Showing Percentage of Literacy of the Selected STWs Owners and Water Buyers

5.5 Occupational Status of the Respondents

Most of the owners, either single or partners, were directly involved in agriculture/farming activities as their main earning sources and rural livelihoods directly depended on agriculture. Few STW owners were involved in business and services as their main occupations. The STW owners, who worked abroad, ran their businesses through partnership arrangements.

It is evident from Table 5.4 and Figures 5.2 and 5.3, that 50.00 per cent, 16.67 per cent and 20.00 per cent of STW owners were engaged in agriculture, business and service, respectively as their main occupation, while in the case of water buyers, 90.00 per cent of buyers were engaged in agriculture and 6.67 per cent in business and 1.67 per cent in service as their main occupation.

As subsidiary occupation, business was found to be the most important occupation for STW owners. Besides business, both the owners and buyers were involved in other subsidiary occupations including agriculture (Table 5.4).

Table 5.4 Occupational Status of the Selected STW Owners and Water Buyers

Occupation	Owners		Buyers	
	Main	Subsidiary	Main	Subsidiary
Agriculture	15 (50.00)	3 (33.33)	54 (90.00)	6 (26.08)
Business	5 (16.67)	5 (55.55)	4 (6.67)	6 (26.08)
Service	6 (20.00)	-	1 (1.67)	3 (13.04)
Others	4 (13.33)	1 (11.11)	1 (1.67)	8 (34.78)
All	30 (100)	9 (100)	60 (100)	23 (100)

Source: Field survey (2008).

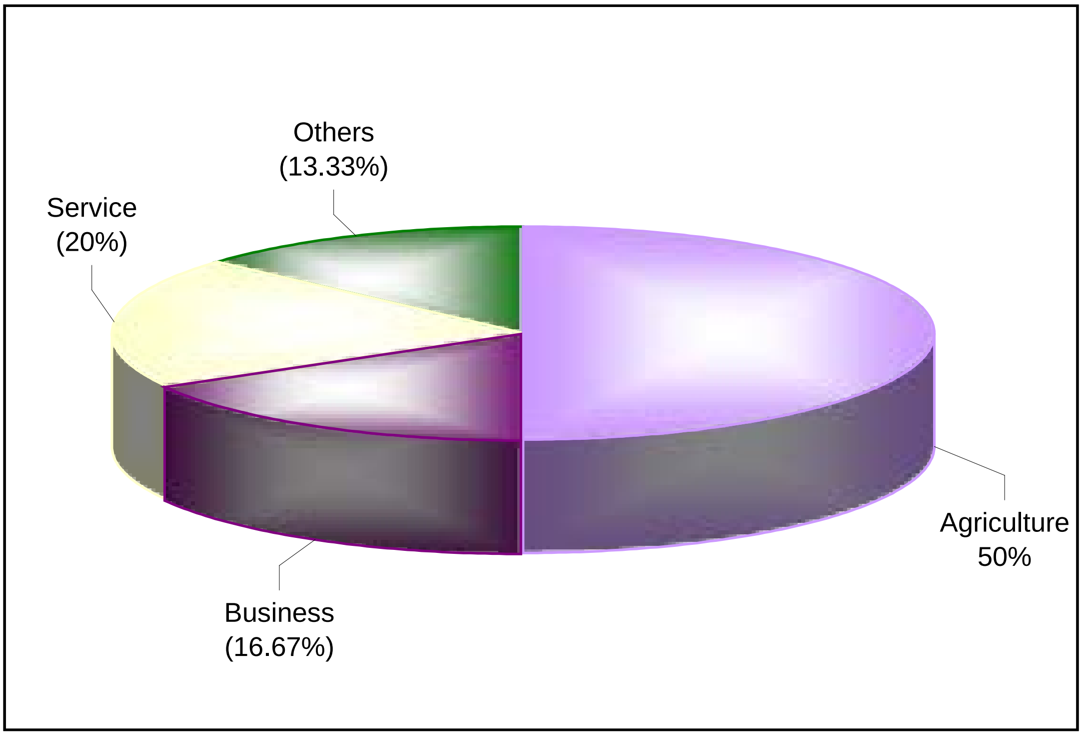

Figure 5.2 Pie Chart Showing Main Occupation of STW owners

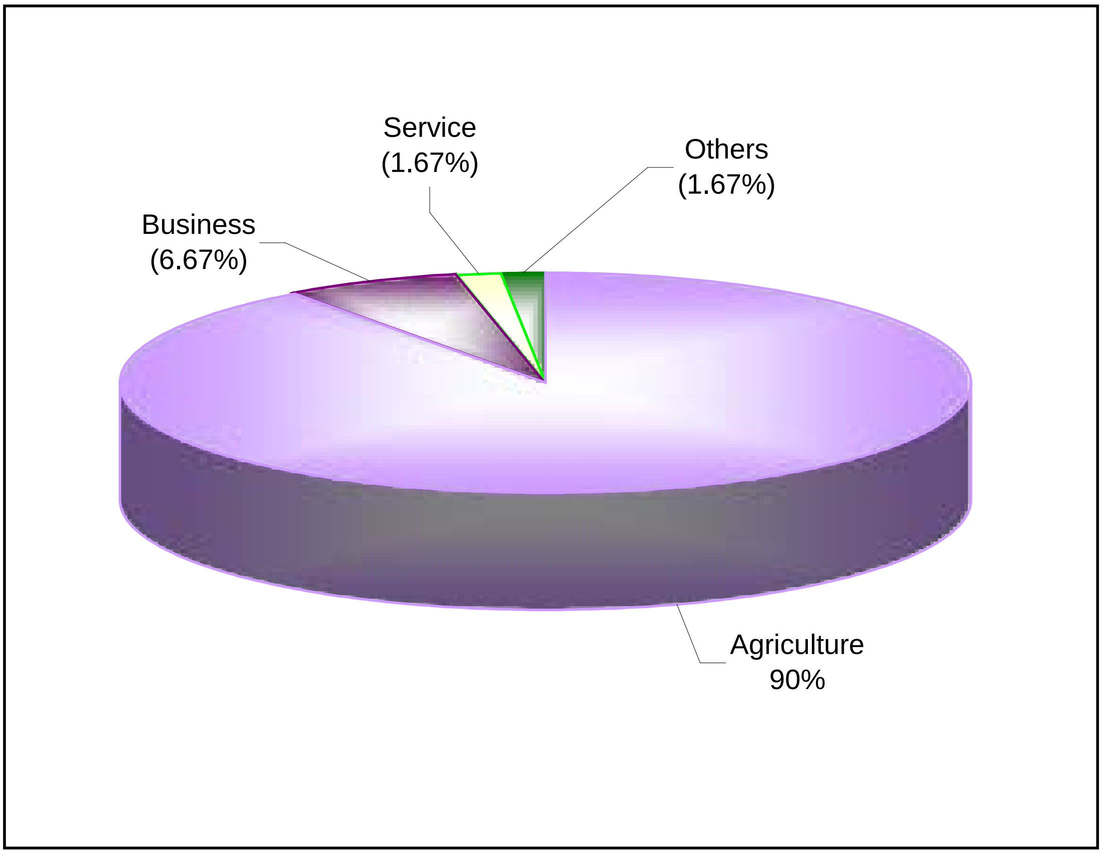

Figure 5.3 Pie Chart Showing Main Occupation of Water Buyers

5.6 Land Ownership Pattern

Farm size plays an important role in resource allocation in agricultural production. According to Yang (1965), farm size computed by the entire land area operated by the operator. It is computed by adding the area of land owned, and rented/mortgaged in from others and subtracting the area rented/mortgaged out of others. Thus farm size was measured by using the following formula:

Farm size = Homestead area (including pond and gardening) +Owned land+ Rented in area +Mortgaged in area-Rented out area-Mortgaged out area.

The land ownership and its utilization patterns are presented in Table 5.5. It appears from Table 5.5 that the average farm size was 1.76 ha for STW owners while the corresponding figure was 0.91 ha for water buyers. So, it can be said that the average farm size of STW owners was relatively higher than that of water buyers.

Table 5.5 Average Farm Size of the Selected STW Owners and Water Buyers

Category of land	Owners' farm (ha)	Buyers' farm (ha)
i. Homestead area	0.15	0.15
ii. Owned land	1.85	1.00
iii. Rented in	0.05	0.33
iv. Rented out	0.29	0.57
Farm Size (i+ ii +iii-iv)	1.76	0.91

Source: Field survey (2008).

5.7 STW Ownership Formation

Both single and partnership arrangements were available in the study areas to perform the STW business. Majority of STW (57 per cent) owners had no partner (Table 5.6). The partnership was formed by 2-5 farmers. The farmers who were involved as partners had one or mix of the following features: higher social power, less amount of own land under their command areas, job or technical experiences, inadequate investment capital.

Table 5.6 STW Ownership Patterns in the Study Areas

No. of partner	No. of owner	Percentage
One	17	57
Two	8	27
Three	2	6
Four	2	6
Five	1	3
Grand Total	30	100

Source: Field survey (2008).

5.8 Sharing Arrangement

There were several types of sharing arrangements observed in the study areas. Majority of the partners had 50 per cent of share. One-fourth share was also observed. Some unequal distributions of shares were also found in field survey (Table 5.7). The partners having larger shares generally have larger portions of command area land and they took other partners as co-investors and as a helping hand by allocating small shares.

The managers/drivers of the STWs were appointed by the owners and their salaries were paid only for *Boro* season (about 4 months). Their payment was also made in kind, and the amount of 12-16 maunds paddy (480 kg. to 6400 kg.). In case of larger command area, most of the partners tried to employ himself or his family members as a manager to earn some salary and also to establish control over the STW business.

Table 5.7 Sharing Arrangement among STW Partners

Percentages of share of ownership of the STWs	Number of partners	Percentage
Up to 25	36	44
26 to 50	42	51
51 and above	4	5

Source: Field survey (2008).

5.9 STW Owners' Land in Command Area

Generally, it is expected that STW owners will have some own land in their command areas for running their business. But exception was observed in the study areas as 20 per cent of STW owners had no own land in their command areas (Table 5.8). Therefore, it seems that they took up irrigation water selling solely as a business. In such cases, the owners installed their STWs to others' plots and the compensation was made as reducing irrigation charge (1/8 of crop share) or free irrigation for that particular plot. Land holding size was categorized into five types and it appears that on an average, own landholding of single STW owners was higher compared to STWs partners. Individual partners had small amount of land but joining together in partnership allowed them larger command areas. Both single or partners increased their command area by irrigating land from their kinship, clan and neighbors.

