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Shallow Tubewell Irrigation System in Bangladesh: Perspective Structure, Management and Performance

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SHALLOW TUBEWELL IRRIGATION SYSTEM IN BANGLADESH: PERSPECTIVE STRUCTURE, MANAGEMENT AND PERFORMANCE

SUBMITTED BY

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Abbreviations and Acronyms

Acre	: Land measuring unit (100 decimals= 1 acre)
Aman rice	: Non-irrigated Paddy (Wet season paddy)
BBS	: Bangladesh Bureau of Statistics
BCR	: Benefit Cost Ratio
BDT	: Bangladeshi Taka (currency)
BER	: Bangladesh Economic Review
BHP	: Brake Horse Power
Beel	: Wetland (Natural store of water in low land)
Boro rice	: Irrigated paddy (Winter and dry season paddy)
BWDB	: Bangladesh Water Development Board
CEGIS	: Centre for Environmental and Geographic Information Services
DTM	: Digital Terrain Model
DLRS	: Department of Land Survey and Records
DOS	: Diesel Operated Shallow Tube Well
DTW	: Deep Tube Well
EOS	: Electric Operated Shallow Tube Well
FGD	: Focused Group Discussion
ft	: Feet (Length measuring unit in British system)
GBM	: Ganges-Brahmaputra-Meghna
GM	: Gross Margin
GPS	: Global Positioning System
Gusthi	: Lineage
GW	: Groundwater
ha	: Hectare [Land measuring unit (1 Hectare = 247 decimals or 10,000 m2)]
Hat/Bazar	: Local market place
HP	: Horse Power
IIMI	: International Irrigation Management Institute
IRR	: Internal Rate of Return
IRS	: Indian Remote Sensing Satellite
LISS	: Linear Imaging and Self Scanning
LP	: Land Productivity
m	: Meter (Length measuring unit in SI system)
Maund	: Weight measuring unit (1 Maund = 37.32 kilograms)
Mauza	: Smallest revenue boundary in Bangladesh (similar to village)
MP	: Murate of Potash
MV	: Modern Variety
NPV	: Net Present Value
NWRD	: National Water Resources Database
O & M	: Operation and Maintenance
PDB	: Power Development Board
RADAR	: Radio Detection and Ranging
RPM	: Revolution Per Minute
Salish	: Legitimate
Samaj	: Village Community
SAR	: Synthetic Aperture Radar
SFC	: Specific Fuel Consumption
STW	: Shallow Tube Well
Tk.	: Taka (Bangladeshi currency)
TSP	: Triple Super Phosphate
TA27	: ID use for static water level observation well of BWDB; TA stands for Tangail
TA38	: ID use for static water level observation well of BWDB; TA stands for Tangail
WL	: Water Level
WP	: Water Productivity

ABSTRACT

Shallow Tube Well (STW) irrigation system in Bangladesh reduces the uncertainty of variable rainfall patterns for rice production. The application of groundwater irrigation by STW technology increased with the introduction of High Yielding Variety (HYV) seeds to meet the food requirements of a growing population. STW irrigation system has utmost importance for food production and food security and ultimately raises the income of farming households and enables them to attain a better quality of life. That's why, the present study was undertaken to introduce structure, management and performance of STW irrigation technology. The objectives of this study were to acquire an integrated understanding of the structure of STW irrigation, to examine the management system of STW irrigation business, to understand the profitability both for STW owner and irrigators (water buyer) and to draw recommendations for sustainability and cost-effective STW irrigation business as well as Boro rice production for the coming future.

Field survey and different field measurements were carried out in Dighalkandi Union (covering five mouza) under Ghatail Thana of Tangail District during Boro (winter, irrigated) season in 2016 and 2017. Both STW owners and irrigators were chosen as samples for this study and they were surveyed through two sets of questionnaire. Complete survey technique was used for the STW owners. A total of 50 STW owners were found in the study area operating their STW irrigation business. Out of 50 STW owners, Diesel Operated STW (DOS) owners were 2 and Electric Operated STW (EOS) owners were 48. To assess the performance of business in both cases, two-stage stratified random sampling technique was used to collect data from the irrigators. Firstly, 12 STW owners were selected randomly from all and then five water buyers were also randomly chosen from each of the selected 12 STWs. So a total of 110 samples (50 STW owners, 10 DOS irrigators and 50 EOS irrigators) were used for this study. Selected 12 STW schemes performances were evaluated using some standard hydraulic, agricultural and socio-economic indicators.

The study revealed that the study area was suitable for Boro rice cultivation using groundwater by STW irrigation due to its geographical and physical features such as water bodies, rainfall, land type category, soil type, topography, lithology, aquifer characteristics and groundwater availability and suitability. At present electric operated STW (EOS) was mainly used in the study area for groundwater abstraction. In 2017, diesel operated STW (DOS) were 4% and EOS were 96% in the study area. Last 10 years DOS has been decreased and EOS has been increased 40% respectively in the study area.

The study findings showed that belonging wide ranges power of engines or motors were found in use in the study area and most of the engines were Chinese and Japanese. Pump discharge, water productivity and land productivity of both engines (diesel and electric motor) considering same as BHP were little bit similar. The performances of selected 12 STW schemes were performing better than in the past. There was almost trapezoidal characteristic of channel and all field channels were Kutccha in the study area. There was scope for improvement of channel dimension to save land as well as water losses by reducing width of distribution channel. The research findings showed that mis-match among different parameters of STWs were observed in the study area and this overall mis-match mainly occurred due to lack of technical knowledge and information of the STW owner, mechanics, farmer, equipment traders and installers.

The data showed that the majority of the STW owners (60 percent) run their management activities through partnership arrangement and 40 percent STW owners run by single ownership. The management of STW operation by partnership was found to be more efficient compared to management by single owners. Also data revealed that a majority (57 percent) of the owners was found to possess higher social statuses who actively engage in local social institutions.

The STW irrigation business was reasonable profitable at the current (2017) price of input cost and output return, but this business will become unprofitable for DOS in uncertain situation considering 10 percent increasing of O & M cost or 10 percent decreasing of benefit or 10 percent increasing of diesel price. The EOS was more profitable than DOS due to increasing of diesel price and lower electric charges compared to fuel and lubricant cost and coverage of higher command area by EOS. Boro rice production was higher profitable when farmers grown it in his own land with family labor. In this case, returns to family labour were US$ 6.41 (Tk. 500) and US$ 7.17 (Tk. 560) per man-day considering the year 2016 and 2017 respectively, which was quite higher the then normal wage. When all inputs including land and labor are hired, Boro rice production was not profitable. In cases of all inputs hired except labor, Boro rice production was reasonably profitable and all inputs hired except land, Boro rice production was marginal profitable to the farmers.

Boro rice production was a competitive business in rural market and was strongly able to compete with other business. Boro rice production has great importance for the socio-economic development of Bangladesh due to its suitability and sustainability. This study recommended that STW irrigation business and Boro rice production could be made profitable with proper management of input cost and output price, effective use of the system and improving the management practices of soil, water and crop.

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Statement of Authorship

"Except where reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

No other person's work has been used without due acknowledgements in the main text of the thesis.

This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution".

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CERTIFICATE

Certified that this thesis entitled "**SHALLOW TUBEWELL IRRIGATION SYSTEM IN BANGLADESH: PERSPECTIVE STRUCTURE, MANAGEMENT AND PERFORMANCE"** is a record of research work done independently by **Mr. Md. Alauddin Hossain** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Prof. Dr. Md. Toufiq Iqbal
Supervisor

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"The Authour"

DEDICATED

TO

THE MEMORY OF MY BELOVED FATHER

LATE ALHAJ MD. MOZIBAR RAHMAN

AND BELOVED MOTHER LATE ALEYA

KHATUN

Chapter 1

GENERAL INTRODUCTION

Chapter 1

GENERAL INTRODUCTION

1.1 BRIEF INTRODUCTION

Bangladesh is located in the low lying delta of one the world's largest and three mighty river systems the Ganges, the Brahmmaputra and the Meghna (GBM) and is subjected to alternating annual periods of extreme excesses and deficits of water. It is situated between 88°10' and 90°40' east longitude and between 20°34' and 26°38' north latitude. Bangladesh has plenty of water but its uneven distribution, over abundance in monsoon often causes catastrophic floods and scarcity in dry season causes severe drought conditions leading to loss of crops, livestock, fisheries, public health problems and environmental degradation (Banglapedia, 2015).

Rice is the main and staple food of Bangladeshi people that constituted about 90% of the total food grain production in Bangladesh (Huda, 2001). Of the three types of rice *aus*[1], *aman*[2] and *boro*[3], the *Boro* rice alone contributed the highest share (55%) of total rice production since 1998-99 to till now (BER, 2015). Boro rice is the main irrigable crop in Bangladesh. About 80 percent of groundwater was used for crop production in which *Boro* paddy consumed 73 percent of total irrigation (Rahman and Ahmed, 2008). Groundwater contributes to 80 percent of total irrigated area and STWs coverage about 62% of total irrigated area in Bangladesh (BADC, 2013). Boro rice is produced under completely irrigated condition in dry season. So, it can be said that increase of *Boro* rice production through STW irrigation can be a significant possible way to overcome food deficiency as well as ensuring food security in Bangladesh. Irrigation plays a critical role in Bangladesh through increasing the yield and cropping intensity (Abu Sayed *et al*., 2014). Over the years, the proportion of irrigated area based on groundwater has changed significantly. It is estimated that, out of 9.03 million ha of total cultivable area, 7.56 million ha (84 %) are suitable land for irrigation (Shahabuddin and Rahman 1998). To meet up the different requirements of growing population, the using of agricultural land for the non-agricultural purpose has been increased a large extent. As a result, total cultivable land of the country has been reached to 8.50 million ha and approximately 7.41 million ha (87%) land is under irrigation (BBS, 2015). As STW irrigation is the only system/technology for further intensification of agriculture, its rational use should be ensured with sustainability in relation to the profitability. Therefore, exists for future expansion of irrigation that depends on available technological options and their economic and social viability in exploiting surface water and groundwater.

[1] Mostly rain fed rice
[2] Mostly rain fed rice
[3] Irrigated rice

1.2 BACKGROUND OF THE STUDY

Bangladesh is a home of 160 million people and it is the largest delta in the world. It has fertile agricultural land and abundant water in the wet season but limited water in dry season. It is the most densely populated country in the world suffered from food deficiency for a long time and it was the major challenge of government since liberation up to 1990s decade, because of increasing food grain production to meet up the growing population demand. According to Rahman and Parvin (2009), Bangladesh has made impressive progress in agriculture sector in the last three decades and has almost become self-sufficient in food grain production. This is a tremendous achievement owing to its small territory and huge population and this was achieved through agricultural mechanization and modernization. Irrigation is one of the leading inputs has direct influence to increase yield, food grains production and plays vital role for ensuring food security in Bangladesh (Rahman and Parvin, 2009). The economy of the country is dominated by agriculture and the livelihoods of the farmers are largely connected with intensive agriculture production. Food grain occupies the lion’s share of agricultural GDP and it employs about 60% of total labour force (Alam *et al*., 2008). Hence, any internal and external threat (social, political, natural and environmental) to agriculture directly affects food grain production as well as food security of the country.

Boro rice is produced in Rabi season (October to March) which grows completely under irrigated condition. Thus, irrigation availability and irrigation technologies / facilities are playing a vital role in this regard. Moreover, intensive land use is directly related with availability of irrigation system to the farmers in Bangladesh. Groundwater access has increased a great extent which enhanced the farmers’ productivity. Therefore, developments of irrigation systems are the crucial issue for sustainable Boro rice production in Bangladesh.

There was a tube well sitting regulation that required obtaining government permission for sinking irrigation wells up to 1992 in Bangladesh. Up to 1992 there was 0.389 million STW used for irrigating 1.392 million ha land, but when government suspended the sitting regulations and selling of STW was handed over to the private sector at the end in 1992, as a result in 2006, 1.129 million STWs were used to irrigate 3.160 million ha of land. During the last 13 years (from 1992 to 2006) the irrigation scenario in Bangladesh has changed with more use of ground water and the number of STW has increased many times (MoA, 2006). Groundwater contributes to 80 percent of total irrigated area and STWs coverage about 62% of total irrigated area in Bangladesh (BBS, 2008). The total irrigation coverage was increased 1726 to 5898 thousand hectare within the period of 1981-82 to 2006-2007 (242 per cent) whereas irrigation potential is estimated at 7550 thousand hectares (Ernest, 2007). There is still possibility to expand 22 percent of irrigated area according to irrigation potentiality.

About 80 percent of groundwater was used for crop production in which *Boro* paddy consumed 73 percent of total irrigation (Rahman and Ahmed, 2008). *Boro* rice production contributes to 55% of the total rice production (BBS, 2007). The application of groundwater irrigation as well as STW irrigation increased with the introduction of High Yielding Variety (HYV) seeds to meet the food requirements of a growing population (BER, 2006). The yield potential of the existing HYV rice is more than 4 MT/ha, whereas the average yield realized by the majority of farmers is less than 3.0 MT/ha (Talukder, 2008). Thus, on farm research is important to reduce the production gap. In addition groundwater based irrigation as well as STW irrigation economy is crucial for increasing domestic production with sustainability, attaining food security and lifting millions of poor farmers out of poverty. Hence, this research study intends to acquire an integrated understanding of the structure of STW irrigation system, to examine the management issues of STW irrigation business, to understand the profitability Boro rice production both for STW owner and irrigators (water buyer) and also to draw recommendations for sustainability and cost-effective STW irrigation business as well as Boro rice production for the coming future.