Table 5.8 Distribution of Own Cultivable Land under Self Command Areas of STWs

Land Under Self Command Areas	Average size of land (dec)		
	Single owner	Partnership	Total
No land	0.0 (9)	0.0 (24)	0.0 (20)
1 - 50 dec.	15.8 (23)	27.9 (29)	24.9 (27)
51 - 100 dec.	72.4 (34)	71.0 (24)	71.5 (27)
101 - 150 dec.	122.5 (23)	122.9 (16)	122.8 (18)
Above 150 dec.	202.5 (11)	350.0 (6)	284.4 (8)
Grand Total	79.6 (100)	66.3 (100)	70.3 (100)

Source: Field survey (2008).
Note: 100 dec. = 1 acre
Note: Figures within parentheses indicate percentages of total.

5.10 Ownership Type and Energy Uses

Most of the single owned STWs were operated by diesel, whereas partnerships STWs were operated by electricity (Table 5.9). Here, one thing is clear that partners accumulated their capital for paying the larger fees for getting the electric connection. Some diesel operated single STW owners joined together and formed new partnership, which allowed them to shift to electric motors for pumping of water. In the last few years, Government of Bangladesh increased diesel prices several times. So, irrigation business is facing challenges to cope with the rising energy prices. Therefore, diesel operated pump owners have been thinking of new management practices. They were trying to take in more partners or were individually trying to convert to electric operated STWs. The farmers feel that the partners can share the risks and costs incurred for converting the STW engines to electric motors. Table 5.9 shows that 60 per cent of the partnerships STWs were already connected to electricity, while more than 70 per cent of single owner STWs were still being operated by diesel engines.

Table 5.9 Relationship between Ownership and Sources of Energy

Sources of energy	Single owners		Partners	
	No.	%	No.	%
Diesel	21.00	72.4	8.00	27.6
Electricity	14.00	40.0	21.00	60.0
All	35.00	54.7	29.00	45.3

Source: Field survey (2008).

5.11 Electric Connection and Billing System

STW owners were not familiar with official rules and regulations and most of them did not know how to contact with local Power Development Board (PDB) office. The EOS owners stated that they got electricity connection with the help of middle men, who have good linkage with some of the PDB officials. Middle men charged fixed cash to arrange electricity connection, but the charges also varied depending on relationship between the STW owners and the middle men and the distance of STWs from the main electric line. The owners claimed that the major portion of electricity connection charges goes to middle men and PDB officials. Miah and Mandal (1993) also reported that the STW owners had to pay bribes to the concerned officials for getting electricity connections. In the study area, there was no electric metering system. The PDB officials informed that in case of no-metering system they prepared the electric bills on the basis of HP. Table 5.10 shows the standard rate of non-metering bills, which were collected from PDB office. But real scenario was different from their provided information; EOS owners claimed that they paid higher electric charge due to non-metering system. Again they blamed about illegal practice between EOS owners and PDB officials. The STW owners with large HP motor and higher command areas had hidden negotiation for preparing electricity bills at lower rate. Moreover, they faced trouble in frequent electricity supply particularly in peak season (March-April). Whatever is the fact, the STW owners showed keen to connect their STWs with electricity for higher profitability of EOS. Research findings of Miah and Hardaker (1988) also showed that the electricity operated STW was more profitable than diesel operated STW. This was even before steep hikes in diesel prices, so now EOS all the more profitable than DOS.

Table 5.10 Standard Billing System of PDB Office

Motor Capacity (HP)	Unit (Kwh)	Vat and Service charge	Total bill (Tk)
5.0 - 6.0	3500	@ Tk. 1.93 per unit and 5% vat of the bill	7,092
7.0 - 7.5	4000		8,106
8.0 - 12.0	5000		10,133

Source: PDB office data (2008).

5.12 Command Area Formation

The command area was usually settled in negotiating with surrounding STW owners, but if there is any disputes for command area plots, *samaj* (community and its leaders) settle through village litigation. After fixing command areas for particular STWs, there was little scope to change within a short period. In most of the command areas, water buyers came from neighborhood of the STWs. In few cases water buyers committed to irrigate their land under the selected STW command formalized through some form of written contact, this was found in Kaijalpur muaza. Again irrigation charges in the form of crop-share were settled by the *samaj* at the initial stage in the study areas (Palmer-Jones, 2001). In this system, STW owners have been sharing risk and benefited more compared with the previous cash payment system. On the other hand, water buyers also benefited because they did not have to charge STW owners for irrigating their plots. Moreover, the crop sharing system reduces the conflict between water buyer and seller. Continuation of one-fourth crop sharing system for three decades, obviously, indicates its sustainability.

The community approved new entrepreneur for running STW business in his own land but they were discouraged to take in plots from the existing command areas. A few diesel operated STW owners failed to continue their business due to high fuel prices, but they did not allow other STW owners to operate in the same command area. Rather they tried to engage as partner to the surrounding electric operated STWs (Appendix 10).

An established command area decreased due to many externalities such as new STW installation nearby, new housing settlement, pond excavation, etc. Conversely, the command area also increased due to exit of STW owners from the adjacent area, inclusion of irrigator as new partner, partnership formation among DOS owners to connect with electricity, and formation of new relationship with prospective water buyers (marriage of son or daughter). Collected data shows that 47 per cent STW command areas decreased and only 6 percent command areas increased over time.

About a half of command areas remained unchanged. However, increase of command area was observed mainly for EOS.

5.13 Social Status of the STW owners

The present study considered Union *Parishad,* School and Madrasha as formal social institutions and *samaj, Gusthi* (lineage), mosque, *Bazar/Hat*, local *Samitee,* graveyard, Eid field, play ground as informal social institutions. The STW owners were mainly involved in social institutions in the study areas. Comparatively, single STW owners held more positions of power within social institutions, compared to STW partners (Table 5.11). Ninety seven per cent of single STW owners were involved with different formal and informal social institutional committee. On the other hand, only 53 percent for STW partners were involved with such social institutions. Generally they settled one-fourth crop share as irrigation charge but a few exceptions were found in the case of low lying plots. The lower plots were irrigated from *Beel*s or ponds at the beginning of crop cultivation. But a few of them paid 1/8 crop share as irrigation charge for such plots. The water buyer having low lying plots bargained for reduced water charge but did not always succeed. Owners having economic solvency along with social status could already connect their STWs with electricity and those having less economic solvency were still negotiating with others, middle men, to connect STWs with electricity.

Table 5.11 Involvement with Social Institutions by STW Owners

Committee type	Single	Partner	All
Union *Parishad*	14	5	8
School committee	17	7	10
Madrasa committee	17	2	7
Bazar committee	3	2	3
Mosque committee	20	7	11
Samitee	3	1	2
Others (Eid field, graveyard, playground)	23	9	13
All	97	34	53

Source: Field survey (2008).

5.14 Conflict and Mitigation

Conflict of interests is found in every society; particularly latent conflict is common in social relationship. The irrigation business is run by water buyers and water sellers and they interact each other for their interests. Conflicts between water buyers and sellers were not frequent in the study areas, but a few cases were reported particularly in the case of low landholders, as they were not allowed 1/8 crop share as irrigation charge. Some conflicts among STW owners were also observed, particularly in redistribution of command area plots to new STWs. Most of the problems were mitigated by the *Samaj* and even by the local union *parishad* representatives (Appendix 11).

5.15 Concluding Remarks

It is evident from the above discussions that there are some distinct differences in the socioeconomic characteristics among the owners of STW as well as water buyers. In other words, the results presented in the above mentioned tables clearly support the rejection of null hypotheses (a) and (b). This means that there are some distinct differences in the socioeconomic characteristics among the owners of STW as well as water buyers and there is some impact of increased energy prices on command areas under diesel and electrically operated STWs.

Chapter 6

PROFITABILITY OF IRRIGATED MV *BORO* PADDY AND ITS CONTRIBUTION TO HOUSEHOLD INCOME

6.1 Introduction

This chapter deals with costs, returns, profit of MV *Boro* paddy production and income share of paddy to total household income. The profitability of MV *Boro* paddy production was estimated considering irrigation made by both diesel and electrically operated STWs. Income shares to total household income was described in this chapter. This chapter also attempts to test the set hypothesis (c), as stated in Section 1.9.

6.2 Costs of MV *Boro* Paddy Production

The item wise per hectare costs of MV *Boro* paddy production have been presented in the following sub-sections. Cost of human labour, power tiller cost, cost of seedlings, cost of fertilizer, cost of irrigation, cost of insecticides and cost of land use were the costs of the paddy production. Paddy and straw of paddy were the return from *Boro* paddy.

6.2.1 Costs of human labour

Human labour cost is one of the most important and largest cost items in the production process of MV *Boro* paddy. It is required for different farm operations like land preparation, transplanting, weeding, application of fertilizers and insecticides, supplying irrigation water, harvesting and carrying, cleaning, drying, storing, etc. It is broadly classified into two categories i.e., family labour for which no payment is made and hired labour for which farmers have to pay in cash. Family labour consists of farm operator himself and other members of his family while the hired labour includes permanent hired labour, labour employed on monthly or daily contact basis. Family labour was priced at the prevailing wage rate paid in cash to hired labour. In this study, human labour was measured in terms of man-days, which usually consist of 8 working hours a day. For women and children, man equivalent hours were estimated. This was computed by converting all women and children hours into man equivalent hours by assigning a ratio of 2 children =1.5 women =1 male (Rahman 2000 and Ali 2001).

Both human and hired labours were used to cultivate *Boro* paddy in the study areas. To produce one hectare of *Boro* paddy, 40 man-days hired labours and 21 man-days family labours were utilized. The average wage rate was Tk 140 per man-day, although it varied during different intercultural operation in the same irrigation season (Table 6.1). Farmers generally paid higher wages during transplanting and harvesting period. The marginal farmers, who produced *Boro* paddy in rented in land they mainly used family labour to cultivate their plots. But the rich farmers highly depended on hired labour.

6.2.2 Power tiller cost

The use of power tiller for land preparation has currently been increasing rapidly in the study villages. In the study area, it was observed that almost all the sample farmers used power tiller for their land preparation because of scarcity of draught animal power (DAP). Most of the farmers used hired power tiller. There was a competitive ploughing rate of power tiller in the study areas. Average per hectare tillage cost was Tk 2,470 for two cross ploughings by power tiller (PT) @ Tk 5 per decimal per ploughing in *Boro* season.

6.2.3 Cost of seedlings

In the study area, it was found that farmers used both home supplied and purchased seedlings. The cost of purchased seedlings was calculated on the basis of actual price paid by the farmers and home supplied seedlings price were also considered the same rate. The average per unit price was used to calculate the cost of seedlings. In the study area, the market price of MV *Boro* seedling on an average was Tk 53.00 per kg. Table 6.1 shows that per hectare cost of MV *Boro* paddy seedlings for STW farmers was Tk 2,968 which constituted 7.87 Per cent of total costs.

6.2.4 Cost of fertilizer

Application of recommended doses of fertilizer is a major requirement of MV *Boro* paddy production. In the study area, it was found that most of the farmers mainly used three types of fertilizer namely Urea, Tripple Super Phosphate (TSP) and Muriate of Potash (MP). The cost of fertilizer was calculated at the prevailing farmgate price during the study periods and the rates were Tk 6.00 per kg for Urea, Tk 16.00 per kg for TSP and MP, respectively (Table 6.1). The farmers used 292 kg, 120 kg and 57 kg of Urea, TSP and MP respectively, which represent 4.64, 4.24 and 2.42 per cent of total costs (Table 6.1). For the plots which were cultivated for mustard production before cultivation of *Boro* paddy, farmers applied low doses of TSP and MP to cultivate *Boro* paddy. They applied higher amount of TSP and MP during mustard cultivation and felt that the residual amount of fertilizer would be used by *Boro* rice. The farmers generally did not apply any manure in their plots. Some farmers, however, used ash to increase soil fertility. Though, no established ash market was reported in the study area, the ash price was calculated @ Tk 0.5 per kg as some rice mill sold ash at this rate. Majority of the farmers in the study areas did not use any insecticide and herbicide in their plots. Farmers did not apply sufficient amount of TSP and MP for *Boro* paddy. They applied higher amount of TSP and MP during mustard cultivation and feel that the residual amount of fertilizer will be used by *Boro* rice. Some farmers applied salt when the growth of plant is abandoned.

6.2.5 Cost of irrigation

Irrigation was a leading input for MV-*Boro* production. The cost of irrigation water was charged at fixed rate per unit of area. In the study area, farmers paid their irrigation charge with two installments. One installment was paid before harvesting and another installment was paid after harvesting. In the case of STWs operation, farmers paid 10 kg rice for lineman. Thus the per hectare water charge for irrigation water was Tk 12,750 for MV *Boro* cultivation under STWs respectively (Table 6.1) which represent 33.81 Per cent of total cost.

Table 6.1 Per Hectare Cost of MV *Boro* Paddy Production under STW Irrigation

Cost Items	Quantity	Unit Price (Tk)	Total cost (Tk)	Per centage of total cost
Human labour	100 man-days	140	14,000	37.11
Power tiller	-	-	2,470	6.55
Seedlings	56 Kg	53	2,968	7.87
Urea	292 Kg	6	1,752	4.64
TSP	120 Kg	16	1,600	4.24
MP	57 Kg	16	912	2.42
Zinc and gypsum	17 Kg	8	136	0.36
Water charge	-	-	12,750	33.81
Insecticide and herbicide	-	-	208	0.55
Total variable cost	-	-	36,796	97.56
Interest on OC	-	-	920	2.44
Gross cost	-	-	37,716	100.00

Source: Field survey (2008).

6.2.6 Cost of insecticides

Only a few farmers used insecticides in producing MV *Boro* paddy in the study area. Almost all the selected farmers, who used insecticides for their MV *Boro* paddy, were not sure about the name, brand, quantity and or/per unit price of the insecticides. Sometimes, they even did not know which insecticides should be used. In the most cases they used insecticides as per suggestions of insecticide traders, neighboring farmers, friends and relatives. This cost includes the actual costs incurred by farmers for purchasing insecticides from the dealers or retailers. It was found that per hectare cost of insecticide and herbicide for STWs farmers was Tk 208 respectively, which was 0.55 per cent of total costs. Major farmers in the study areas did not use any insecticide and herbicide in their plots and for this reason the cost of insecticide and herbicide was very low.

6.2.7 Cost of land use

The price of land was different for different plots depending upon location and topography of the soil. Land use cost considered the land renting arrangement prevailed in the study areas. In the study area, for renting one Pakhi (33 decimals) of land in *Boro* season, farmers (tenant) had to pay 240 kg of paddy to the land owner. On the basis of this value of paddy for renting one hectare of land was estimated as Tk 11,520 which have been considered as land use cost.

6.2.8 Interest on operating capital

Interest on operating capital (OC) included all costs in the process of growing MV *Boro* paddy excluding which interest had already been charged. Interest on OC was estimated actually on an average operating costs over the production period because not all costs were incurred at the beginning of the crop season; rather they were spread over the whole production period.

The Interest on OC was, therefore, calculated using the following formula, which also was used by many other researchers (Miah 1987, Hasan 1990 and Hossain 1999).

Interest on OC =AI it

Where, AI =Average Investment (i.e., total investment /2);

i = Interest rate per month; and

t = 5 months (i.e., *Boro* production period),

The Interest on OC on an average was Tk 920 for MV *Boro* paddy production under, which cover 2.44 per cent of total costs.

6.2.9 Total costs

Summation of all the above individual costs gave per hectare total costs for MV *Boro* paddy production. Per hectare total costs or average total costs for producing MV *Boro* paddy under STWs was Tk 37,716 (Table 6.1). The total costs of producing MV *Boro* paddy was the highest for STWs farmers which might be due to higher amount of irrigation cost, human labour cost by STWs farmers.

6.3 Yield and Gross Return of MV *Boro* Paddy

Per hectare yield of *Boro* rice was 5100 kg and average price of *Boro* rice at harvesting period was Tk 10 per kg.

Table 6.2 Per Hectare Yield and Gross Return of MV *Boro* Paddy Production under STW Irrigation.

Particulars	Unit	Under STW irrigation
Yield (main product/paddy)	kg/ha	5100
Unit price	Tk/kg	10.00
Value of main product	Tk/ ha	51,000
Value of by product/Straw	Tk/ha	2,146
Gross returns	Tk/ha	53,146

Source: Field survey (2008).

6.4 Gross Margin

Gross margin is the gross returns over variable costs. Gross margin of MV *Boro* paddy production was calculated by deducing total variable costs from the gross returns. Per hectare gross margin of MV *Boro* paddy was Tk 16,350 for farmers (Tables 6.1 and 6.2).

6.5 Net Return

Net return (i.e., profit) of MV *Boro* paddy was calculated by deducting gross costs from the gross return. Tables 6.1 and 6.2 reveal that the net returns of MV *Boro* paddy production for STW farmers was Tk 15,430 per hectare, respectively.

6.6 Household Income of Water Buyers

Remittance was the major source of household income for water buyers about similar to water seller but they earned the second highest income from *Boro* rice (29.34 per cent). Table 6.3, obviously, reveals that household income of water buyers prominently depend on *Boro* rice in rural areas. Small but countable amount of income came from business, services and labour selling and rickshaw pulling. *Aman* rice is also their main source of household income but the crop is not risk free and the income from this crop is sometimes uncertain. Due to flood and heavy rainfall they lost their *Aman* rice and got 1.38 Per cent of total household income which was very insignificant. Average household income of water buyers was much lower than water sellers because the landless, tenant, marginal farmers also engaged with water buying.

Table 6.3 Annual Household Income of Water Buyers

Income sources	Annual Income (Tk)	Per cent of total
Aman rice	1,153	1.38
Boro rice	24,561	29.34
Mustard, pulses, jute, wheat, sugarcane and vegetables	5,609	6.70
Water selling	4,702	5.62
Livestock, poultry and fisheries	4,142	4.95
Services	2,891	3.45
Business	7,008	8.37
Remittance	25,583	30.56
Labor selling and rickshaw pulling	6,422	7.67
Others (trees selling)	1,635	1.95
Average	83,706	100

Source: Field Survey (2008).

6.7 Concluding Remarks

The study clearly indicates that per hectare MV *Boro* paddy production was profitable under both DOS and EOS irrigation business. Among the costs items for producing MV *Boro* paddy, human labour was the vital cost. Irrigation was the second highest cost which is the essential for MV *Boro* paddy production. From the above discussion, it clearly indicate that the hypothesis (c) is rejected. The yield of MV *Boro* paddy was quite satisfactory in the study areas. Farmers gained a significant profit from MV *Boro* paddy. In such way, the farmers earn a handsum amount which contributed around 29 per cent of total household income.

Chapter 7

PROFITABILITY OF STW IRRIGATION BUSINESS AND ITS CONTRIBUTION TO HOUSEHOLD INCOME

7.1 Introduction

The main purpose of this chapter is to present the essence of the survey results on costs and benefits of the selected STW owners for MV *Boro* paddy production. The benefit and cost streams are the core of the present study since these will directly be used in the appraisal calculations of farmer-managed STW irrigation business. Financial analysis was analyzed in this chapter to see the profitability of investing in STWs for MV *Boro* paddy production. The sensitivity analysis also was worked out in this chapter to examine the sustainability of STW irrigation management from owners' point of view. In this chapter STW owners' profitability has been examined through financial analysis using the discounted measures. Profitability with change in diesel price which is the key element in determining level of STW owners' profit. This chapter also attempts to test the set hypotheses (d) and (e), as stated in Section 1.8.

7.2 Costs of STW Irrigation Business

Cost items included investment/capital costs, O&M costs as described below:

7.2.1 Investment Costs of STW

Investment cost is the fixed cost of tubewell operation. Investment cost includes the cost of engine/motor, pump, pipe and strainer costs, installation cost, cost of electricity connection, cost for construction of STW shed, irrigation channel making cost, etc.

Purchasing costs of diesel engine and electric motor. Purchasing costs of both diesel engine and electric motor were about the same in the study areas (Table 7.1). Some owners bought second-hand diesel engines and electric motors by lower prices from local markets. Recently some of them also bought old electric motors from ship. Local mechanics helped them to purchase the motor from Chittagong region.

Farmers started to convert their STWs to electricity from diesel for about 5 years. Most of the brands of electric motors came from China. These motors were cheaper than the brands from other countries. But few diesel engines made by Japan were comparatively older which were more costly than electric motors. The diesel engines were purchased in a long time ago, when the engine price was lower compared to current situation (2007/08). Although the life span of engines and motor varied for variation of cares by owners, 10 years for both engine and motor as average life span is assumed.

Pump, pipe and strainer costs of STW. About same quality of pumps for both diesel and electric STWs were used by the owners. A large number of owners used the pumps made by local industries due to its' cheaper price. Most of the owners used plastic pipe, although some of them used iron pipe for their STWs. Though, three types of strainer made by plastic, iron and bamboo were used in the study areas but most of the owners widely used the plastic strainer. The cost of bamboo made strainer was about half compared with plastic strainer but owners did not use it generally because it was not possible to re-bore. Due to higher price, very few owners used iron strainer. Generally larger dia and longer pipe made higher cost to install EOS (Table 7.1). Most of the owners used plastic pipe in their STWs due to its cheaper price and it was possible to re-bore when needed. Slightly higher costs of pump, pipe and strainer of EOS were found due to variation of installation date (Table 7.1).