1.3 RATIONALE OF THE STUDY

Water scarcity and the high cost of surface irrigation have encouraged exploitation of groundwater for irrigation to enhance crop productivity, cropping intensity, and ultimately raise the incomes of farming households and enable them to attain a better quality of life. The expansion of the groundwater irrigated areas in Bangladesh has been based largely on the use of STWs, rather than Deep Tube Wells. STWs are more appealing to small and medium-scale farmers than Deep Tube Wells or surface irrigation due to comparatively low capital investment requirements and suitability for small-scale operations. Concerns have been raised globally over the risk of depleting groundwater resources in response to potentially unsustainable public demand by extracting water faster than aquifers can recharge. Another issue has been the high energy cost of groundwater extraction due to its diesel and electricity requirements. For the farmers in Bangladesh, due to good aquifers in many locations, STWs are an attractive option in the absence of surface irrigation schemes and because of the much higher cost of Deep Tube Wells. However, the absence of reliable supplies of both diesel and electricity for STW irrigation has become a real problem that has substantially constrained investments and hurt crop performance, particularly when STW pumps cannot operate due to blackouts or fuel shortages at critical stages of crop production.

Bangladesh is an agricultural country. The economical development of Bangladesh depends on the agricultural development of Bangladesh. Different types of irrigation technologies are being used in Bangladesh but the extent of success varies due to facilities of technology (fuel consumption, engine efficiency, tackle to handle etc.) and availability of groundwater. Two types of irrigation equipment such as Shallow Tube Well (STW) and Deep Tube Well (DTW) are mainly used for groundwater abstraction, where 60% areas of total irrigated area are covered by STW (BADC 2013). Coverage of STWs irrigation areas increased by about 17% during 6 years from 2000-2001 to 2005-2006 (BER 2006). So, it can be said that most of the irrigation system in Bangladesh mainly depends on STWs. These STWs are operated by diesel and electricity. Number of electricity operated STWs have been increasing due to upward trend of diesel price and expansion of rural electrification (Rahman *et al*., 2011).

It is noticed that in the beginning of privatization STW irrigation system, the farmers used STW singly to irrigate their own land. Following over time, farmers used STW jointly to irrigate their own land. Consequently, they also sell water to other farmers. It was reported that farmers sell water commercially to earn profit like in other businesses (Zahid and Ahmed, 2005). Following the process of time, STW irrigation development has been established as a form of business in rural Bangladesh which ensures food security, livelihood and poverty alleviation as well as economic development of the country. Therefore, sustaining the groundwater markets and a growing groundwater-based irrigation economy is critical for food security as well as for lifting millions of poor farmers out of poverty (Zahid and Ahmed, 2005). In changing situation over time some issues (structure, management and technical and economical performance of STW irrigation business) regarding groundwater irrigation / abstraction by STWs need to be understood well in order to improve the irrigation technology sustainability and cost effective in Bangladesh. That's why “Shallow Tube Well Irrigation System in Bangladesh: Perspective Structure, Management and Performance” was selected as a study title. In this regard, the following key issues were addressed for the study.

1.4 RESEARCH QUESTIONS OF THE STUDY

This study will answer the following questions:

1) How profitable is irrigation system from STW owners' point of view in the increasing energy price regime?
2) How profitable is Boro rice production under STW irrigation in a changing input- output price regime?
3) What are the socio-economic profiles of STW owners and how they perform their managerial functions?
4) How performing the STW equipments based on some selected standard hydraulic, agricultural and socio-economic indicators?
5) Why do some STW owners have business partners, while others don’t have and what are the specific function/contributions of the partners?
6) How the indigenous local institutions i.e. samaj (village community), shalish (litigation), family lineage and relationship, etc. regulate operation of STWs in a competitive local environment and how the conflicting business interests are mitigated?
7) What are the coping strategies of STW owners to adjust the increasing prices of diesel and electricity?
8) What sorts of policies/guidelines/recommendations are needed for increasing sustainability of groundwater irrigation by STWs for future?

9) What adjustments/measures to be taken by the government to support STW owner and farmer for improving productivity in the public sector?

1.5 OBJECTIVES OF THE STUDY

Keeping in mind the above-cited issues, the study was undertaken with the following specific objectives:

a) To understand the socio-economic and agro-ecological characteristics of irrigated area;
b) To assess the suitability of Shallow Tube Well for irrigation in the study area;
c) To examine the structure, management and performance of STW irrigation technology;
d) To estimate and examine cost and return / benefit from STW irrigation system both for the farmer's (water buyer) and STW owner's;
e) To compare and identify the suitability of type of energy either diesel operated STW (DOS) or electric operated STW (EOS) to abstract groundwater for irrigation purpose;
f) To evaluate the performance of STW irrigation system using some performance indicators;
g) To draw recommendations for improving of water selling business through STW irrigation system and Boro rice production for future.

1.6 HYPOTHESIS OF THE STUDY

To achieve the above mentioned objectives, the following hypotheses were formulated:

a) The subsurface profile of the study area (i.e. lithology, aquifer and groundwater availability) is suitable for STW irrigation.
b) STW irrigation technology is profitable both for STW owners and farmers (water buyer).
c) Indigenous village institutions play a crucial role in STW command area management.
d) Mismatch among STW equipments interrupt irrigation efficiency.
e) STW irrigation technology is sustainable in the perspective of Bangladesh agriculture.

Chapter 2

LITERATURE REVIEW

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

Irrigation is the application of water to the dry agricultural land for crop production by means of dams, barrages, channels, or any other devices. Irrigation reduces the uncertainty of variable rainfall patterns for crop production. Irrigation has been practiced for thousands of years, mainly in regions with annual rainfall of less than 500 mm, including many countries of Africa, Asia and America (Banglapedia, 2015). Before starting irrigation, i.e. ancient time peoples depend on rain fed agriculture, i.e. peoples depend on nature. In this chapter, an attempt was made to review the research activities done in Bangladesh regarding the minor irrigation system specially STW irrigation system in rural Bangladesh. Through this attempt it was tried to get information about STW irrigation system such as structure, management, performance, profitability and sustainability. For the future utilization strategies of the STW irrigation system should be based on the detailed information generated at present and in the past. For this research study a number of journals, proceedings and recent publications regarding STW irrigation system were reviewed thoroughly, so that there is no occurred repetition which is already studied in the past. The available literature on Shallow Tube Well revealed that a good number of research works had been carried out in the past. Some of these studies have been illustrated below:

2.2 HISTORY OF MINOR IRRIGATION SYSTEM IN BANGLADESH

Systematic irrigation in Bangladesh started at early 1960s with the introduction of deep tube wells and low-lift pumps. Shallow Tube wells came into operation after 1980 (Banglapedia, 2003). Before that period (1960s), i.e. in 1950s farmers used to grow crops under rainfed conditions and traditional or local method for manual water lifting devices such as doons (open-ended, canoe-like devices) and swing baskets drawing on surface water sources as well as dug wells to tap shallow groundwater aquifers and managed individually. However, public sector was institutionalized to modernize irrigation with the creation of the Bangladesh Water development Board (BWDB) in 1959 and the Bangladesh Agricultural Development Corporation (BADC) in 1961.

BWDB was primarily involved in developing canal irrigation projects but during 1962-68, it launched a tube well project in the north-western part of Bangladesh using 380 four-cusec DTWs. For the project agency initiated electricity generation, pump operation and water distribution to farmers' fields. The project was heavily subsidized and bureaucratically managed and performed very poorly in terms of pump capacity utilization, irrigation coverage, water management, O & M and cost recovery from water users (GOB and FAO/UNDP 1977; Hamid et al. 1978; Bottrall 1983).

BADC first entered minor irrigation through a low lift pump (LLP) system in 1961 and a DTW program the following year. The LLPs were initially operated by BADC's own field staff with diesel fuel supplied by the agency and the farmers being required to pay water fees on a unit area basis. In 1969, BADC started renting the LLPs on a yearly basis and the farmers had to pay for fuel. The DTW program began with 200 two-cusec wells in the Comilla area between 1962 and 1970. These DTWs were about 75 percent subsidized, were much less expensive than the earlier BWDB wells, and were rented to farmers cooperatives (KSSs). BADC supplied fuel/oil and the Integrated Rural Development Program (IRDP) organized the cooperatives. These BADC DTWs did have a better performance than the BWDB ones in terms of yield and cost recovery but well capacity were still seriously underutilized (Alam, 1975).

After Bangladesh's liberation war in 1971, BADC expanded its LLP and DTW rental programs and started to include STW rentals in the early 1970s. The STW rental program was converted to a sales program after 1974-75. A process of minor irrigation sector privatization, however, began in the late 1970s. Since that time, a number of policies have been instituted which have had the effect of pulling back the government involvement in minor irrigation support and boosting the scope of activity of the private sector (Mandal and Parker, 1995).

2.3 TYPES OF IRRIGATION SYSTEM IN BANGLADESH

According to Chowdhury (2012), there are five types of irrigation systems in Bangladesh and these are 1) traditional or local method, 2) canal irrigation project of the government, 3) low lift pump, 4) Shallow Tube Well and 5) Deep Tube Well. When surface water was abundant, farmers solely depended on rivers, canals and ponds to irrigate their fields with traditional local methods and where irrigation cost were involved with labor charge only. With the growing population and the introduction of high yielding varieties of rice, the government built huge surface water irrigation projects (canal irrigation project) to take care of dry season irrigation. The cost of irrigation became the maintenance of the field channels from the tertiary outlets to the farmers' fields. With the scarcity of surface water in the rivers and canals and advent / initiation of groundwater irrigation, farmers started paying for pumping water which consists of maintenance of the pumps, fuel cost (electricity or diesel) and the salary of the pump mechanic if required. Farmers use low lift pump to pump water from surface water sources and shallow or Deep Tube Wells for groundwater which are known as minor irrigation devices. The use of low lift pump is limited by the availability of surface water in the canals and rivers during the dry season.

2.4 SOURCES OF IRRIGATION WATER IN BANGLADESH

Surface water and groundwater are major sources of irrigation in Bangladesh (Rahman and Parvin, 2009). River water, canal water, pond water and low land water (Beel, haor, baor, gang) are considered as surface water and subsurface water is considered as groundwater in Bangladesh. Low Lift pump (LLP), Canal and Traditional (Dhone and Swing basket) are used as a means of technology for surface water irrigation while Deep Tube Wells (DTW)[1], Shallow Tube Wells (STW)[2] and Hand Tube Wells are used for groundwater irrigation.

2.5 COMPARISON BETWEEN STW AND DTW IN BANGLADESH PERSPECTIVE

Before 1970s, irrigation was mainly dependent on surface sources and in the mid-seventies government emphasized on groundwater irrigation with DTW projects. But government soon shifted to STW because of it's suitability to socio-economic status of the farmers, due to less investment cost, small land holdings, availability in the market, withdrawing restriction on import and STWs spacing (Rahman and Parvin, 2009). Biswas and Mandal (1993) concluded that the overall conveyance efficiency of STWs projects is less than 70% and the efficiency of STWs is better than DTWs. Most Deep Tube Wells are government owned and maintained by the public authority. The rest are run on a cooperative or joint ownership. Since investment in Deep Tube Well is lumpy in nature, farmers prefer Shallow Tube Wells irrigation system in a great extent (Chowdhury, 2012).

2.6 COMPARISON BETWEEN DOS AND EOS USED IN BANGLADESH

Miah (1989) conducted a study on comparative performance of engine operated STW (DOS) and electrically operated STW (EOS) irrigation project in Tangail district. He found that the participating farmers were earning profits from HYV Boro cultivation and both electrically and engine operated STW project were profitable from the view point of management as well as the economy as a whole. Paul and Gupta (1997) recommended that all Shallow Tube Well (STW) irrigation schemes are profitable (except in sandy loam soil). It was a case study, which was conducted in the Tangail district of Bangladesh. Miah and Mandal (1993) made a financial analysis of STW projects in Ghatail of Tangail district. They calculated that the benefit cost ratio ranged from 1.30 to 1.51 for 20 percent and 25 percent crop share respectively.

2.7 REASONS FOR FAILURE OF DTW IRRIGATION PROJECT IN BANGLADESH

Morton (1994) found that the reasons for poor performance of the deep tube well may be grouped into five separates areas: (i) Poor technical performance of the tube well, (ii) Social barriers, (iii) Mode of operation (iv) The land class, and (v) Economics. Main technical reasons of the well were aquifer problems, poor well design, poor construction and maintenance, and slow engine running speed. Social Barriers were the wide spread factional conflicts among the farmers. The conflicting interests and relationships between large and small farmers who typically come to control water supplies often lead to failure of co-operation. Economic factors were subsidy on the capital cost of tube well and other mechanical irrigation equipment. Islam et

[1] The discharge capacity of Deep Tube Wells are about 50 lt/sec having greater depths (up to 100-120m) and larger diameter compared to shallow wells

[2] Shallow Tube Wells are small irrigation wells having discharge capacities of 12-15 lt/sec with maximum depths of 40-60m and well diameter of 100-150mm.

al., (2004) reported that some farmers often use pond water for irrigation purpose being as DTW is very expensive to install. So, large portion of irrigation water comes from STWs in dry season.