Installation costs of STW. Installation cost of EOS was higher than DOS due to longer and larger pipe dia. According to farmers' opinion and mechanics views it was assumed that the STW was needed to reinstall in every 5 years, although it varied from STW to STW (Annex 1- Annex 6). Otherwise, the cost of reinstallation (Tk 2,500) was higher than initial installation because the cost included both de-installation and installation of pipes.

Cost for construction of STW shed. Each STW owner temporarily made STW shed in the field during *Boro* rice for 4 month. The average initial cost of new shed making was around Tk 2,000 (Table 7.1). The costs varied from owners to owners because some owners used tin only and some of them used both bamboo and tin as shed materials. However, most of the sheds were made by tin and bamboo. Other costs such as rope, pin, human labour, earth work etc., were also incurred for constructing the new shed. At the end of *Boro* season, STW owners packed the shed materials and kept the materials to use in the next season.

Irrigation channel making cost of STW. In the study areas, whole irrigation channel networks of command areas of all STWs were katcha (earthen). Human labour was the only cost for making the channel. STW owner made the channel on an average cost of Tk 925 for DOS and Tk 974 for EOS (Table 7.1). The higher cost of irrigation channel of EOS was incurred due to longer irrigation channel for covering larger command area along with more number of irrigators' plots.

Other investment costs of STW. Other investment cost included registration fee to get electricity connection, electric switch board, connection cable, electric light, iron/wood made base to setting up the machine, etc. The costs are mostly related with EOS and normally the other investment costs of EOS were higher than DOS. Especially, the electricity connection fee was much higher than other investment costs.

Table 7.1 Investment Costs of STW Irrigation

Sl. No.	Items of costs	cost of DOS (Tk)	cost of EOS (Tk)
1	Purchase of diesel engine/electric motor	13,800	12,706
2	Purchase of pump, pipe and strainer	4,467	6,652
3	Installation	990	1,505
4	Construction of STW shed	1,882	2,201
5	Irrigation channel making	925	974
6	Others (Registration fee for electric connection, switch board, connection cable, iron/wood made base, electric light)	1,215	11,432
	Total investment cost	23,279	35,470

Source: Field Survey (2008).

7.2.2 O & M costs

The O&M cost of STW varied from owner to owner, but its average cost per season represented the real world situations of the STW irrigation business. The different components of O&M costs for STW irrigation business are discussed below and presented in Table 7.2 and Figures 7.1 and 7.2.

Power, fuel and lubricant costs of STW. The average fuel cost per season of DOS was Tk 15,855, although fuel consumption of DOS varies with different types of engines powered by different horse power (HP) (Table 7.2). The diesel price varied from owners to owners in these areas due to purchase of diesel from different sources such as local diesel shop, upazila level diesel shop and diesel selling pump and during different time of the season. Electric charge of EOS varied from Tk 9,000 to 15,000 in these areas. Electric bills mainly depend on different motors' capacities (HP) and command areas. Variation of mobil prices was quite high because the owners purchased mobil of different quantities from different retail sellers.

Spare parts and mechanic costs. Most of the DOS owners paid mechanics fee in kind as about 300 Kg rice per STW for a season. The mechanics fee, however, varied due to relationship between owners and mechanics as well as condition of engine. Each DOS owner fixed a mechanic to repair his STW before starting irrigation of *Boro* season. But the EOS owner paid mechanics in cash when they repaired their STWs. As speak from EOS owners, the cable burning of motor is the main trouble and when their motor made trouble they brought it in mechanics shop to repair and they paid mechanics fee in cash (Appendix 8 and 9). Table 7.2 shows that spare parts and mechanic costs of EOS was quite higher than DOS.

Repairing costs of STW. Generally, STW owners repaired the old irrigation channel and made STW shed before starting irrigation. They, however, used some old corrugated lines as old tin had been used in previous season to make the tubewell shed. Human labor was the only cost for repairing irrigation channel. But for making STW shed both human labor and materials such as rope, iron pin, bamboo, wood etc., were utilized. Repairing cost for making irrigation channel of DOS (Tk 858) was slightly higher than EOS (Tk 803).

STW operator's salary. STW operator is also known as lineman (man who maintains irrigation line/channel) in these study areas. Payment for operator was paid in kind as 16.5 maund *Boro* rice for the period of irrigation season. The payment varied from operators to operators due to differences in experiences. The main task of STW operator was to operate and maintain STW but they also maintained irrigation channel. They managed the serial of the irrigators to irrigate their plots to avoid any conflict among irrigators. He was also careful about collection of rice paid by irrigators as irrigation charge. The costs of operators' salary for both of the STWs were about same (Table 7.2).

Other costs. Most of the STW owners appointed contract labor to collect rice from plots to owners' house when rice harvest was started. Some STWs were needed bamboo made pillar to connect with transformer of electricity. Lubricant cost was very low but the DOS owners used grease in the moving parts of the engine. Above-stated other costs were made by STW owners in the study areas shows in Table 7.2.

Table7.2 O & M Costs of STW Irrigation

Sl.No.	Items of Costs	Cost of DOS (Tk/season)	Cost of EOS (Tk/season)
1	Diesel cost	15,855	-
2	Mobil cost	977	-
3	Electricity cost	-	14,401
4	Spare parts and mechanics fee	1,527	5,500
5	Operator's salary	6,199	6,000
6	Irrigation channel repairing	858	803
7	STW shed repairing	636	783
8	Others (Labour for collection of rice from field)	1,000	1,150
	Total O&M costs	27,052	28,637

Source: Field Survey (2008).

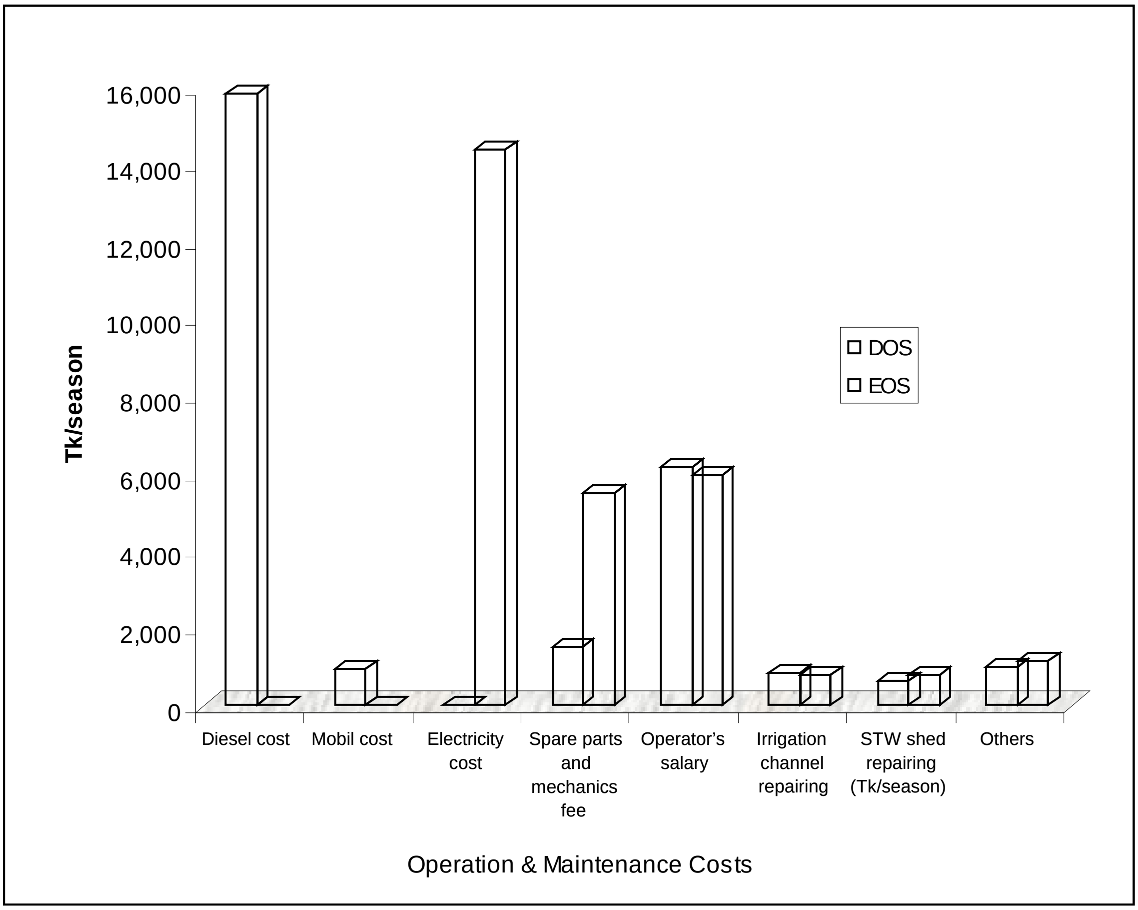

Figure 7.1 Bar Diagram Showing Average Operation and Maintenance Costs of DOS & EOS

7. 3 Benefits from STW

STW owners charged one fourth share of total production of *Boro* paddy as irrigation charge from water buyers. Straw of *Boro* rice was also shared at the same rate. As payment of water charge, DOS owner got 3,200 Kg rice while EOS owner got 4,120 Kg rice from each STW per season. Additionally, DOS owner got Tk 1,527 of *Boro* rice straw and EOS owner got Tk 1,809 (Table 7.3). DOS owner also got a small income for irrigating vegetable plots during the off *Boro* season. But EOS owners were quite unable to irrigate vegetable plots because there electricity connection in off season *Boro* is cut off. Total return from EOS was higher than DOS due to larger command area by EOS. A few water buyers also paid one-eighth share of paddy as water charge, because their plots were near the *Beel* area (low water bodies) and they irrigated their plots 3-5 times taking advantage of surface water from *Beel* in the beginning of the season.

The owners feel that an attractive amount of salvage value from their STWs is possible to get when it will not run. They also mentioned that iron made equipment of STW will enfold major share of salvage money. The salvage value of EOS (Tk 9,285) was higher than DOS (Tk 5,167) (Table 7.3). EOS included the salvage value of connection cable of electricity which would have high value in present market.

Table 7.3 Benefits of STW Irrigation

Items of benefit	Unit	Benefits of DOS	Benefits of EOS
Paddy as water charge	Kg	3,200	4,120
Value of paddy	Tk	32,470	40,034
Straw from paddy	Tk	1,527	1,809
Charge for watering the vegetables plots and others	Tk	992	353
Total return	Tk/year	34,989	42,196
Salvage value of STW	Tk in last year	5,167	9,285

Source: Field Survey (2008).