Mandal and Parker (1995) stated that the start and early growth of minor irrigation (especially DTW) relied heavily on public agency action and support. While the public sector never actually operated more than a small number of pumps schemes, agencies have until very recently been variously (and often deeply) involved in the procurement, distribution, installation and maintenance of irrigation equipment as well as in the supply of fuel / oil and spare parts.

2.8 POOR WATER MANAGEMENT IN BANGLADESH IRRIGATION SYSTEM

Dutta and Mandal (1985) reported from case studies of landless group controlled irrigation projects that water loss per 100 meters length of the canal could rise from 12 to 30 percent of the pump discharge. They also reported that the seepage and percolation water loss in the earthen canals is not only due to seepage and percolation but most of it occurs through cracks, holes and bank overflow. Khair and Hossain (1978) and Khair et al., (1980) observed that about one fourth to one third of irrigation water in Bangladesh is lost in conveyance through the unlined earthen channels where seepage accounts to high rates due to various socio-technical reasons. Michael (1978) reported that seepage rate depends on wetted perimeter of the channel and the capacity of the soil to conduct water both vertically and laterally.

Dutta (1982) found from two case studies of deep tube wells and low lift pump irrigation project located in Mymensingh district that the water loss in the main canal range from 25 to 60 percent of the total flow. He also reported that the water loss in the main channel varied from 31.65 to 65.50 percent for distances of 300 to 1400 ft channel, from 40.50 to 60.00 percent for distances of 110 to 700 ft from the source of water in Satrasia and Baira respectively.

Hasan et al., (1992) conducted a field study in two selected tube wells of North Bangladesh tube wells project to evaluate the water distribution status in relation to maximizing the command area of the tube wells. Water loss in the main canals of two tube wells were 91.0 and 52.01 $l/hr/m^2$ before repairing of the canals. Similarly, water losses in earthen canals were 105.0 and 208.0 $l/hr/m^2$ which were 8% and 9% of the outlet discharges. Total distribution losses for each tube wells were about 42% and 30%. Field data indicated that the deep tube well command area could be increased significantly through reduction of conveyance losses and improved water management practices.

2.9 SOCIO-ECONOMIC ASPECT OF STW IRRIGATION SYSTEM IN BANGLADESH

Mandal and Parker (1995) stated that minor irrigation plays a crucial role in Bangladeshi’s agriculture and therefore, in the national economy. Bangladesh is a densely populated, mostly rural country beset by endemic poverty and malnutrition and very much in need of enhanced crop production. Almost all of its 9.1 million hectares of net cultivable area, however, is already in use and any additional crop output can only come from increasing yield or cropping intensity. Methods that are available to achieve these ends depend heavily on irrigation, particularly minor irrigation technologies comprising low lift pumps (LLPs), deep tube wells (DTWs), Shallow Tube Wells (STWs) and manually operated pumps (MOPs), which together are responsible for 80 percent of irrigation coverage in the country.

Alam, (1989) conducted a study regarding different socio-economic indicators of tube well irrigation in the rural areas of Bangladesh and synthesized the results of a number of empirical investigations into an overall picture. A variety of socio-economic indicators such as capacity utilization of a tube well, productivity, employment and wage rate, net return, price and subsidy, tube well distribution and privatization policy, institutional arrangements, progress in the sale of equipment, distribution of rural income and choice of technology are examined in this study. The author concluded that there is an urgent need to encourage and restructure the cooperative management of equipment for the efficient utilization of tube wells.

2.10 MODE OF PAYMENT IN STW IRRIGATION SYSTEM IN BANGLADESH

Rahman et al., (2015) conducted a study and focus group discussions (FGDs) at 96 villages in Bangladesh and identified root level information regarding irrigation and its mode of payment. Irrigated land, especially rice land, has increased remarkably in Khulna and Rangpur divisions. There are plenty sources of clear water in the villages, however it has been observed that quality of water worsens over the period of time from clear to cloudy and reddish color. Due to tremendous increase in numbers of STW, DTW command area decreases and command area under STW decreases with the significant increase in the number of machine owners. It implies the suitability of STW as farmers' friendly irrigation technology. Owners' land increases and buyers' land decreases, which indicate that more farmers have more opportunity to own STW. Irrigator farmers are shifting from crop share to fixed rate and two part tariff payment systems since it is economically viable for the buyers. Prices in fixed charge and two part tariff are changing over time. Using more water from underground, the depth of groundwater level is going down and problems on iron, arsenic and saline contamination are becoming a big issue in some areas. More than seventy percent farmers are taking credit from bank, money lenders and NGOs. Due to higher interest rates implemented by money lenders, farmers are getting more credit from NGOs now. In selling irrigation water, there arise some disputes due to have insufficient and irregular supply of water. Most of the disputes resolve in the village level-village council or people of the particular area resolve the problems and few of them come to legal court system. Division wise irrigation technology and efficient payment method and guidelines for price fixation of irrigation may help to reduce the use of groundwater. Observing these dramatic a structural change in water market, in addition the study is investigated to focus the determinants of water price, contract choice and dispute resolution of groundwater irrigation in rural area.

2.11RESEARCH DEVELOPMENT OF STW IRRIGATION SYSTEM IN BANGLADESH

Gopal et al., (2013) reviewed the research developments with renewable energy source water pumping systems (RESWPSs). The reported investigations are categorized into five major groups as follows: (i) solar photovoltaic water pumping systems (SPWPSs), (ii) solar thermal water pumping systems (STWPSs), (iii) wind energy water pumping systems (WEWPSs), (iv) biomass water pumping systems (BWPSs) and (v) hybrid renewable energy water pumping systems (HREWPSs). More than a hundred published articles related to RESWPSs are briefly reviewed. Additionally, the limitations with RESWPSs and further research needs are described. This paper concludes that renewable energy sources (RESs) play a vital role in reducing the consumption of conventional energy sources and its environmental impacts for water pumping applications.

2.12 CONCLUDING REMARKS AND RESEARCH GAP

Although there were many studies on STW irrigation in Bangladesh but still no study was found to examine the structure, management and technical and economic performances of the STW irrigation system under the present unsubsidized conditions. Therefore, this study attempts to examine the structure, management and technical and economic performances of the STW irrigation system from the viewpoint of STW owners and farmers (water buyer / irrigators) under changing input and output price regime and uncertain situation over time. Through this study it is expected that an overall idea or picture about STW irrigation system over the country would be displayed / presented and to be investigated the access of small farmers to STW groundwater irrigation. Also this study attempts to understand whether the groundwater irrigation abstraction by STWs in order to sustain for the future or not.

Chapter 3

GENERAL APPROACHES AND METHODOLOGIES

Chapter 3

GENERAL APPROACHES AND METHODOLOGIES

3.1 INTRODUCTION

Methodology is a key part of any study or thesis. This is not quite the same as 'methods'. The methodology describes the broad philosophical underpinning to any chosen research methods, including whether it is using qualitative or quantitative methods, or a mixture of both, and why. The methods section describes the rationale for the application of specific procedures or techniques used to identify, select, and analyze information applied to understanding the research problem, thereby, allowing the reader to critically evaluate a study's overall validity and reliability. The methodology section of a research paper answers two main questions: How was the data collected or generated? And, how was it analyzed?

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

"Methodology" implies more than simply the methods what we intend to use to collect data. It is often necessary to include a consideration of the concepts and theories which underlie the methods. For instance, if we intend to highlight a specific feature of a sociological theory or test an algorithm for some aspect of information retrieval, or test the validity of a particular system, we have to show that we understand the underlying concepts of the methodology.

When we describe our methods it is necessary to state how we have addressed the research questions and/or hypotheses. The methods should be described in enough detail for the study to be replicated, or at least repeated in a similar way in another situation. Every stage should be explained and justified with clear reasons for the choice of our particular methods and materials.

3.2 APPROACHES

3.2.1 Selection of study title

"Shallow Tube Well Irrigation System in Bangladesh: Perspective Structure, Management and Performance" was selected as a study title. Eighty percent (80%) people live in rural area of Bangladesh and their livelihood based on agriculture. Agriculture is the main source of income of the rural people. The study title is relatively associated with the agriculture**.** That's why this study title was selected.

3.2.2 Selection of study area

Five adjacent villages (mauzas) were selected for the study area in which the entire irrigation system mainly depends on Shallow Tube Well (STW) irrigation technology. The name of mauzas were Kagmari Beltail, Saitapara, Kurmushi, Kaijalipur and Shekhsimul of Dighalkandi Union under Ghatail Upazila, Tangail district of Bangladesh.

3.2.3 Rationale of selecting the study area

The site of the study area was chosen as an intensively irrigated area in the central part of Bangladesh, which falls in the middle part of Indo-Gangetic basin region. Agriculture is the main source of income of this study area and Boro rice is the main crop of this area, which is cultivated in winter / dry season by Shallow Tube Well (STW) groundwater irrigation. Entire irrigation system of these areas mainly depends on STWs. Following the time, Boro rice cultivation as well as STW irrigation system has been raised up in this study area. So, the development of this area depends on the development of Boro rice cultivation as well as development of STW irrigation system. Considering these the area was selected for this study.

Further, Bangladesh is a land of rivers and it is flood prone country. The study area is medium highland category, which means the area inundated at least 30 to 90 cm by flood even in normal flood condition. The average annual rainfall of the study area is about 1750 to 2000 mm. Amount of rainfall, land type and flood water showed that there are many source of surface water that can contribute the groundwater table to recharge every year and Boro rice cultivation by STW irrigation might be suitable for the study area. This was also considered for selecting the study areas.

3.3 METHODOLOGIES

3.3.1 Sampling techniques and sample size

Field survey and different field measurements were carried out in Dighalkandi Union under Ghatail Thana of Tangail District during Boro (winter, irrigated) season in 2016 and 2017. Both STW owners and irrigators were chosen as samples for this study and they were surveyed through two sets of questionnaire. Complete survey technique was used for the STW owners. A total of 50 STW owners were found in the study area operating their STW irrigation business. Out of 50 STW owners, Diesel Operated STW (DOS) owners were 2 and Electric Operated STW (EOS) owners were 48. To assess the performance of business in both cases, two-stage stratified random sampling technique was used to collect data from the irrigators. Firstly, 12 STW owners were selected randomly from all and then five water buyers were also randomly chosen from each of the selected 12 STWs. So a total of 110 samples (50 STW owners, 10 DOS irrigators and 50 EOS irrigators) were used for this study. Selected 12 STW schemes performances were evaluated using some standard hydraulic, agricultural and socio-economic indicators.

3.3.2 Research or survey tools

The research study was mainly based on field survey through formatted questionnaire, direct field measurement using some selected standard indicators, focused group discussion with different stake holders through checklist and secondary sources of data. The locations of STWs were identified in the field by using Global Positioning System (GPS) and plotted them on the mauza maps by GIS application. Performances of diesel operated STW (DOS) and electricity operated STW (EOS) irrigation schemes of the study area have been evaluated using some selected standard indicators, broadly classified into three groups: hydraulic, agricultural and socio-economic. For the quantitative and qualitative assessments of the indicators, field measurements and questionnaire survey of farmers and STW owners were made during the 2016 and 2017 Boro season.

3.3.3 Data collection procedure

The primary data were collected through two sets of interview schedule (structured/formatted questionnaire, attached herewith as Annexure-1, 2 in Chapter-12) from STW owners and water buyers and through direct field measurement from selected 12 STW irrigated schemes in 2016 and 2017 Boro season (January-May). Additionally focused group discussions (FGD) were conducted with rural STW/motor mechanics, drivers/operator/managers, STW installers, spare parts sellers and local workshop owners based on three sets of checklist (attached herewith as Annexure-3 in Chapter-12) in order to collect primary data.

Figure 3.1: A view of interview between investigator and a farmer

Here it is needed to mention that primary data regarding STW irrigation business such as investment cost, operation and maintenance cost (fuel / energy, driver salary, mechanics cost etc), market price of output product and regarding Boro rice production such as labor cost, tillage cost, price of seed, fertilizer, herbicide, insecticide, pesticide, water charge, rate of land rent, market price of Boro rice etc rate were collected from study area and those were verified with other different zone of the country.

The secondary data were collected from different organization like Bangladesh Water Development Board (BWDB), Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), Center for Environmental and Geographic Information Services (CEGIS), Bangladesh Agricultural Development Corporation (BADC) and Department of Land Records and Survey (DLRS). In addition different published journals, different reports, books, articles, News paper and internet were also taken as a crucial source of secondary data.

Figure 3.2: A view of interview between investigator and STW owner

3.3.4 Analytical techniques

To evaluate the hydraulic and agricultural performance of selected 12 STW irrigated schemes, different empirical formula were used in this study. To evaluate the economic performance of STW irrigation technology and Boro rice production, profitability analysis both for STW owner and water buyer (Boro rice production) were did. Production period of Boro rice was about 4 months and due to such short production period the following profit function was fitted.

$$\prod = \sum Y_i - \sum X_i$$

Where,

Π = profit (Taka/hectare)

X = Input costs (Tk/hectare)

Y = Output (Tk/hectare) and

i = number of items

Investment in STW irrigation technology is made for a long period and for this reason to estimate the profitability of STW irrigation business the project appraisal method was followed. Thus, discounted measures such as internal rate of return (IRR), benefit-cost ratio (BCR) and net present value (NPV) were used in this study. In the recent past 10 percent discount rate was usually used for financial project appraisal in Bangladesh. In this study, 10 percent discount rate was also used in the sensitivity analysis.