7.4 Financial Analysis of STW

The main purpose of this section is to present the profitability of irrigation business from the view point of STW owners. As stated in Section 3.8, mainly three discounting measures such as BCR, NPV, and IRR have been employed in this study to assess the profitability of the business. The financial analysis of the STW, however, is based on the following assumptions:

i. All the STWs were purchased with cash;

ii. The project life has been assumed 10 years for STW;

iii. Salvage values were assumed 10 per cent of the initial investment for STWs ;

iv. Prices of all inputs and outputs are given and constant throughout the project life.

The financial analysis in this study has been conducted from the viewpoint of STW owners. The analyses were performed considering only *Boro* season. The financial analysis from the viewpoints of STW owners are presented in Appendix Tables 1 and 2. The summary results of financial analysis of the selected STWs irrigation business are presented in Table 7.4

Table 7.4 Summary Results of Financial Analyses of STWs Irrigation Business

Discounted measures	Diesel Operated STW	Electrically Operated STW
BCR at 10%	1.15	1.25
NPV at 10% (Tk)	28,189	53,238
IRR (per cent)	50	61

Source: Adapted from Appendix Tables 1 and 2.

It is evident from the results presented in Table 7.4 that investment in both DOS and EOS were profitable. It is also evident from the table that BCR of the STWs were more than unity and NPV were also positive at 10 per cent discount rate. The IRR of both DOS and EOS were much higher than the opportunity cost of capital but the IRR of EOS was much higher than the DOS of STW irrigation business. From financial analysis, BCR, NPV and IRR of the Diesel Operated STWs irrigation business were 1.15, Tk 28,189 and 50.00 per cent, respectively, whereas the corresponding figures for STWs irrigation business under Electrically Operated STWs were 1.25, Tk 53,238 and 61.00 per cent, respectively. The null hypothesis (d) is therefore, rejected. In other words, owners of EOS can earned more profit than the owners of DOS.

Therefore, it is concluded that that the irrigation business in the study areas was highly profitable under EOS than DOS because IRR was quite higher than bank rate (10 percent). This lower IRR rate in present situation clearly proved that the IRR rate decreased over time mainly due to increase of diesel price and repair costs. Again, lower electric charges compared to fuel and lubricant costs and coverage of higher command areas by EOS promoted the irrigation business of DOS, which proved to be more profitable than DOS.

The above-mentioned findings of the financial analysis from the viewpoint of STW owners under DOS and EOS, based on the assumptions are not free from criticisms. On the basis of the survey results the O&M costs of STWs may not be the same throughout the relevant project life. The prices of inputs and production technology may not also be same over the project life. Little And Mirrless (1974) and Miah (1987) pointed out that the uncertainties of a particular project arise from many unpredictable influences. One cannot perfectly predict future technology or actions of the government; any of these can quite easily falsify the assumptions upon which the appraisal is based. Keeping in view, the limitations of the appraisal calculations of STWs irrigation business under DOS and EOS, before making any generalizations it is, therefore, felt necessary to conduct sensitivity analyses, which have been done in the following section.

7.5 Interpretations of Sensitivity Analyses of STWs Irrigation Business

The results of sensitivity analysis show how the value of the investment criteria changes due to changes in the value of any variable in the discounted cash flow analysis. The profitability of the projects may be expected to be sensitive to O&M costs, and gross benefits of the projects. Even the project itself may not perform in the way expected. Many authors (George and Shorey 1978, Miah and Hardaker

1988) also argue that the problem of uncertainty is another knotty problem to which there is no tidy solution. A great deal will inevitably depend upon the judgment of those making decision and no amount of clever statistical manipulation should conceal this fact. Only two vital factors such as costs involved and gross benefits of the projects are considered in this study for the sensitivity analysis due to limitation of time. The aim is to see what happens to profitability under the changed circumstances.

It is evident from financial analysis, as stated earlier; the owners of STW irrigation business are making great profits. In this study, sensitivity analysis has been conducted based on the assumptions that all benefits and investment costs would remain the same, then what would happen in the profitability of the relevant projects, if only O&M costs would increase by 10 per cent. Again, sensitivity analysis was done based on the assumptions that all costs and salvage value would remain the same, then what would happen in the profitability if benefits would decrease by 10 per cent. Therefore, two factors were taken into consideration for STW owners in this respect as (i) reducing existing benefits (other than salvage values of the concerned equipment) at the rate of 10 per cent and (ii) O&M costs increase at the rate of 10 per cent.

Under the changed circumstances, the financial analysis of Section 7.5 has been reworked separately in this section to see what happen in the profitability of STWs irrigation business. Under the changed circumstances, sensitivity analysis of STWs irrigation business from the viewpoints of owners considering the above mentioned factors are present in Appendix Tables 3 to 6. Summary results of the sensitivity analyses are presented in Tables 7.5 and 7.6.

7.6 Sensitivity Analysis of STWs Irrigation Business Considering 10 Per Cent Increase in O&M Costs

In Appendix Tables 3 and 4, sensitivity analysis has been done taking into account 10 per cent increase in O&M costs while all other costs would remain the same.

Table 7.5 Results of Sensitivity Analysis of STWs Irrigation Business Considering 10 Per cent Increase in O&M costs

Discounted measures	Diesel Operated STW	Electrically Operated STW
BCR at 10%	1.06	1.16
NPV at 10%	11,568	35,648
IRR(per cent)	25.00	41.00

Source: Adapted from Appendix Tables 3 and 4.

It is evident from Table 7.5 that the BCRs of STWs are still greater than unity, NPVs are positive and IRRs are higher than opportunity cost of capital (i.e., 10 percent). This implies that if O & M costs would increase at the rate of 10 per cent, while gross benefits and other costs would remain the same, investment in EOS would still be profitable. On the other hand, Table 7.5 also indicates that BCRs of DOS are greater than unity, NPVs are positive and IRR are greater than the opportunity cost of capital (i.e., 10 per cent). This result implies that If O & M costs increased at the rate of 10 per cent, while gross benefit and other costs would remain the same, investment on both type of STWs business would be profitable. It is evident that the electrically operated STW was more profitable than the diesel operated STW.

7.7 Sensitivity Analysis of STWs Irrigation Business Considering 10 Per Cent Decrease in Gross Benefits

In this section, sensitivity analysis has been done considering 10 per cent decrease in gross benefits while all other costs would remain the same (Appendix Tables 5 and 6).

Table 7.6 Results of Sensitivity Analysis of STWs Irrigation Business Considering 10 Per Cent Decrease in Gross Benefits

Discounted measures	Diesel Operated STW	Electrically Operated STW
BCR at 10%	1.03	1.13
NPV at 10%	6,492	26,955
IRR(Per cent)	18.00	33.00

Source: Adapted from Appendix Tables 5 and 6.

It is evident from the above table that the BCR of both types of STWs were greater than unity, NPVs were positive and IRRs were higher than opportunity cost (i.e., 10 per cent). It may be concluded that in this situation the electrically operated STW could survive in the water market at the break-even level. This implies that if benefits decrease at the rate of 10 per cent, while all costs remain the same, investment on both types of STWs would still be profitable but the rate of return of electrically operated STWs would be greater than diesel operated STW.

7.8 Water selling and household income of STW owners

Table 7.7 clearly shows the income from water selling had a significant role in total household income of STW owners. About 9.74 per cent of total income was earned by STW owners from water selling, which was the third highest income. Incomes from EOS owners were much higher than DOS owners. Remittance income from abroad (46.05 per cent) was very much dominant in household income in these study areas. STW owners earned 27.29 per cent of household income from *Boro* rice which was much higher than *Aman* rice (Table 7.7). However, *Aman* production was lost in this season (in 2007) due to uncertain flood and heavy rainfall.

Table 7.7 Annual Household Income of STW Owners

Income sources	Diesel Operated STW		Electrically Operated STW		All types	
	Income(Tk)	% of total	Income(Tk)	% of total	Income(Tk)	% of total
Aman rice	1113	056	2883	1.83	1998	1.20
Boro rice from own plots	51100	25.77	45480	28.81	48290	27.29
Water selling	21153	10.67	13930	8.82	17541	9.74
Aus rice, mustard, pulses, jute, sugarcane and vegetables	2925	1.48	5768	3.65	4346	2.56
Livestock and poultry and fishes	2867	1.45	2616	1.66	2741	1.55
Services	8000	4.04	7613	4.82	7804	4.43
Business	4000	2.02	14097	8.93	9048	5.47
Remittance	106333	53.66	60688	38.44	83510	46.05
Others (trees, labour selling and rickshaw pulling)	667	034	4780	3.01	2723	1.68
Total	198158	100	157855	100	178001	100

Source: Field survey (2008).

7.9 Determinants Influencing the Participation in STW Irrigation Market

In this section, an attempt has been taken to identify main factors which influence the participation in STW irrigation business. In this regard some variables such as age, cultivable land, farm size, education level, subsidiary occupation and household income were assumed as influencing factors for participation in the STW irrigation business.

To run the STW irrigation business, it is essential to understand the technical aspects and business strategies. Farmers having higher level of education may have higher technical and business knowledge. It was assumed that higher educated farmers may be involved with the STW irrigation business. Again, higher amount of investment is needed to start STW irritation business, even good amount of operating capital is essential to run the business during irrigation season. So, the rich farmers having higher earnings may come to this business. However, larger area of cultivable land provides higher income of farm households. A significant amount of household income comes from subsidiary occupation and the farmers who have subsidiary occupation may participate in the STW irrigation business. Generally experienced farmers come to operate any business and it was assumed that higher aged farmers may run the irrigation business. Larger number of family members may be able to provide sufficient time to operate the business and assumed that households with larger numbers may participate in the irrigation business.

The log likelihood function and the proportions of samples correctly predicted for their likely status in terms of participation indicate a good fit of the equation. Though it was not significant but the coefficient of education level of farmers indicates that higher educated farmers might not be involved with STW irrigation business. The explanation is that university degrees do not enable the farmers to actively participate. Technical training on running the irrigation equipment could display a positive relationship. The coefficient of household income explains that households having higher income might participate in STW irrigation business and it was significant at less than 10 percent level. There was no any significant relationship between area of cultivable land and operation of STW irrigation business. Otherwise, occupational coefficient did not support the assumption that assumed for occupation.

No significant relationship but negative sign of the coefficient of age of household head and family size indicate that lower age of household head and family size might be encouraged to operate irrigation business. The Young entrepreneurs might come to the business taking into risk (Table 7.8).