3.4 STATISTICAL / DATA ANALYSIS

Primary and secondary data were analysed using different simple statistical techniques (Analytical techniques, econometric techniques, Pearson co-relation test, Probit model, MS Excel and SPSS program) in a meaningful way. Findings were represented in different way (tabular form, graphically and GIS mapping) and discussed in details chapter-wise separately.

Chapter 4

GEOGRAPHIC AND PHYSICAL FEATURES EVALUATION PERSPECTIVE SHALLOW TUBE WELL IRRIGATION SYSTEM IN BANGLADESH

Chapter 4

GEOGRAPHIC AND PHYSICAL FEATURES EVALUATION PERSPECTIVE SHALLOW TUBE WELL IRRIGATION SYSTEM IN BANGLADESH

4.1 INTRODUCTION

Each place has distinctive characteristics that distinguishes it from other places is called Geographic characteristics. Geographic characteristics are divided into two categories: physical characteristics and human characteristics. Physical characteristics describe the natural environment of the place. They include physical features, weather, climate, soil, minerals, vegetation, and animal life.

Physical features in geography include bodies of water and landforms, for example, oceans, mountains, lakes, rivers, plateaus, plains, streams, hills, bays, gulfs, volcanoes, canyons, valleys and peninsulas are all various physical features. Anything that describes the Earth's topography is a physical feature.

In this chapter evaluation of geographic and physical features of the study area means has been tried to understand that how the existing condition of aquifer/lithology/stratum, what type of soil type and texture, what about rainfall, temperature, floods, agricultural land & agricultural practices, water bodies, topographic & physiographic condition, settlement, infrastructure & installation etc. of the study area.

Shallow Tube Well (STW) irrigation water is abstracted from the subsurface soil or aquifer. This subsurface water in aquifer depends on many factors, such as soil type and texture, rainfall, temperature, floods, water bodies of the surrounding area, uses of groundwater, cropping patterns, cropping intensity, agricultural practices, topographic condition, physiographic condition etc. It is recommended that when any study/project is taken any where, it is necessary to investigate physical features of the study area to understand well about for the future prediction and as well as necessary following steps to be taken if necessary. The study objective of this chapter is to focus the geographical and physical features of the study area perspective STWs irrigation for Boro rice cultivation.

4.2 APPROACHES AND METHODOLOGIES

4.2.1 Location of the Study Area

The study area was within Dighalkandi union, which is under Ghatail Upazila of Tangail district in Bangladesh. The area is situated between 24^0 24' 08.55" to 24^0 25' 17.5" North Latitude and 89^0 57' 26.84" to 89^0 59' 10.10" East Longitude. The study area comprises five Mauzas of Dighalkandi union as shown in Figure 4.1. The five Mauzas are Kagmari Beltail, Saitapara, Kurmushi, Kaijalipur and Shekh Shimul. The Mauza is revenue boundary and it is the smallest land boundary unit in Bangladesh. This Mauza map is actually cadastral map and it is similar to villages in terms of area. The total study area is about 376 hectares (DLRS, 2014 and CEGIS, 2014). The study area was chosen from an intensively irrigated area in the north central region of Bangladesh, which falls under the Indo-Gangetic basin region. Boro paddy was the main crop of this area, which cultivated in rabi season by groundwater irrigation. The entire irrigation system of the area mainly depended on STW technology.

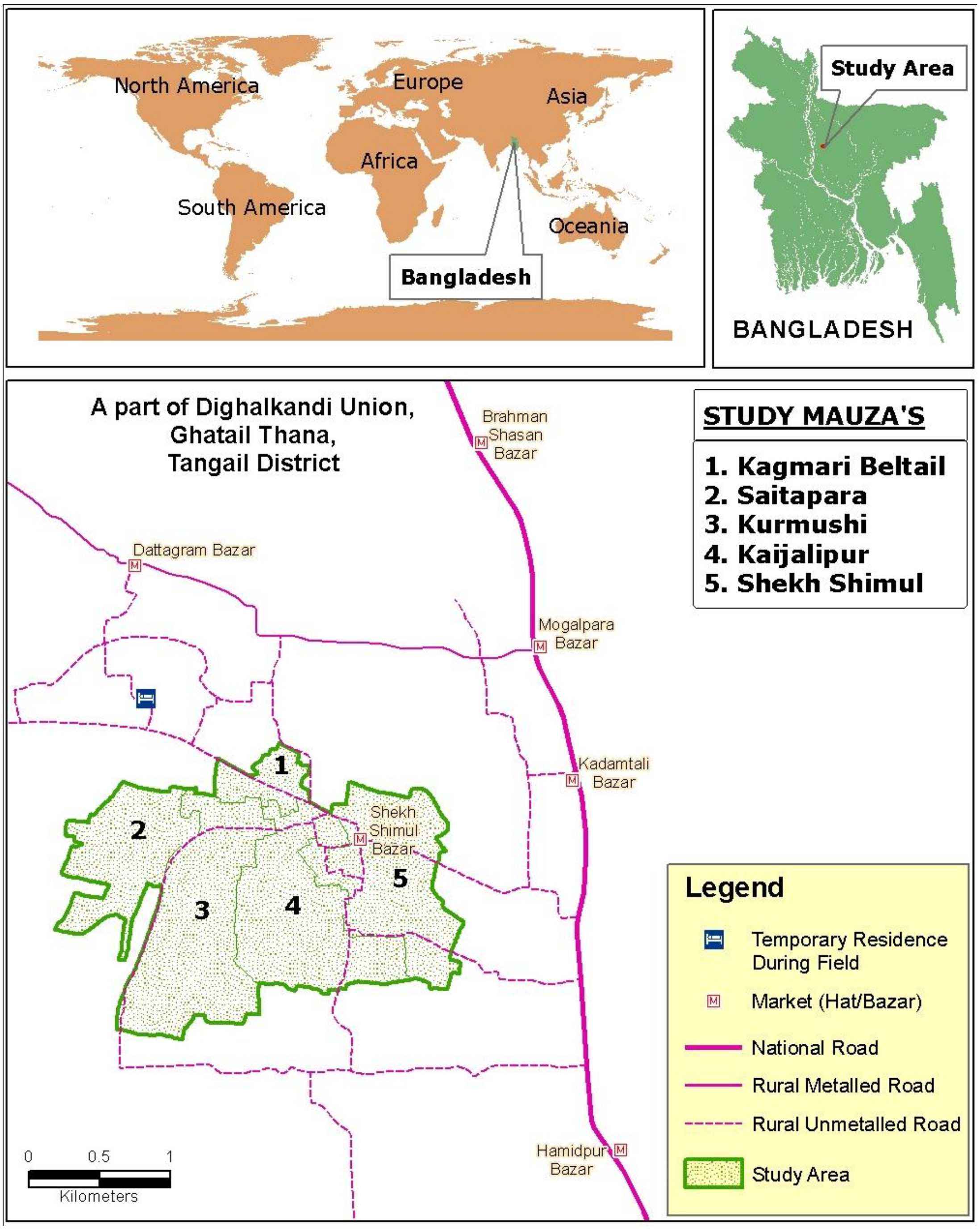


Figure 4.1: Showing location of the study area

4.2.2 Data collection

In this chapter data were collected of the study area to understand the agro-ecological characteristics, geographical and physical features, lithological and aquifer information, availability and suitability of groundwater abstraction by STWs. In this connection, four bore logs of Bangladesh Water Development Board (BWDB) present in the nearby of the study area were used for subsurface lithological and aquifer information. Data on groundwater level were collected from two observation wells maintained by BWDB which were very close to the study area. Both static water level and pumping water level were measured by avometer. These measurements were done four times in a year and for the year 2016 and 2017 were measured. Besides these, the secondary data such as water table, rainfall, groundwater recharge, soil structure, land type, water bodies as well as geographical and physical features were collected from different secondary sources and these are BWDB, CEGIS, weather office, different journals, reports and internet.

4.3 DATA ANALYSIS, RESULT AND DISCUSSIONS

Various observations regarding geographical and physical features such as location, physiographic, topographic features (agricultural land, settlement, water bodies, forest), land type based on flood inundation level, subsurface lithology and aquifers, soil type, rainfall, water table, groundwater table recharge and availability and suitability of groundwater for STWs irrigation etc. of the study area were conducted to evaluate geographic and physical features perspective STW irrigation technology. These are described as below:

4.3.1 Physiographic characteristics of the study area

Physiographic unit refers to a region of which all parts have similar physical characteristics and which have consequently a uniform geomorphic history, and whose pattern of topographical features or landforms differ significantly from the adjacent regions.

Bangladesh is located at the lowermost reaches of three mighty river systems, the Ganges-Padma River System, Brahmaputra-Jamuna River System and Meghna-Surma River System. The lands of Bangladesh can be divided into four major categories of physical units based on altitude, relief and type of sediment cover. These are Tertiary hills, Pleistocene uplands, recent floodplains (formed in recent Holocene epoch) of GBM rivers and the delta of the remaining country.

The physiographic of the country has been divided into 24 sub-regions and 54 units. The study area is the Young Brahmaputra and Jamuna Floodplain physiographic unit (Figure 4.2) under the sub-region which is mainly covered by alluvial silt and clay type of sediment.

The deposition of quaternary sediments began about 2 million years ago and extends to the present and deposited mainly by the Ganges (Padma), Brahmaputra (Jamuna) and Meghna rivers (GBM River System) and their numerous distributaries which covered about three-quarters parts of Bangladesh. The physiographic and the drainage pattern of the vast alluvial plains in the central, northern and western regions have gone under considerable alterations in recent times. The deposition of quaternary sediments was influenced and controlled by structural activities.

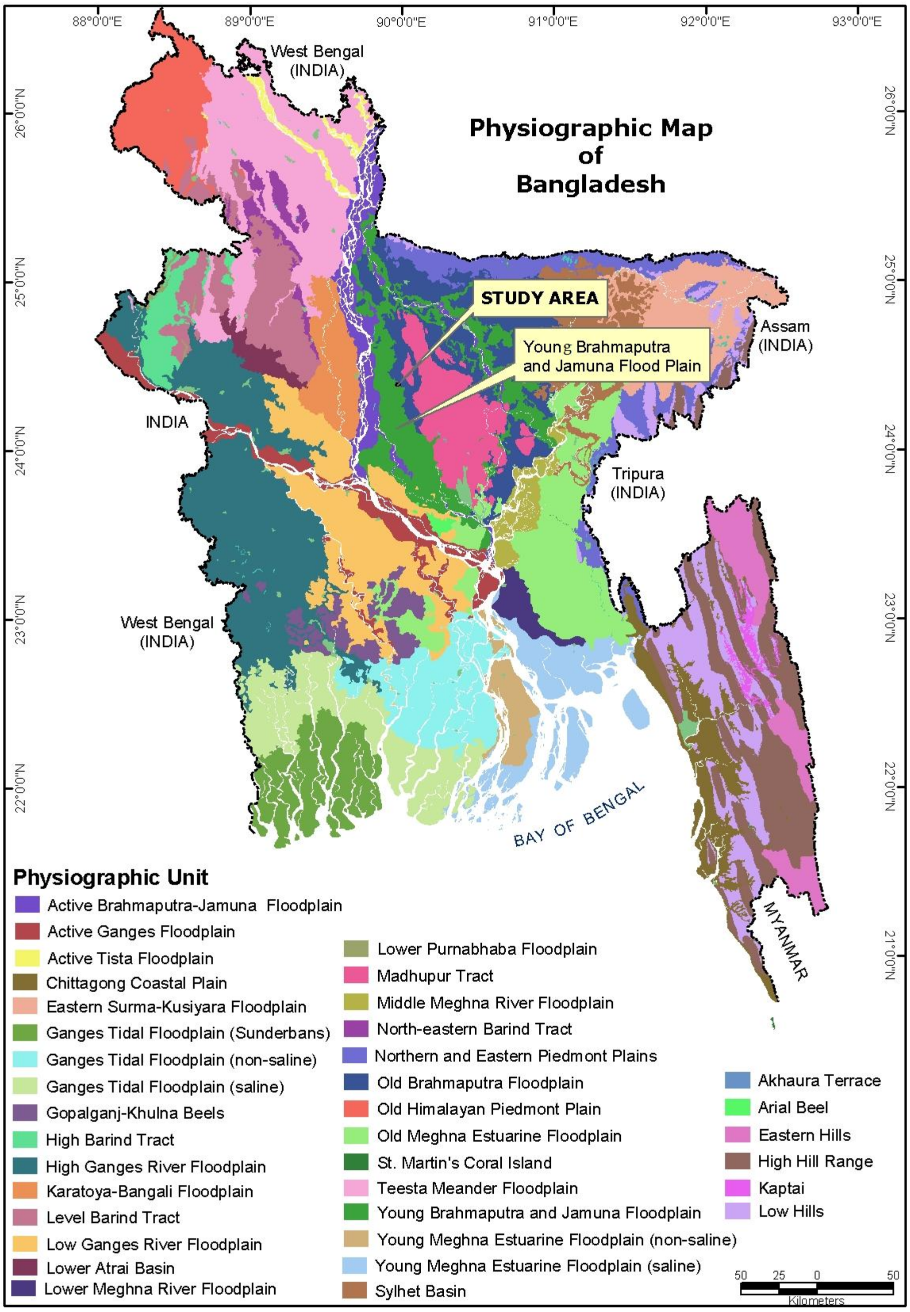


Figure 4.2: Physiographic map of Bangladesh showing the study area

4.3.2 Geomorphology and Land Use Pattern

Rivers and wetlands (beel) are two major geomorphic features in and around the study area. Kalidaha River is in the south and a small river named as Beldaha gang is present in the north of the study area. Kalidaha River is a meandering type of river that contains many sandbars. There is also a channel Parshi gang in the east, which is actually a dead channel. A national high way is passing in the east just after the Parshi gang. This road connects Kalihati and Ghatail Upazilas directly to the Tangail district head quarters.