Table7.8 Factors Influencing the Participation in STW Irrigation Business

Variables	Coefficient
Education level (year)	-0.023 (0.038)
Income (Tk in lack)	0.193 (0.125)*
Cultivable land (acre)	0.120 (0.103)
Occupation-sub (1=yes, 2=Otherwise)	0.015 (0.283)
Age (year)	-0.010 (0.009)
Family size (no.)	-0.029 (0.094)
Regression estimates	
Log likelihood function	-56.66
Restricted log likelihood	-57.29
Chi-squared	1.25
Significance level	0.94
Corrected prediction	43%

Note: * significant at less than 10% level, n=90

From the above table it clearly indicated that the null hypothesis (e) is rejected. The results of the probit model revealed that the key variables considered in the model were individually or jointly more or less responsible for participation in the STW irrigation business.

7.10 Concluding Remarks

It is clear from the above discussion that both electrically and diesel operated STWs were profitable in financial analysis, but the internal rate of returns of electrically operated STWs were higher than diesel operated STWs. It implies that more and more STWs may expand in future. The results of sensitivity analysis also clearly indicate that operation and maintenance cost and gross benefits have a strong influence on the profitability of tubewell operation. The results of sensitivity analysis indicate that if operation and maintenance cost increased by 10 per cent, the electrically operated STW could earn marginal profit but diesel operated STW could run only break-even level. Sensitivity analysis also reveals that if 10 per cent decrease in gross benefit, the diesel operated STWs could run only at break-even level.

During the uncertain situation as 10% increase of operation and maintenance (O&M) costs or 10% decrease of benefits when other costs remaining the same, DOS business will be unprofitable while the EOS business will still be a profitable business. The main reason for lowering of profit from DOS was the significant increase of diesel price. Otherwise, other things remaining the same, only diesel price increase by 10 percent will still give a higher profit for the DOS owners (IRR 34 percent), (Appendix Table 7). During the recent past, both diesel and output price increased by more than 10 percent in Bangladesh and in this regard appraisal analysis was also done considering the both certain and uncertain situations. Other things remaining the same, if both diesel and paddy price increase by 10 percent the irrigation business will be highly profitable.

Chapter 8

SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

This chapter attempts to summarize the major findings of the study. Section 8.2 presents a summary of the major findings of the study; conclusion and future policy guidelines are given in Sections 8.3 and 8.4, respectively. Sections 8.5 and 8.6 show the shortcomings of the present study and avenues for further research.

8.2 Summary

South Asia is a home of 1.5 billion people most of which live in India and Bangladesh. Bangladesh, the most densely populated country in the world suffers from food deficiency for a long time. And it is the major challenge of government since Liberation for increasing foodgrain production to meet up the growing demand. Moreover, the economy of an agrarian society (like Bangladesh) is dominated by agriculture and the livelihoods of the farmers are largely connected with intensive agriculture production. Again intensive land use is a pre-requisite to overcome this deficiency. *Boro* rice contributed 55 per cent of total rice production in 2004/05. So, increase of *Boro* rice production would be a significant possible way to remove food deficiency in the country. *Boro* rice produced in Rabi season and mainly irrigation was used for crops grown in Rabi season in Bangladesh. Groundwater covers 75 per cent of total irrigated area alone. About 80 per cent of groundwater used for crop production where *Boro* paddy alone used 73 per cent of total irrigation. Irrigation covered about 34 per cent of total cultivated area of Bangladesh. Moreover, intensive land use is directly related with availability of irrigation facilities to the farmers. The groundwater resource is one of the key factors in making the country self sufficient in foodgrain production. Groundwater access was increased by about 26 per cent during last 5 years which enhanced the farmers' productivity. Moreover, *Boro* production is increasing at about 1 per cent annually. So, developments of irrigation facilities are the crucial issue to increase and sustain MV *Boro* production.

The study area is suitable for STW irrigation business due to geographical location, topography, aquifer characteristics and groundwater availability. Farmers are interested to invest their money in shallow tubewell business by single and partnership arrangement. The usual cost of irrigation is 1/4th crop share received by the STW owners as irrigation charges. Most of the partnership STWs were operated by electricity while most of the single owner STWs were run by diesel. Since STWs are mostly operated by diesel, the price of diesel is very important for STW owners to make a profit. Shares allocated among the partners were not necessarily equal, and cost and return of their business were also shared according to their actual share.

In changing situation over the time some existing issues regarding groundwater irrigation by STW is essential to study to improve the irrigation business in Bangladesh. With the above background, the specific objectives of the study are as follows:

i. to identify socioeconomic status of STW owners and water buyers;

ii. to assess the impact of increased energy prices on command areas under diesel and electrically operated STWs;

iii. to estimate the relative profitability of farmers producing irrigated MV *Boro* paddy under diesel and electrically operated STWs and its contribution to household income;

iv. to estimate the profitability of STW irrigation business and its contribution to household income;

v. to estimate contribution of key inputs to the production processes of irrigated MV *Boro* paddy production; and

vi. to suggest some policy guidelines/recommendations.

The following hypotheses have been set to test the above-mentioned objectives:

(a) There is no variation in socioeconomic characteristics between the owners of STW and water buyers producing MV *Boro* paddy.

(b) There is no impact of increased energy prices on command areas under diesel and electrically operated STWs.

(c) There is no difference in profitability of farmers producing irrigated MV *Boro* paddy under diesel and electrically operated STWs and its contribution to household income.

(d) STW irrigation business is unprofitable and its contribution to household income is almost nil, and

(e) Contribution of key inputs to the production process of MV *Boro* Paddy is negligible.

Keeping in mind the main objectives of the present study, five adjacent mauzas/villages namely Shekh Shimul, Saitapara, Kurmushi, Kaijalipur and Kagmari Beltail of Dighalkandi union under Ghatail Upazila of Tangail district were randomly selected for the study where a considerable number of STW owners and water buyers were available. In the study, 30 STW owners and 60 water buyers from 5 villages of Ghatail Upazila in Tangail district were selected randomly. For collecting data, two sets of questionnaire were prepared to record the required information in accordance with the objectives of the study. One set was for the STW owners and the other one was used for the water buyers. The survey covered a whole crop season of MV *Boro* production from January to May 2008. In this study tabular methods as well as project appraisal techniques were used.

In respect of socioeconomic characteristics of the STW owners and water buyers, the study reveals that the average age to be found about 55 years for STW owners and it was 48 for water buyers. The average family size of STW owners stood at 5.2 members while the corresponding figures for water buyers were 5.5. These figures show that the average family size of both the owners as well as buyers were relatively higher than the national average (4.8) of Bangladesh (BBS 2001). In the case of STW owners, average own land under cultivation was 214 decimal and for water buyer was 138 decimal.

Average level of education was slightly higher for STW owners than water buyers. Some conflicts or misunderstanding among the partners, owners, and water buyers did occur. A greater extent of conflict appeared for new STW entrepreneurs in irrigation business, particularly for reallocating command areas. Misunderstandings and conflicts were handled and mitigated by local institution (*samaj*) with participation of stakeholders from different *gusthi* (lineage).

Most of the owners and buyers were engaged in agriculture as their main occupation. About 86.00 per cent STW owners and 90.00 per cent water buyers were engaged in agriculture as their main occupation. As subsidiary occupation, business was found to be the most important occupation for both owners and buyers (Table 5.4). The above mentioned results support the rejection of the null hypothesis (a). This means that there is a variation in major socioeconomic characteristics among the owners of STWs as well as water buyers.

The command area of the STWs are settled by a combination of factors such as pump capacity, availability of irrigable plots, soil types, slope of lands, land elevation variations, etc. The farmers strongly felt that the smaller sizes of command areas were possible to irrigate by the smaller engines/motors. Fuel consumption for smaller engines whether of Japanese or Chinese origins, was reasonably satisfactory which indicates good performance of the engines with their pumps.

It is evident from the above-mentioned results that MV *Boro* paddy production under DOS were profitable but the profitability of MV *Boro* paddy production under EOS was relatively much higher. In other words, these findings clearly support the rejection of null hypotheses (b) and (c). This means that there is a distinct difference in profitability of growing MV *Boro* paddy under diesel and electrically operated STWs.

The results of financial analyses show that the BCR, NPV and IRR of STWs under diesel operated were 1.15, Tk. 28,189 and 50 per cent, respectively and the corresponding values for STWs under electrically operated were 1.25, Tk. 53,238 and 61 per cent, respectively. The results of the present study clearly indicated that the investment in STW business under DOS and EOS is a profitable business. For each of the selected STW owners under DOS and EOS the values of IRR were higher than the opportunity cost of capital (i.e., more than 10.0 per cent). Similarly, BCRs at 10 per cent discount rate are greater than the unity and NPVs at 10 per cent discount rate are also positive for both DOS and EOS. The IRR of both DOS and EOS were higher than the opportunity cost of capital but the IRR of EOS was much higher than the IRR of DOS. Thus, the results of project appraisal revealed that investment in both DOS and EOS were profitable but the investment in EOS was relatively more profitable than the STWs irrigation business under DOS. So the null hypothesis (d) could be rejected. This means that there is a much difference in profitability between the investors of STWs under DOS and EOS**.**

The results of the probit model revealed that the key variables (i.e., education, age, occupation, land size) included in the model were individually or jointly responsible for variation of their characteristics. So, the null hypothesis (e) could be rejected. This clearly indicate that contribution of key variables to the production process of MV *Boro* paddy is not negligible.

Although the appraisal in this study has been done taking into account the real world situation still sensitivity analyses have also been done to make sure how the profitabilities of these business respond to change in gross benefits and O&M costs. In fact, two situations have been taken into considerations for sensitivity analyses to capture more realistic situation. These were; if (i) O&M costs were increased at the rate of 10 per cent while benefits would remain the same; and (ii) if benefits were decreased at the rate of 10 per cent while other costs were remained the same.

The results of the sensitivity analyses added further weight to the evidence of the profitability of STWs irrigation business. Even with considering at 10 per cent increase in O&M costs and 10 per cent decrease in gross benefits, STWs irrigation business under DOS and EOS were allowed positive NPV and BCR is still greater than unity and IRR is greater than opportunity cost of capital. However, the results of sensitivity analyses clearly indicate that STWs irrigation business under DOS and EOS are making still profit at the rate of 10 per cent increase in O&M costs and decreases of gross benefits.

Diesel engine or electric motor purchase, purchase of pump, pipe and strainer, registration fee for electricity connection, purchase of electric cable etc., were the main investment costs of STW. A good marketing facilities would able the framers easy access to the business. Electricity facilities were available in 4 out of 5 study areas but the farmers were unable to get electricity connection in their STWs due to huge amount of connection fees were charged illegally by concerned authority. Dissemination of transparent information about electricity connection to the farmers might improve the situations. Energy price was the main operating cost of STW business. The DOS owners were anxious about increase of diesel price over time because they were in break-even stage of this business. If diesel price increases this way, it would be very difficult to run STW irrigation business profitably.