There are three wetland areas (Beel) present in and around the study area. Kaicha Beel is present in the northern part of Saitapara. The Beel become almost dry during dry season (Boro season) and the total Beel area is cultivated. There are two other Beels present in the south of Kaijalipur and Shekh Shimul named as Naksala and Salenka Beel, respectively. Most of the part of these two Beels is cultivated during the Boro season. During the Boro season, these Beels are also used as one of the water sources at the beginning of Boro irrigation.

The total study area covers about 376 hectares. Topographically the study area is under Medium Highland (F2 land) category, which means the area is inundated at least 30 to 90 cm by flood water in normal flood year. The three major classes of land use and land cover present in the study area. The table 4.1 presents different classes of land use (topographical features) and their coverage areas in the study area. About 77 percent of the study area is covered by agricultural land (Table 4.1). From the field survey, it is evident that more than 95 percent of agricultural land is under irrigation during dry season.

Table 4.1: Different types of topographic features of the study area

Feature	Area (Hectare)	Percentage (%)
Agricultural Land	288	77
Settlement	73	19
Water bodies	15	4
Total	376	100

(Source: NWRD, 2014)

Settlement classes include household, surrounding homestead vegetation, some agricultural lands surrounding homestead etc. The geomorphic variations sometime help to increase STWs command area and also some cases act as a barrier to expansion. Settlements with homestead vegetation, water bodies and agricultural lands were digitized from a resolution merged (6m Pan of Jan 2016 and 24m LISSIII multispectral of Feb 2016) IRS satellite image of 6m ground resolution (Figure4.3).

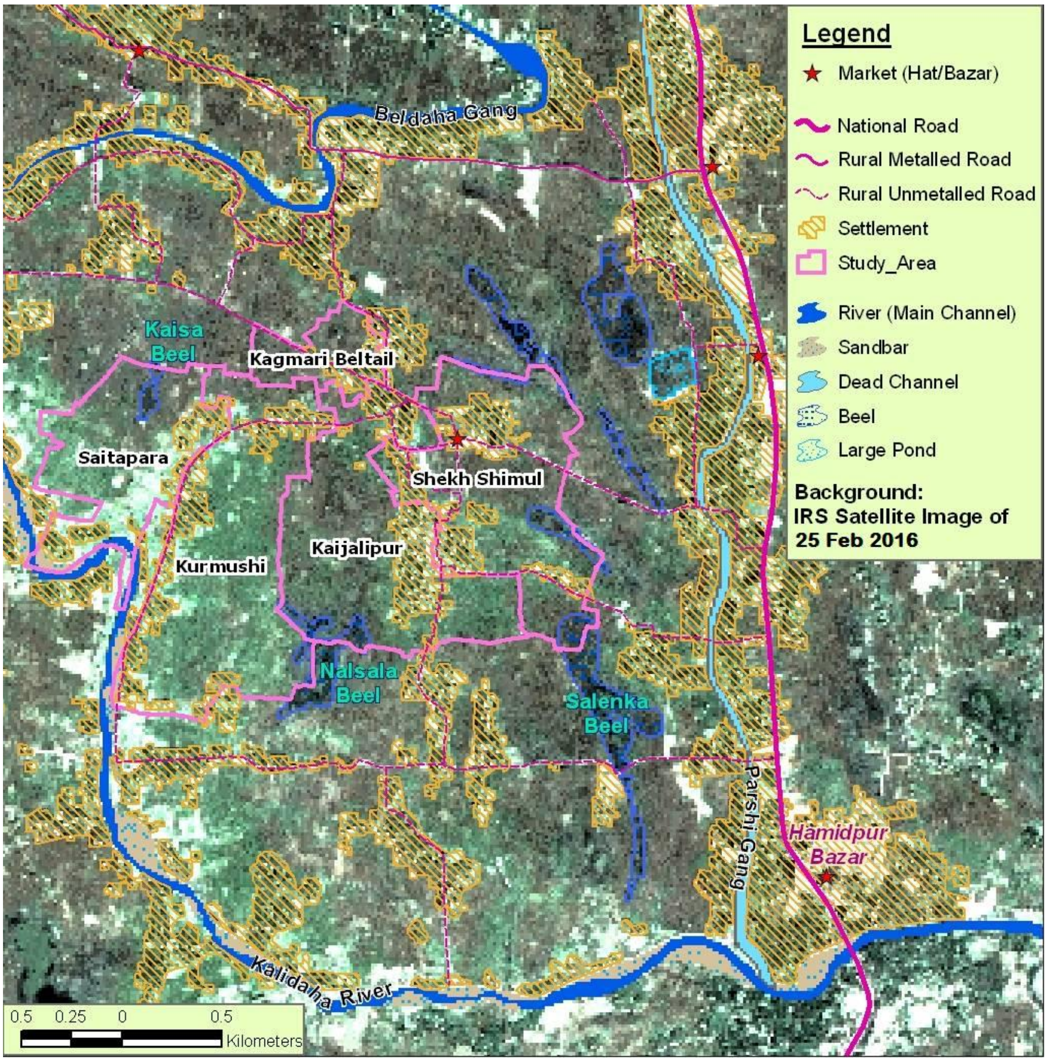


Figure 4.3: Topographical features are shown in IRS satellite images of February 2016.

4.3.3 Lithology and Aquifer

Unit bore-log data is widely used to understand and interpret the subsurface lithology. Bangladesh Water Development Board (BWDB) has completed a groundwater survey in 2014 for all over the country and during the project they have collected unit bore-log data. The BWDB unit bore-log data was used for this study.

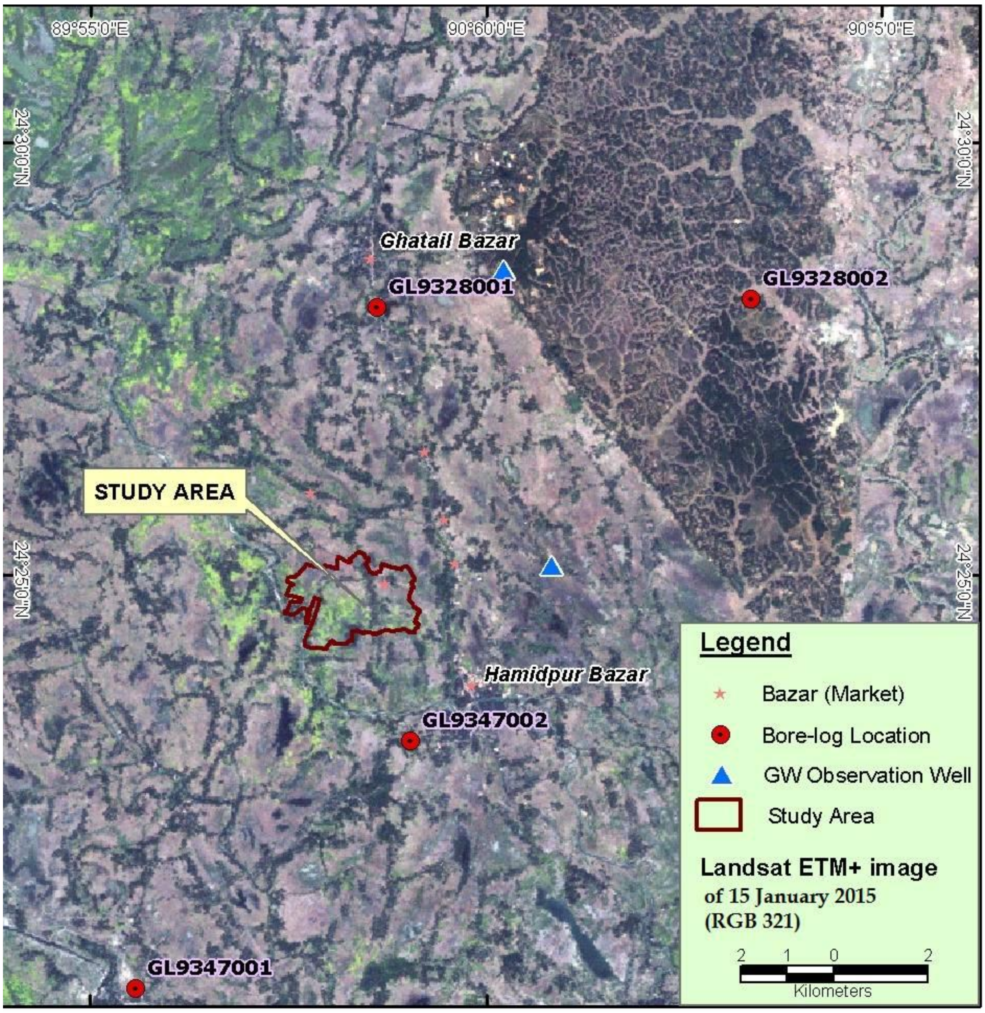


Figure 4.4: Showing bore-log locations used for lithology model of the study area

No unit bore-log is available inside the study area. Thus four unit bore-log data were selected from the surrounding areas that could represent the study area. The location and distribution of the bore logs are shown in the Figure 4.4. The bore-logs consist of several small lithological variations. A detail variation is shown in Chapter 12 (Annexure-4a, 4b, 4c and 4d. All the lithology classes of the area are generalized and grouped into ten major classes i.e. silt, very fine sand, fine to very fine sand, fine sand, fine to medium sand, medium sand, coarse sand, coarse sand to gravel, pebble and gravel. Each of the lithology class is actually a mixture of different percentages of grain sizes. For generalization, the grain size that has the highest percentage of presence is considered as that class. Generalized lithological stratums for four bore-logs are shown in Figure 4.5.

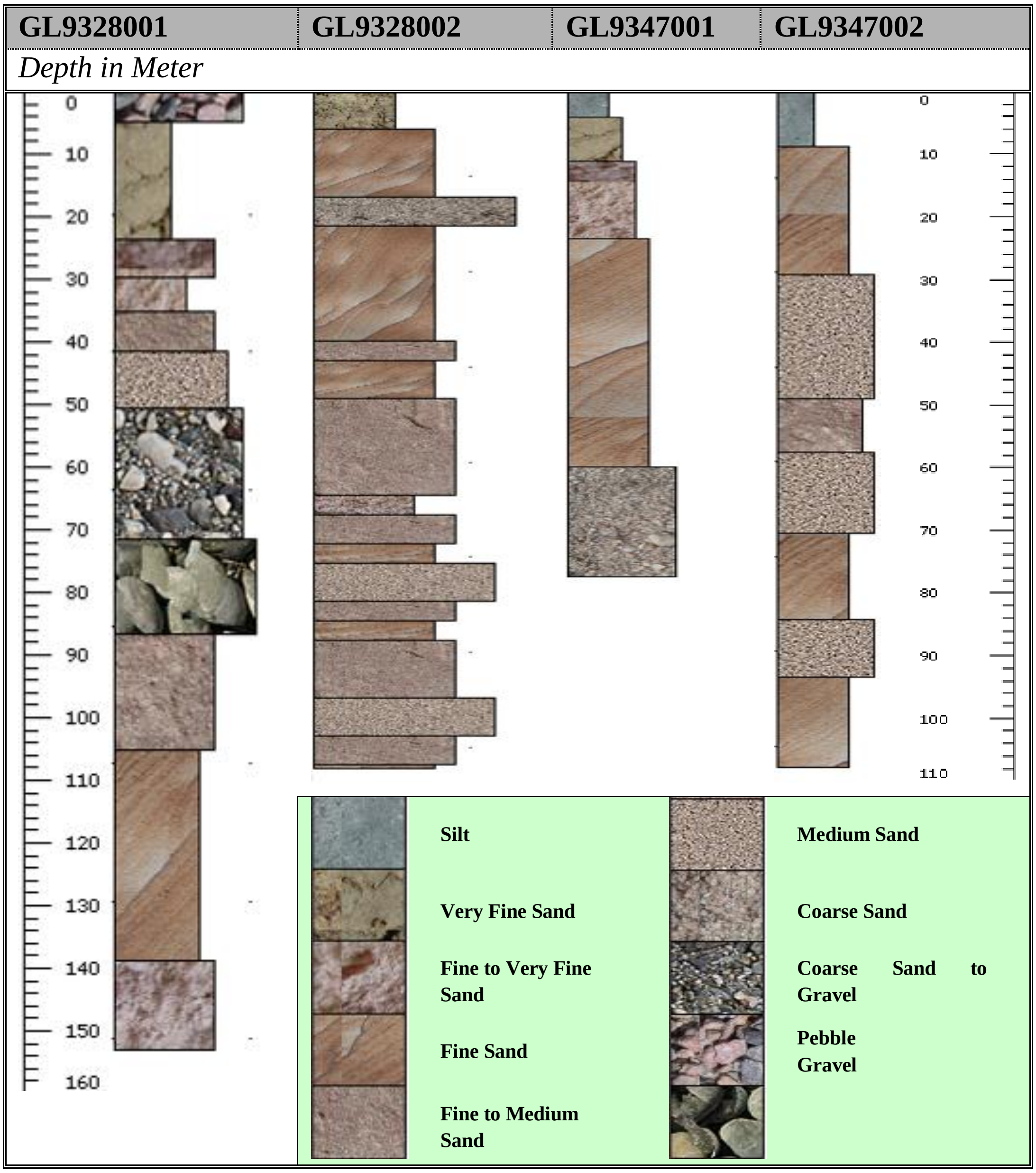


Figure 4.5: Generalized lithological stratum of four bore logs around the area (Source: BWDB, 2014)

Bore-log stratum represents only the vertical discrete lithological information of bore location or position. To understand the lithology of the total area, a lithology model of 3-dimentional block diagram (Figure 4.6) were built by using the four bore-log stratum. The model represents lithology of the entire area covered by the four bore-logs i.e. the study area and also some surrounding areas. To understand the lithology of the study area, two cross sectional profile were generated from the model; one is from east to west (Figure 4.7a) and another is from north to south (Figure 4.7b) of the study area.

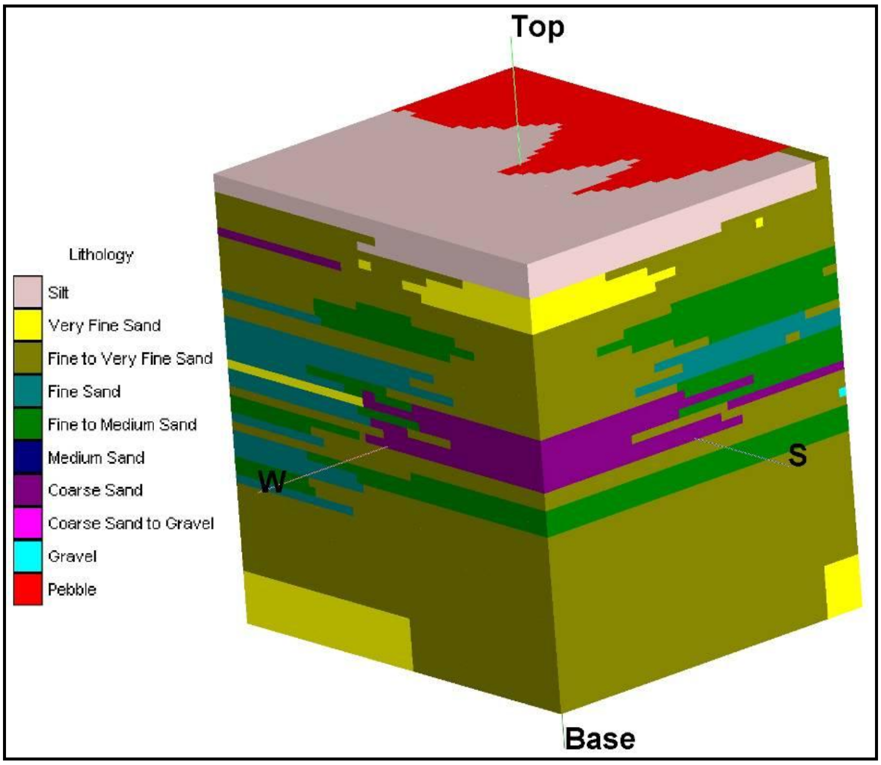
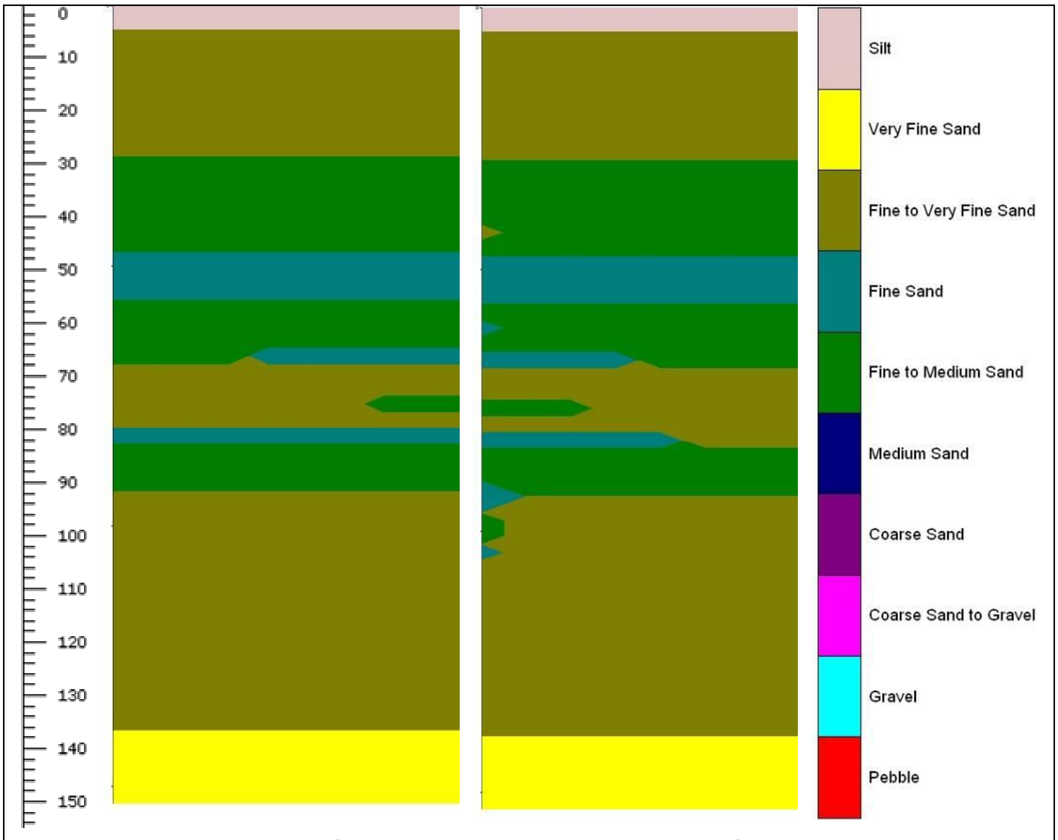


Figure 4.6: 3-dimentional block diagram of a lithology model of the study area and surroundings using nearest four bore log data



(a) East-West profile (b) North-South profile

Figure 4.7: Two profiles of sub-surface lithology of the study area developed from the lithology model

The two lithological profiles of the study area represent / suggest that the area mainly governed by different grades of sand, where fine to very fine sand is the dominant (predominantly fine to very fine sand.). A silt layer is present at the top of the lithology and it is probably the top soil where agricultural crops are grown. Fine to medium sand and fine sand is also present alternatively in certain depths.

The lithological characteristics (up to 153 meter depth) of the study area represents that the subsurface is an unconfined aquifer, which is a good source of groundwater reservoir. It is the upper water bearing zone i.e. the upper (shallow) aquifer of the area. From the field survey, it is shown that the sampled 50 STWs of the study area have boring depths from 18m to 30m and the strainers were put in between 5m to 21m. The lithological model and profiles showed that the strainers are put in the very fine to fine sand layers.

4.3.4 Groundwater Recharge for Irrigation

The subsurface of the study area is governed by different grades of sand and sand is a good reservoir to store water and there is no confined layer present. Thus it is an unconfined aquifer and the strainers of STWs of the study area are put in an unconfined aquifer, which is composed of sands. Usually the percolation is good where the subsurface lithology is composed of sand. So if there are good sources of water available on the surface it can easily penetrate and thus contribute to the groundwater and can recharge the groundwater table. The area has good sources of water on the surface that can contribute to the groundwater table easily. The sources of surface water over the year are plenty of rainfall (yearly average 1896 mm), Kalidaha River in the south & west and Beldaha Gang (River) in the north, four Beel (wetland) areas and flood inundation every year during rainy season. . These sources of surface water contribute to the recharge of groundwater table of the area.

4.3.5 Land Type

Bangladesh is a flood prone country and it is divided into five category land type based on topographically or the flood inundation level in normal flood years. The categories are presented in Table 4.2. The Land type map of Bangladesh (Figure 4.8) shows that the study area is under Medium Highland (F2 land) category, which means that the area inundates at least 30 to 90 cm by flood water in normal flood year.

Table 4.2: Land type's classification of Bangladesh based on flood inundation level.

Land Type	Description	Inundation Level (cm)
F1	Highland	0 – 30
F2	Medium Highland	30 – 90
F3	Medium Lowland	90 – 180
F4	Lowland	180 – 300
F5	Very Lowland	> 300

(Source: NWRD, 2014)

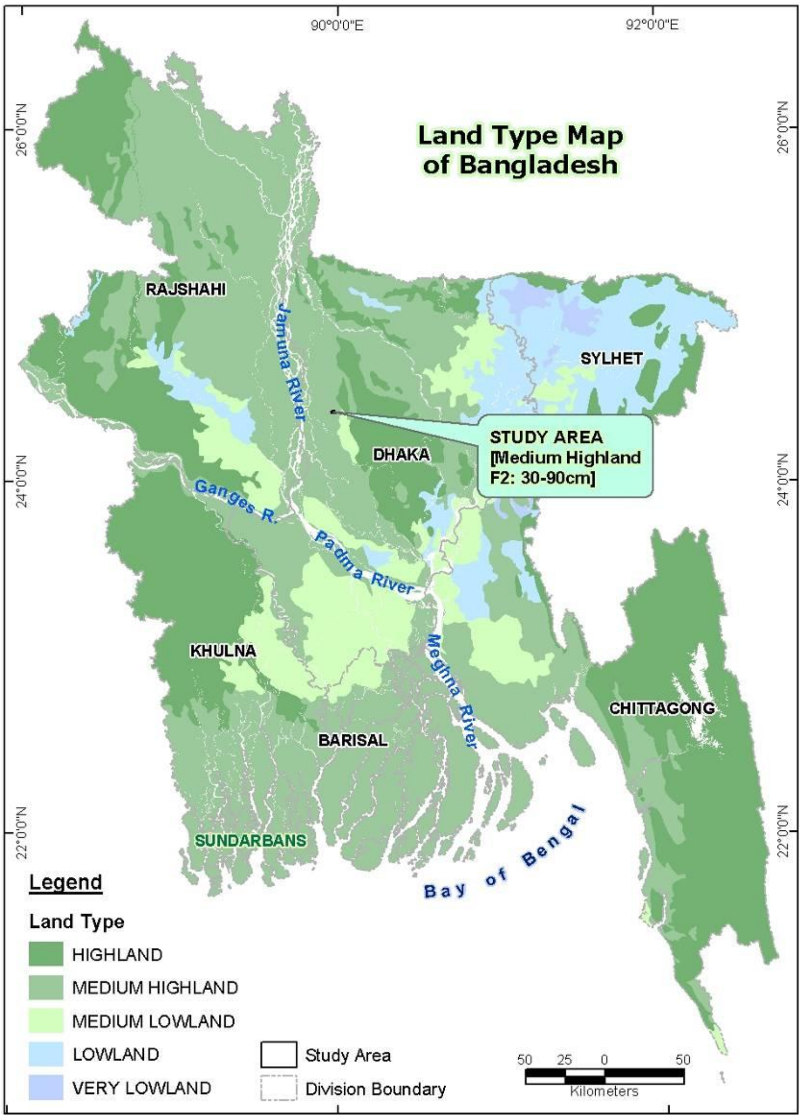


Figure 4.8: Land type Map of Bangladesh showing the Study Area (Source: NWRD, 2014)

4.3.6 Flooding

RADARSAT ScanSAR 100m Wide Beam satellite image of the 7th August 2016 is used to map the flood extent of the area. The flood map (Figure 4.9) shows that the study area was inundated by flood on the 7th August 2016, except the settlements and its adjoining higher elevated areas. The flooded areas are actually the agricultural lands where *Boro* rice is planted during dry season by groundwater irrigation.