According to farmers' opinion, the output sharing system is superior to other systems of payment for water because the STW owners become more careful about watering the plots regularly. The buyers were also aware about higher profitability of EOS and were not fully satisfied with the prevailing one-fourth water charge and claimed for reduction of water charge.

The STW irrigation business was profitable in current normal price of inputs and paddy but the business will unprofitable for DOS in uncertain situation considering 10 percent increase of cost or 10 percent decrease of benefit. But it would be fairly unable to sustain the STW business in severe uncertain situations with rise in diesel/electricity prices without commensurate rise in paddy prices.

8.3 Conclusions

Water selling, *Boro* production, and remittance income were the major sources of income for STW owners, while *Boro* production and remittance were the main sources of income for the water buyers. About 10 percent water buyers borrowed money for buying inputs of *Boro* rice. Production of *Boro* rice was highly profitable at the current high foodgrain prices, although the buyers paid one-fourth crop share as payment for water. Moreover, higher income earnings may encourage the farmers to participate in the STW irrigation business.

From the results of the present study it can easily be concluded that there is a considerable scope apparently exists in the study area for the expansion of STWs to enhance the productivity of MV *Boro* paddy and to increase farm income of the STW owners as well as water buyers. The study revealed that MV *Boro* paddy production under EOS was relatively more profitable than that of DOS. Thus, it could be concluded that the performance of irrigation business under EOS was relatively far better than that of irrigation business under DOS.

8.4 Policy Recommendations

Considering the major findings of the study following recommendations may be put forward which are likely to be useful for policy formulation:

i. It is evident from the above discussion that due to uncertain supply of fertilizers, farmers could not apply required fertilizers when needed. The supply of fertilizers should be ensured to the farmers in right quantity at right time. This will help farmers to mobilize the earning coming from mustard and vegetables production to *Boro* crop cultivation.

ii. With the elimination of the BADC's mechanics, there are few opportunities for proper mechanical training in the study area, which is the major problem of the STW owners to maintain their tubewell in irrigation season. The mechanics feels that there is no any formal training center in this area. The training facilities might enhance their works efficiency which may ensure the repairing of STWs within a short period and also ensure the higher yield of *Boro* rice. Thus, government should establish good training centers in rural areas and involvement of youths for attending training on mechanical services.

iii. There were frequent occurrences of major breakdowns of engines and the farmers often had to wait for a long time for the completion of repairs, particularly for older Japanese engine operated STW. This was a real problem in critical periods of crop growth. The increase and improvement of local workshop facilities could relax this problem to some extent. Bank loans on easy terms could be made available to establish rural workshops so that they can take up major repairs.

iv. Although Japanese and others STW engines were preferred by pump owners, equipment purchasers have gone for cheaper engines-even with a perceived lower level of durability and a higher rate of breakdown (though those perceptions as reported by the STW owners). The engines are now being bought have ready availability of spares and quick repair service (as well as, of course, lower price). Therefore, the liberalized importation of smaller and cheaper engines should be continued.

v. Non-metering rate of electricity should be rational as the rate should be billed on the basis of command area, not on the basis of engine capacity. In spite of the flat rate system, the meter system would be a quite good one. In that situation, the owners would mentally satisfied with meter system and water loss also be managed.

vi. Supply shortage of diesel and rise in diesel price in peak period of irrigation were reported. The government should monitor the diesel pumps and retail shops to ensure supply at the fixed price. Diesel price should continue to be subsidized to sustain irrigation water selling business.

vii. For improvement of command area level management of irrigation, i.e. allocation of plots, dispute settlement, field channel construction, etc. and also to monitor fertilizer and diesel supplies, potentials of the existing informal social institutions should be fully understood and utilized.

viii. The yield and price uncertainty largely affects on the profitability of MV *Boro* paddy production. So, the study recommended for strengthening of technology research to maintain yield growth of MV *Boro* paddy as well as stable input market price.

Thus the profitability of the owners of tubewell as well as the water buyers can thereby be increased, which in turn will help to achieve self-sufficiency in food grains and thereby increase income and thus to promote better living standard of the people of Bangladesh than ever before.

8.5 Shortcomings of the Study

The present study provides some useful information for farmers, researchers and extension workers, decision makers regarding STW irrigation business. Nevertheless, this study suffers from the following limitations:

i. Only financial analysis was undertaken in the present study, but economic analysis is very important for a developing country like Bangladesh. Despite its importance, the economic analysis of STWs was ignored in this study due to limitations of time and resources.

ii. In rural Bangladesh, most of the farmers do not keep any records of their farm business transactions. As a result, the accuracy of data fully depends upon their memories and sincerity. The task of obtaining accurate data proved to be very challenging and the possibility of data errors, therefore, cannot be ruled out.

iii. The findings of the study are based on micro-level data of a specific area (Ghatail Upazila of Tangail district) of Bangladesh. These findings should, therefore, be interpreted cautiously if any greater generalizations are sought for different regions with distinct topographies of Bangladesh.

8.6 Scope for Further Research

Further research may be conducted in a number of areas, which are not adequately addressed in this study due to limitations of time and resources. Avenues for possible future research are outlined below:

i) A broad-based study on STW irrigation business covering all topographical areas could be undertaken to examine various aspects of STW irrigation business. Such a study may be useful not only to check the conclusions of the present study but also to derive total demand and supply functions of irrigation water for a particular region or the country as a whole. The study could contribute to determine analysis effective management policy for irrigation water business in Bangladesh.

ii) An economic analysis of STW irrigation business may be useful to look out the benefits of STWs irrigation business under diesel and electrically operated STWs from the viewpoint of society. Now-a-days, society's costs benefits considerations are important to take policy decisions in the national level. However, profitability of STW irrigation business from the view point of society is another important area of future study.

REFERENCES

Akteruzzaman, M. (1990), A comparative economic study on productivity and equity performances of deep tubewell irrigation under different management systems in a selected area of Comilla district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Akteruzzaman, M. (1997), Competitiveness of groundwater market in privatized shallow and deep tubewell for diversified irrigation: An assessment. Review of Agricultural Economics, 53.

Alam, M.K., Hasan, AKMS. Khan, MR., Whitney, JW. (1990), Geological map of Bangladesh. Geological Survey of Bangladesh, Dhaka.

Alam. J. (1983), Evidence of the causes of low scale of STW irrigation sets in 1983-84: Implication for policy and Research, Research report, Bangladesh Agricultural Research Council, Dhaka.

Ali, M.W. (2001), An investigation into the yield gap of MV *Boro* paddy between the research station and farmers field: a case of Bogra district, MS Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Amin, M.M. (2001), A study on socioeconomic impact of partial mechanization on farm productivity, income and generating employment in Trisal Upazila of Mymensing district, MS Ag. Econ. Thesis, Bangladesh Agricultural University, Mymensingh.

Asad-Uz-Zaman, M. (1998), Impact of irrigation development a case study: Barind Project in Bangladesh. Water and Land Resources Development and Management for Sustainable Use. Vol-II-A. The Tenth ICID Afro Asian Regional Conference on Irrigation and Drainage, Denpasar, Bali, Indonesia, 19-26-July 1998. A-12, 10 pp.

BBS (2006), Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (2001), Population Census 2001, Preliminary Report, Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Bhuiyan, S.I. (1984), Groundwater use for irrigation in Bangladesh: The prospects and some emerging issues, Agricultural Administration, 16.

Boyce, J.K. (1986), Water control and agricultural performance in Bangladesh, Bangladesh Development Studies, Dhaka, 14(4), 37-56.

Brown, M.L. (1976), Budget for Analyzing Farm Income and Agricultural Projects, E.D.I. World Bank, Washington, D.C.

Chakravorty, N (2004), Water pricing in Bangladesh: a pro-poor framework based on two surface water irrigation projects in Bangladesh. Irrigation in a total catchment context sharing the river Proceedings 2nd ICID Asian Regional Conference on Irrigation and Drainage, Moama NSW, Australia, 14-17 March 2004.

Chakravorty, S.S.R. (1985), An analysis of selected irrigation methods under rural development –1 project in Bogra, M.Sc. Ag. Egon. thesis, Bangladesh Agricultural University, Mymensingh.

Dillon, J.L. and Hardaker, J.B. (1993), Farm Management Research for Small Farmer Development, FAO, Agricultural Service Buletin 41, Food and Agriculture Organization of the United Nations, Rome.

Fujita, K., Kundu, A. and Jaim, W.M.H. (2003), Groundwater market and agricultural development in West Bengal: perspectives from a village study, Japanese Journal of Rural Economics, 5.

George, F. (1989), Manual on Buried Pipe Irrigation Systems, BRDB, TADP, Dhaka.

Geroge, K.D. and Shorey, J. (1978), The Allocation of Resources: Theory and Policy, George Allen, London.

Ghani, M.A. (1998), Water management: a key to comprehensive agricultural development in Bangladesh. Proceedings of the International Agricultural Engineering Conference, Bangkok, Thailand, 7-10 December 1998.

Gittinger, J.P. (1994), Economic Analysis of Agricultural Prokects. 2nd Edn. John Hopkins University Press, Baltimore.

GOB (2006), Bangladesh Economic Review, Financial Advisory Subdivision, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

GOB (2007), Bangladesh Economic Review, Financial Advisory Subdivision, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

Hamid, M.A. (1984), A study of the BADC deep tubewell programme in the North western region of Bangladesh, Rural Development Series No. 7, Rajshahi University, Rajshahi.

Haque, M.F. (1975), A comparative analysis of small-scale irrigation system in Bangladesh. Bangladesh Development Studies, 3 (1), 43-52.

Hasan, M.N. and Islam, M.N. (1994), Utilization of water under different deep tubewell management systems in the Rajshahi area of Bangladesh, IIMI South Asian Regional workshop on farmers management of groundwater irrigation in Asian, 1914, 95-106.

Hassan, M.K. (1990), A financial analysis of power tiller utlisation in Gouripur area of Mymensingh district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Herath, G. (2002), Issues in irrigation and water management in developing countries with special reference to institutions. Water policy reform lessons from Asia and Australia Proceedings of an International Workshop, Bangkok, Thailand, 8-9 June-2001.

Hossain, M. (1986), Irrigation and agricultural performance in Bangladesh: some further results. Bangladesh Development Studies, 14(4), 37-56.

IIMI and BSERT (1996), Study on Privatization of Minor Irrigation in Bangladesh, International Irrigation Management Institute, Sri Lanka and Bureau of Socio-Economic Research & Training, Bangladesh Agricultural University, Mymensingh.

Intizar, H. (2007), Poverty-reducing impacts of irrigation: evidence and lessons. Irrigation and Drainage, 56(2/3).

Islam, M.N. (1992), An evaluation of deep and shallow tubewells minor irrigation projects of Thakurgaon Sadar Upazila, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Jaim, W.M.H. (1976), A comparative economic study of the different systems of tubewell irrigation in some selected areas of Mymensingh district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Jaim, W.M.H. (1993), Can Potential Capacity of Deep Tubewells be Utilized? - A Study in Bogra Region of Northwest Bangladesh with Special Reference to Compacted Earth channel. Human Resource Development Programme, Winrock International, Dhaka.

Jaim, W.M.H. and Akteruzzaman, M. (1999), 'Market for groundwater irrigation in Bangladesh; the supply side', Journal of Applied Irrigation Science, 34(1), 23-29.

Jaim, W.M.H., and Rahman, M.M. (1978), Relative profitability of HYV *Boro* under different systems of tubewells irrigation in an area of Bangladesh, Bangladesh Journal of Agricultural Economics, 1(1), 56-92.

Kazi, A.K.S. (1977), Comparative economic study of the production of IRR-8 and local varieties of rice the *Boro* season by low lift power pump irrigation in two villages of Mymensingh district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Khan, M.A.R. (2003), Performance of low lift pumps and Shallow tubewells under farmer-managed irrigation systems in Netrakona district of Banagladesh, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Kumar, D (2003), Impact of electricity prices and volumetric water allocation on energy and groundwater demand management: analysis from Western India. International Water Management Institute, India Project Office, Elecon Building, India.

Kundu, T.K. (1993), Comparative economics of lined and unlined irrigation channels of deep tubewells in some selected areas of Bogra district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Little, L.M.D. and Mirrless, J.A. (1974), Project Appraisal and Planning for Development Countries, Heinemann, London.

Mamun, M.A.A. (2001), Financial analysis of deep and shallow tubewell irrigation and profitability of *Boro* and *Aman* rice in Brahmanbaria district, MS Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Mannan, M.A. (1996), Economics of Shallow tubewells in an area of Bangladesh. M.S. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Mandal, M.A.S. (1989), Declining return from groundwater irrigation in Bangladesh, Bangladesh Journal of Agricultural Economics, 12(2), 43-61.

Mandal, M.A.S. (2000), Dynamics of irrigation water market in Bangladesh, In M.A.S. Mandal (ed.), Changing Rural Economy of Bangladesh, Bangladesh Economic Association, Dhaka, 188-28. .

Mandal, M.A.S. (1987), Imperfect institutional innovation for irrigation management in Bangladesh, Paper presented in the symposium on Irrigation Design for Management at the International Irrigation Management Institute, Sri Lanka, February 1987.

Mandal, M.A.S. (1998), Competition for Command Area Plots. Field Notes from Saitapara, Ghatail, Tangail.

Mandal, M.A.S. and Parker (1995), Study on Privatization of Minor Irrigation in Bangladesh, A Final report, IIMI and Bureau of Socio-economic Research and Training of the Bangladesh Agricultural University, Mymensingh.

Miah, M.L. (2004), Profitability analysis of Shallow Tubewell Owners under crop sharing arrangement in some selected areas of Bogra district. M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Miah, M.T.H. (2000), Irrigation privatization and role of shallow tubewells in the context of small holder rice farming in Bangladesh. Paper Presented for the Seminar on "FMIS in the Changed Context" organized by Farmer Managed Irrigation Systems (FMIS) Promotion Trust, Kathmandu, Nepal, 18-19 April 2002.

Miah, M.T.H. (1987), Appraisal of deep and shallow tubewell irrigation projects in the Tangail district in Bangladesh. M.Ec. dissertation, University of New England, Armidale, Australia.

Miah, M.T.H. (1991), A comparison of farmer and agency-managed minor irrigation projects in Thakurgaon district of Bangladesh, Paper presented fro the International Workshop, Mendoza, Argentina, 12-15 November 1991.

Miah, M.T.H. (1989), A Comparative performance of diesel and electrically operated shallow tubewell irrigation projects in Tangail district. Report No. 17, Bureau of Socioeconomic Research and Training, Bangladesh Agricultural University, Mymensingh, December 1989.

Miah, M.T.H and Hardaker, J.B. (1988), "Benefit-cost analysis of deep and shallow tubewell projects in the Tangail district in Bangladesh", Bangladesh Journal of Agricultural Economics, 11(1): 1-29.

Miah, M.T.H. and Mandal, M.A.S. (1993), Economics of minor irrigation projects: a case of four regions of Bangladesh, In M.R. Biswas and M.A.S. Mandal (eds.), Irrigation Management for Crop Diversification in Bangladesh. University Press, Dhaka, 152-165.

Micheal, A.M. and Khepar, S.D. (1992), Water well and pump engineering. Tata McGraw-Hill Publishing Company Limited, New Delhi.

MOA (1998), National Minor Irrigation Census 1996/97. National Minor Irrigation Development Project. Sir William Halcrow & Partners Ltd DHV Consultants BV.

MOA (2007), Minor Irrigation Survey Report 2006/07. Survey & Monitoring Project for Development of Minor Irrigation. Bangladesh Agricultural Development Corporation.

Mujibullah, M. (1987), A comparative study of deep tube well irrigation performance under different organizations and management practices in some selected areas of Gazipur district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Palmer-Jones, R. (2001), Irrigation service market in Bangladesh: Private provision of local public goods and community regulation, paper presented in Worksop on managing common resources at the department of Sociology, Lund University, Sweden.

Paul, S. (1998), Financial evaluation of force mode tube well in some selected areas of Mymensingh district, MS Ag. Econ Thesis, Bangladesh Agricultural University, Mymensingh

Petty, J.A., Zavaleta, L., Hardin, D.C., Condra, G.D. and Lacewell, R.D. (1978), The Impact of Energy Shortage and Cost on Irrigation for the High Plains and Trans Pecos Regions of Texas. Technical and Special Reports, Texas Water Resources Institute.

Planning Commission (1999), The Fifth Five Year Plan 1997/2002, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Rahman, M.S. (1997), Optimization of shallow tube well owners income in a selected area of Tangail district, MS Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Rahman, M (1998), An economic study of multiple uses of power tiller in an area of Mymensingh District of Bangladesh. M.S. Thesis, Department of Agricultural Economic Bangladesh Agricultural University, Mymensingh

Rahman, R. (2000), Economics of BR-29 *Boro* paddy production of Melandah Uazila of Jamalpur district, MS Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Rahman, S.M and Takeda, J. (2004), Measuring the cost of production of rice in Bangladesh with special reference to irrigation water. Bulletin of the Faculty of Agriculture, Saga University. 2004, (89): 55-70.

Rao, D.S.K. (1996), Treadle pumps: boon to marginal farmers, World Agricultural Economics and Rural Sociology Abstract 1996, 38(8).

Rashid, H, (1993), A comparative analysis of deep tubewells with buried pipe and deep tubewells with open channel irrigation system in a selected area of Shakhipur Thana of Tangail district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Rogers, P., Lydon, P. and Seckler, D. (1989), Eastern Water Study Strategies to Mange Flood and Drought in the Brahmaputra Basin. Irrigation Support project fro Asia and the Near East, Sponsored by the United States Agency for International Development (USAID).

Samad, M. and Vermillion, D. (1999), An assessment of the impact of participatory irrigation management in Sri Lanka. International Journal of Water Resources Development,15(1/2): 219-240.

Samuelson, P.A. and Nordhaus, W.D. (1995), Economics, 15th edition, Mc Graw Hill., New York.

Sarker, R.K. (1992), An economic analysis of tradle pump irrigation for HYV *Boro* producrion in a selected area of Bangladesh, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Sarker, F.I.M.G.W. and Lingard, J. (2001), An optimal cropping plan for farmers in a shallow tubewell irrigated area in Bangladesh. Bangladesh Journal of Agricultural Economics, 24(1/2): 39-55.

Sarwer, R.H., Rahman, W., Ahmed, R., Alauddin, M. and Sharmin. A (2008), Shallow Tubewell Irrigation Business in Bangladesh. A Field Study in Dighalkandi Union under Ghatail Upazila of Tangail District, 2008,A Research Report Submitted to IWMI, India.

Sattar, M.A., Maniruzzaman and Golam, F.I.M. (2002), Technical Economic Performance of Alternative Irrigation Distribution Systems for Promoting rural Development Through Go-NGO Partnership, Paper Presented in the Regional Conference of BAEA-IAAE, Dhaka, 2-4 October 2002.

Shah, (1989), “Efficience and Equity Impacts for Ground Water Markets; A Review of Issues, Evidence and Polices”, Institute of Rural Management, Anand 388001, India, November.

Shikder, P.K. (1986), A comparative economic study of private and rented deep tubewells in some selected areas of Mymensingh and Tangail district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Siddique, S. (1999), An economic analysis of fish seed multiplication farm in some selected areas of Bangladesh, MS Ag. Econ, Bangladesh Agricultural University, Mymensingh.

Sinha, A.K. (1978), Impact of lift irrigation on cropping pattern and crop yields based on a five village survey in Haryana, Indian Journal of Agricultural Economics, 33(2): 77-92.

Tushaar, S., Scott, C. Kishore, A. and Sharma, A. (2003), Energy-irrigation nexus in South Asia: improving groundwater conservation and power sector viability. Research Report, International Water Management Institute. 2003; (70).

Uddin, M.Z. (1992), An evaluation of minor irrigation projects of Tangail district considering different systems of payment for water, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

Wichelns, D., Cone, D. and Stuhr, G. (2002), Evaluating the impact of irrigation and drainage policies on agricultural sustainability. Irrigation and Drainage Systems. 2002; 16(1): 1-14.

World Bank and FAO (1989), "Bangladesh Hand Tubewells 11 Projects Preparation Mission" Report of World Bank/FAO Project Investment Centre.

Yang, W.Y. (1962), Methods of Farm Management Investigations for Improving Farm Productivity, Food and Agricultural Organization of the United Nations, Rome.

Zahid, A. (2006), Development of Groundwater in the Lower Gangetic Plain of Bangladesh. The Impact of Shallow Tubewells on Irrigation Water Availability, Access, Crop Productivity and Farmer's Income.

Zahid, A., and Ahmed, S.R.U. (2005), Groundwater Resources Development in Bangladesh: Contribution to irrigation for Food Security and Constraints to Sustainability. Groundwater Governance in Asia Series-1, 25-46.

Zaman, M. (2002), Resource productivity and adoption of modern technology by tenancy: A study of HYV *Boro* productivity in a selected area of Dinajpur district, M.Sc. Ag. Econ. thesis, Bangladesh Agricultural University, Mymensingh.

.