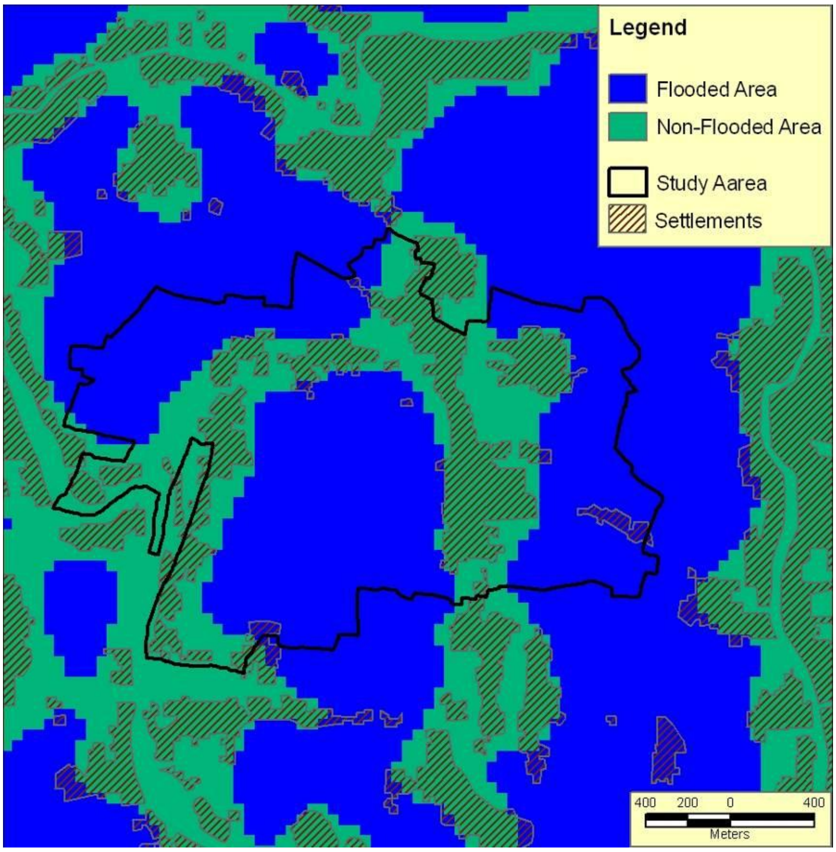
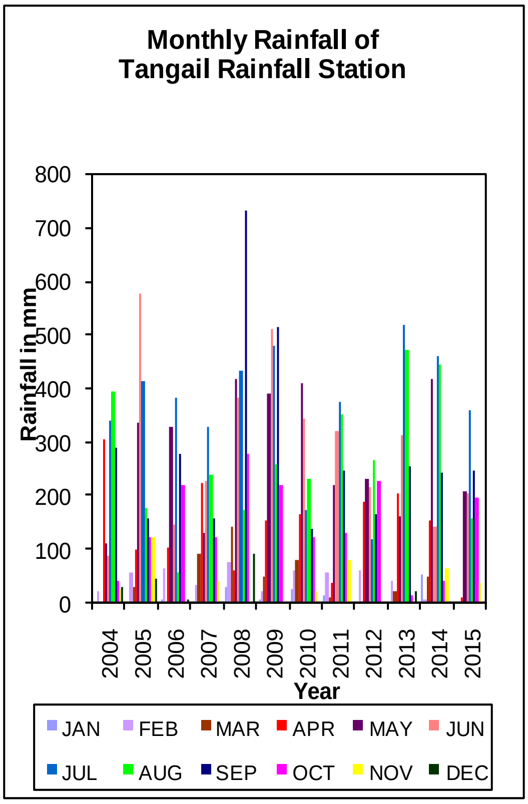


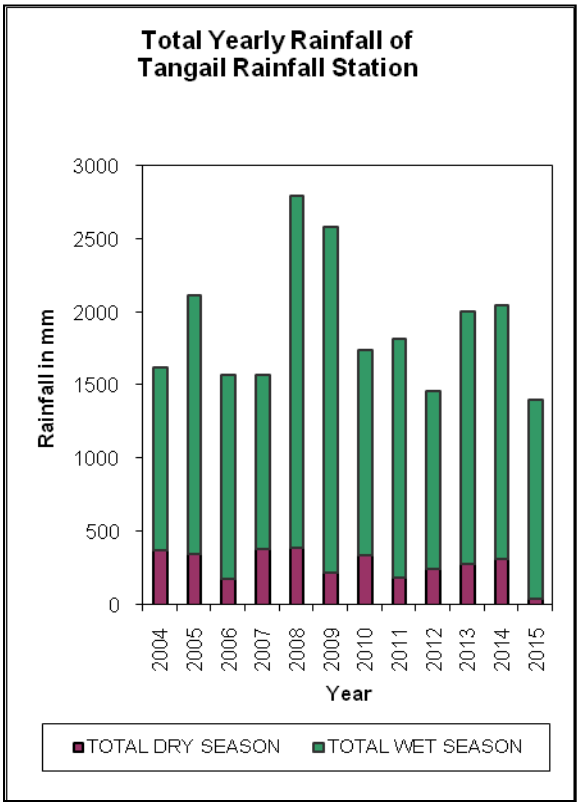
Figure 4.9: Flooded and non-flooded area mapped from ScanSAR Wide Beam 100m Radar image of the 7th August 2016 (Source: CEGIS, 2016)

4.3.7 Rainfall

The yearly total average rainfall of the area was 1896mm, which was calculated from 12 years from 2004 to 2015 (Annexure-5 in Chapter-12) of the Tangail rainfall station. The data also showed that the dry season (November to April) yearly average rainfall was 275mm, whereas the wet/rainy season (May to October) yearly average rainfall was 1621mm. The maximum monthly rainfall recorded over the 12 years period in the station was 730mm on the month of September in 2008. Monthly rainfall and total yearly rainfall of Tangail rainfall station was shown in Figure 4.10. The yearly total rainfall ranges from 1401 mm (in 2015) to 2792 (in 2008). The yearly rainfall indicated that the rainfall was sufficient enough for the area and was good source of groundwater recharge.



(a) Monthly rainfall in Tangail



(b) Yearly total rainfall in Tangail

Figure 4.10: Rainfall information of Tangail rainfall station (Source: CEGIS, 2016)

4.3.8 Groundwater Table Hydrograph

There is no observation well in the study area to monitor and record the static groundwater table. Two nearby observation wells are present (Figure 4.4, BWDB, TA-27 and TA-38), which are maintained by Bangladesh Water Development Board and thus used for this study, which are under Ghatail Upazila. The graph of the observation wells (Figure 4.11) for last five years (2012 to 2016) shows that the static groundwater table drops about 4 to 5 meters every year during the irrigation season due to the tubewell pumping for irrigation and it comes back to its normal position by recharging during wet/rainy season. The normal depth of static groundwater table in the area is 2 to 2.5 m depth from the surface. The static GW table hydrograph (Figure 4.11) 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 requires maximum water and thus highest pumping occurs at that time. There is a declining trend of groundwater table during irrigation period over last five years although static groundwater head comes to its normal level every year (Figure 4.11) during rainy season.

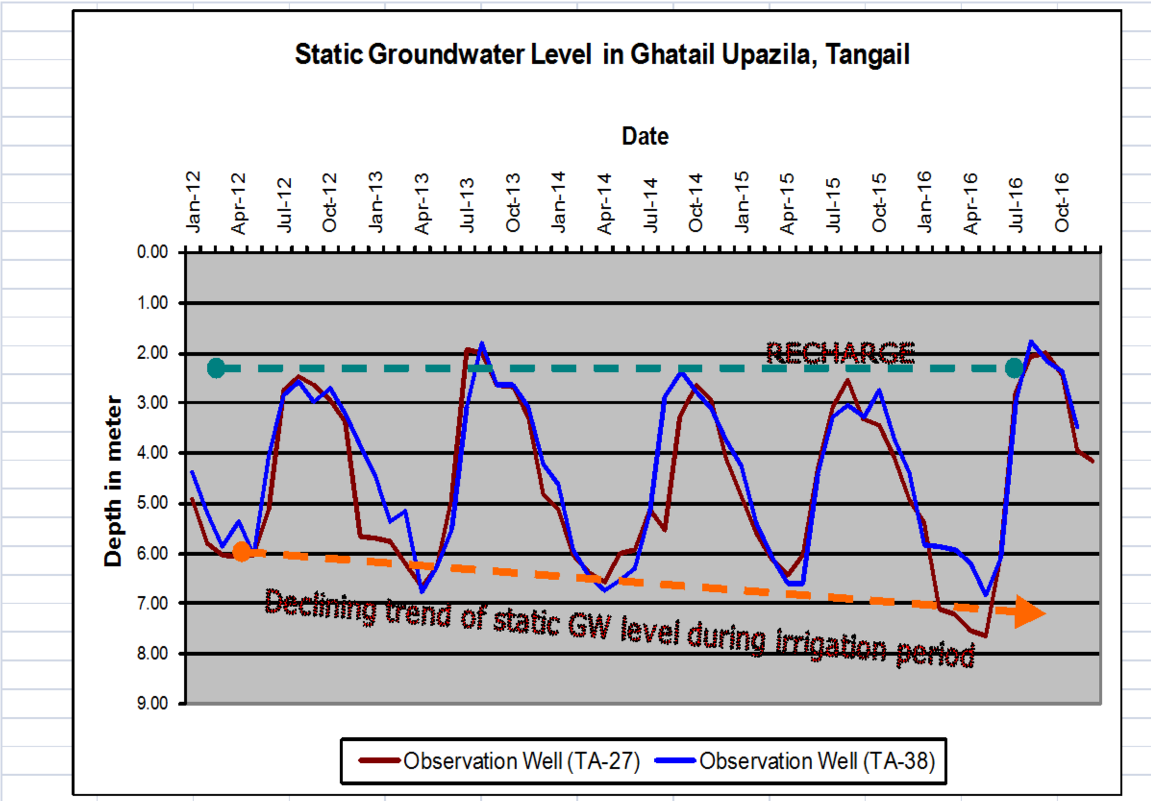


Figure 4.11: Static groundwater table hydrograph in Ghatail Upazila, Tangail
(Source: BWDB, 2016)

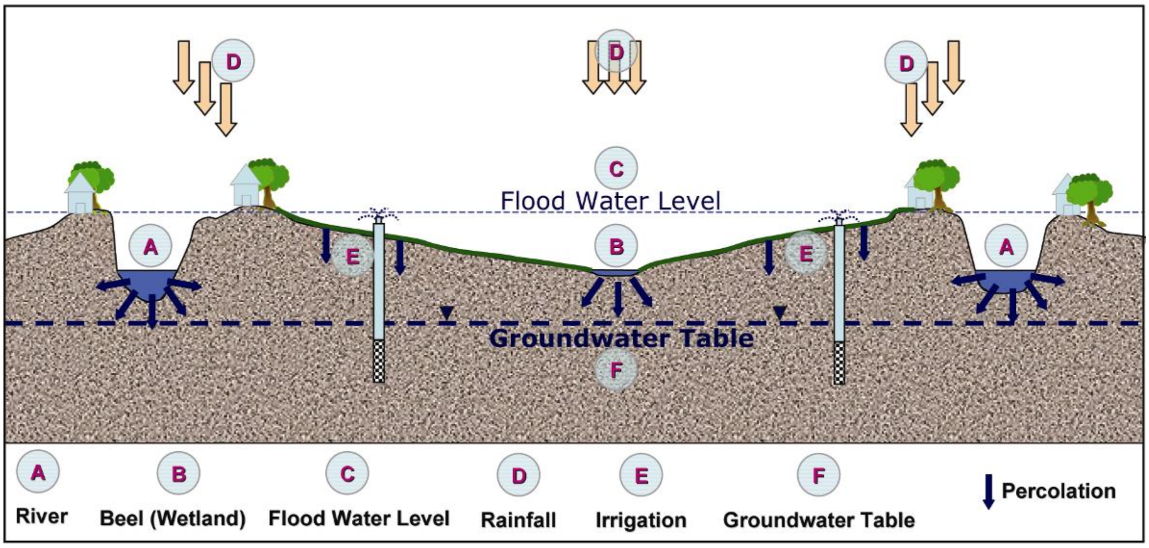


Figure 4.12: A Schematic diagram showing the sources of recharging groundwater table of the study area

4.3.9 Availability and Suitability of Groundwater Irrigation

Each year the groundwater table of the study area comes to its normal water level by regaining water from different sources (Figure 4.12). Plenty of rainfall, Beldaha gang (river) and Kalidaha River, Beels (wetlands), flood water and irrigation water are good sources of groundwater recharge in the study area. So groundwater irrigation is available and suitable in the study area. No major water availability problems due to lowering of groundwater table or any other else were reported by the STW owners of both DOS and EOS schemes and farmers.

4.4 CONCLUSION

This research study concluded that the subsurface of the study area was governed by different grades of sand and the study area was under medium highland (F2 type) category. Moreover, the study area has rivers, beel and water bodies (4%) and the sources of surface water over the year were plenty of rainfall and every year flood inundation during rainy season that can contribute to the groundwater table easily. As a result, groundwater recharge occurs every year in the study area. So, it can be said that the study area was suitable for Boro rice cultivation using groundwater by STW due to its geographical and physical features such as water bodies, rainfall, land type category, soil type, topography, lithology, aquifer characteristics and groundwater availability and suitability. No major water availability problems were reported by the STW owners or water buyer due to lowering of groundwater table or any other else.

However, this research needs further validation. In this regard, further study is needed to be conducted to investigate quantity, density of STWs from a baseline to understand trend line of STW and type of energy used for future prediction. Moreover, spatial distribution and GIS mapping of STWs, cropping pattern, land use pattern in the study area may be plotted on mouza map through which different planning and decision making would be possible easy and meaningful in a constructive way. Therefore, further research focuses about quantity, density of STWs, spatial distribution and GIS mapping of STWs, cropping pattern, land use pattern of the study area (Chapter 5).

Chapter 5

SPATIAL DISTRIBUTION AND GIS MAPPING OF SHALLOW TUBE WELL IRRIGATION SYSTEM

Chapter 5

SPATIAL DISTRIBUTION AND GIS MAPPING OF SHALLOW TUBEWELL IRRIGATION SYSTEM

5.1 INTRODUCTION

Previous chapter (Chapter 4) showed that the selected study area is suitable for STW irrigation business due to geographical location, topography, lithology, aquifer characteristics and groundwater availability. However, this research needs further validation for the context of existing number of STW and future trend whatever that may be affect or not the groundwater storage. An attempt was taken in this chapter to investigate the number of STW and there type of energy, to focus spatial distribution and GIS mapping of STWs in the mouza map of the study area.

A spatial distribution is the arrangement of a phenomenon across the Earth's surface and a graphical display of such an arrangement is an important tool in geographical and environmental statistics. It is the physical location of salient features of a place. A graphical display of a spatial distribution may summarize raw data directly or may reflect the outcome of more sophisticated data analysis. Many different aspects of a phenomenon can be shown in a single graphical display by using a suitable choice of different colours to represent differences. One example of such a display could be observations made to describe the geographic patterns of features, both physical and human across the earth. The information included could be where units of something are, how many units of the thing there are per units of area, and how sparsely or densely packed they are from each other. Geography involves the study of why things vary from place to place on the earth, also known as spatial distributions or anything that can be mapped.

A sustainable development project planning requires comprehensive and reliable information to serve as the base for making timely and reasonable decisions. A Geographical Information System (GIS) can be used to obtain such information in a comparatively quick and easy way using specialized maps and numeric data. Geographic Information System (GIS) and Remote Sensing (RS) technologies are used extensively for scientific investigations, resource management, environmental change detection and impact assessment, disaster management, urban and regional planning, asset management, cartography, history, sales, marketing and logistics. From simple mapping to complex spatial analysis, application of these technologies has become essential tools for managers, researchers, planners and policy-makers. For example, GIS and RS may allow decision-makers to calculate emergency response easily during a natural disaster. These can also be used to find wetlands that need protection from pollution or may be used by a company to select site of a new business to take advantage of a previously undeserved market or even to track down deforestation, river bank erosion, etc.

Spatial distribution may be defined perspective in this chapter that how scattered STW in the study area or right position of STW in the mouza map. It is possible to easily understand the density and distance from one to another STW and their energy type. Since there is no record on STWs mapping in the study area, this study attempts to examine it with the help of GIS application with the following specific objectives:

i. To examine the quantity, location, density and type of energy of STW
ii. To locate STW in mouza map through GIS application
iii. To examine the cropping pattern and mapping through GIS application and
iv. To draw recommendations for the improvement of STW irrigation system.

5.2 APPROACHES AND METHODOLOGIES

5.2.1 Study Area

The study area was within Dighalkandi union, which is under Ghatail Upazila of Tangail district in Bangladesh. The study area comprises five Mauzas of Dighalkandi union namely Kagmari Beltail, Saitapara, Kurmushi, Kaijalipur and Shekh Shimul as shown in Figure 4.1.

5.2.2 Data Collection Procedure

Primary and secondary data were used in this study. The principal tools were questionnaire survey and interviewed with STW owner and farmer for collecting the primary data in 2016 and 2017 Boro season. Complete survey technique was used for the STW owners and required secondary data was collected from a baseline data for the year 2007 in study region. Field survey was conducted to examine the quantity of STW, spatial distribution of STWs and cropping pattern in the study area. Location of STWs was set in the respective mauza map. The locations of STWs were identified in the field by using Global Positioning System (GPS) and plotted them on the mauza maps by by GIS application. The command areas were also demarcated plot by plot on mauza maps by field survey. The changing pattern of STW location and command areas were plotted only of Saitapara mouza in details and also described the causes of changing STW locations and command area in the study area. To understand the cropping pattern dynamics, data were collected from Kurmurshi mauza and Saitapara mauza and cropping pattern was shown in a command area by GIS application. Moreover, to understand the changing landuse pattern of STW command area over the time, Saitapara mauza was selected for this purpose.

5.3 DATA ANALYSIS, RESULT AND DISCUSSIONS

5.3.1 Spatial Distribution of Shallow tube wells

There were 68 shallow tube wells in 1997 irrigation periods in the study area (Mandal, 1997). Among these only two were Deep Shallow tube wells (DTW), one in Kaijalipur and the other one in Saitapara mauza. In 2007 irrigation periods, the total number of shallow tube wells rose to 71 with only one was DTW working in Kaijalipur mauza in the study area (Hossain and

Moududi, 2009). In 2017 irrigation periods, the field survey data revealed that the total number of shallow shallow tube wells down to 50 in the study area. The spatial distribution of the shallow shallow tube wells of 1997, 2007 and 2017 are shown in Figure 5.1. Among the 68 shallow tube wells in 1997, 52 STWs (76%) were run by diesel and the remaining 16 STWs (24%) by electricity (Table 5.1). On the other hand, in 2007 irrigation periods, only 31 STWs (44%) were run by diesel and 40 STWs (56%) by electricity (Table 5.1) and in 2017 irrigation periods, only 2 STWs (4%) were run by diesel and 48 STWs (96%) by electricity (Table 5.1). It is evident that in the last twenty years using of diesel engine has been decreased and using of electricity driven STWs has been increased 40% respectively. Diesel engine is in abolition stage in the study area as well as all over the country for STWs irrigation system.

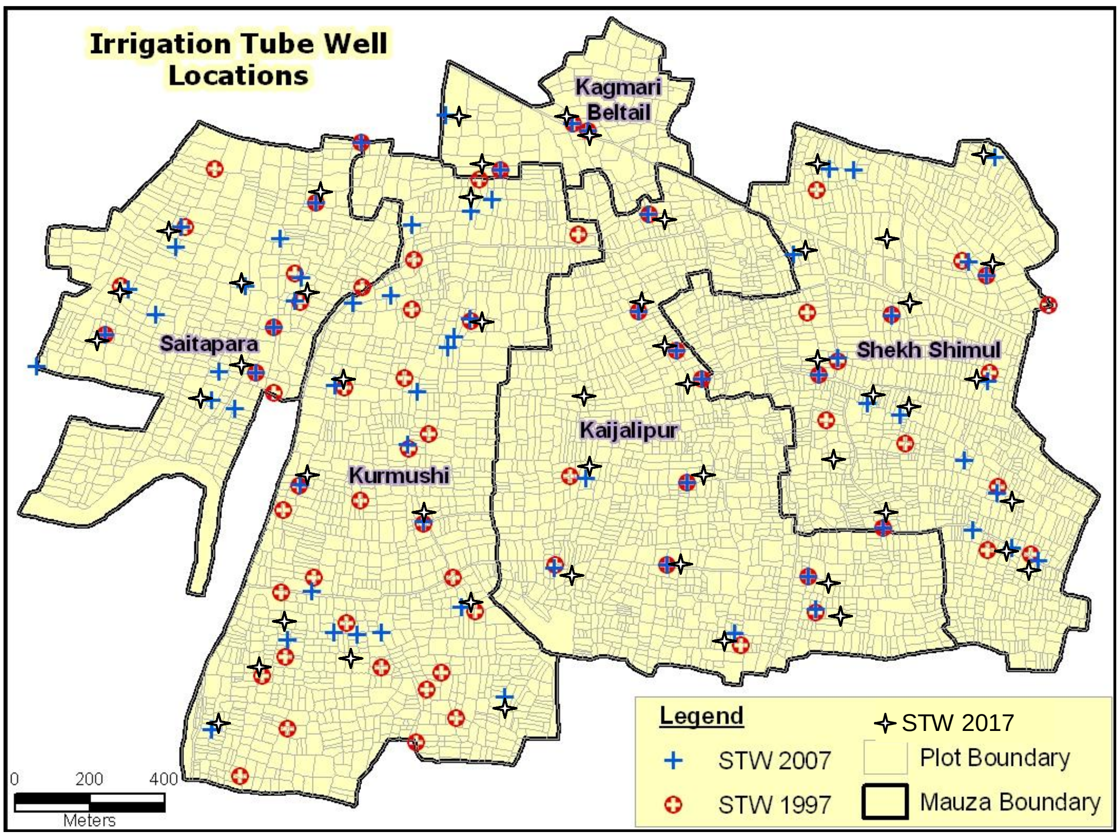


Figure 5.1: STW locations in mauza map of the study area in 1997, 2007 and 2017.

Table 5.1: Mauza-wise number of STW and their energy type.

Mauza	**Number of STW**			**Type of Energy Use**					
	1997	**2007**	**2017**	**1997**		**2007**		**2017**	
				D*	E*	D*	E*	D*	E*
Kagmari Beltail	3	4	4	2	1	2	2	0	4
Kaijalipur	11	11	12	4	7	0	11	0	12
Kurmushi	27	21	11	25	2	10	11	0	11
Saitapara	12	17	8	12	0	14	3	2	6
Shekh Shimul	15	18	15	9	6	5	13	0	15
TOTAL	68	71	50	52	16	31	40	2	48

Note: D* for diesel operated STW and E* for electricity operated STW

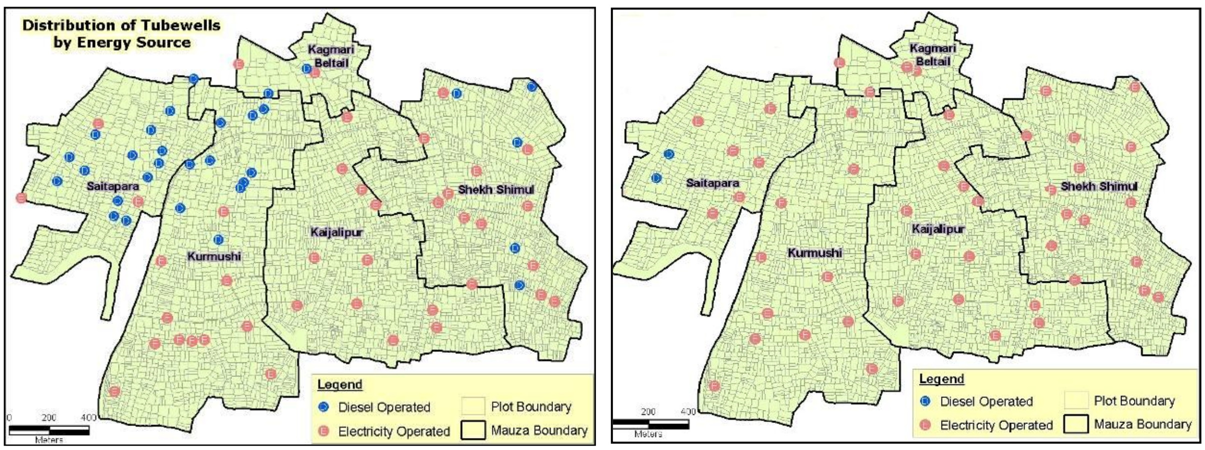


Figure 5.2: Distribution of STWs by energy source in mauza map in 2007 and 2017.

Figure 5.2 (left one) showed that the diesel operated shallow shallow tube wells were mainly concentrated in the northwestern part of the study area i.e. mainly Saitapara and northern part of Kurmushi mauzas in 2007. This was probably because these villages are far away from the existing electricity transformers. On the other hand, electricity operated shallow tube wells were mainly concentrated in the eastern part of the study area i.e. mainly Shekh Shimul & Kaijalipur mauza and southern part of Kurmushi mauzas. This was probably because these villages are near from the existing electricity transformers. But in 2017, there were found almost electricity operated shallow tube wells in the study area Figure 5.2 (right one). Socio economic reasons were identified in this study which is discussed in Chapter 8.

In 1997, the minimum tube well density of a mauza of the study area was 12 per km^2 at Kaijalipur mauza and the maximum was 25 at Kurmushi mauza. In 2007, the minimum density remains the same at Kaijalipur mauza but the maximum density rose to 28 at Saitapara mauza and in 2017, the minimum density at Kurmurshi mauza but the maximum density remains the same 20 at Kagmari Beltail mauza (Table 5.2). The average tube well density of the study area rose from 18 to 20 in 1997 and 2007 and the last 10 years average density has been reduced to 15 (Table 5.2).

Table 5.2: Density of the Shallow Shallow tube wells in 1997, 2006 and 2017

Mauza	Number of STW			Area (ha)	Area (km^2)	Density/km^2			Average Density/km^2		
	1997	2007	2017			1997	2007	2017	1997	2007	2017
Kagmari Beltail	3	4	4	20	0.20	15	20	20	18	20	15
Kaijalipur	11	11	12	95	0.95	12	12	13			
Kurmushi	27	21	11	109	1.09	25	19	10			
Saitapara	12	17	8	62	0.62	19	28	13			
Shekh Shimul	15	18	15	90	0.90	17	20	17			

(Source: Field survey, 2016)

5.3.2 Changing of STWs location and command areas in Saitapara Mouza

The STW irrigation business dynamics was changed in the study area like any other business. Therefore, changing phenomenon of STW locations and corresponding command areas also took place (Figure 5.3). The changing pattern STW location / position and STW coverage area are studied in this section only of Saitapara mouza in details. The command area were affected by partnership, shifting from DOS to EOS, micro variations in topography, soil type, gradient and availability of low lying beels . STW location have been changed little bit over the last 20 years since 1997 (Figure 5.3). If we explain/review the Figure 5.3, then we can see different scenario in the study area, such as some STWs location, ownership and command area have been changed and some location was unchanged but command area was changed or some location was unchanged but ownership was changed etc. However, a case study was described below where was shown the slope profile (Figure 5.4) between two adjacent STW through Digital Terrain Model (DTM)

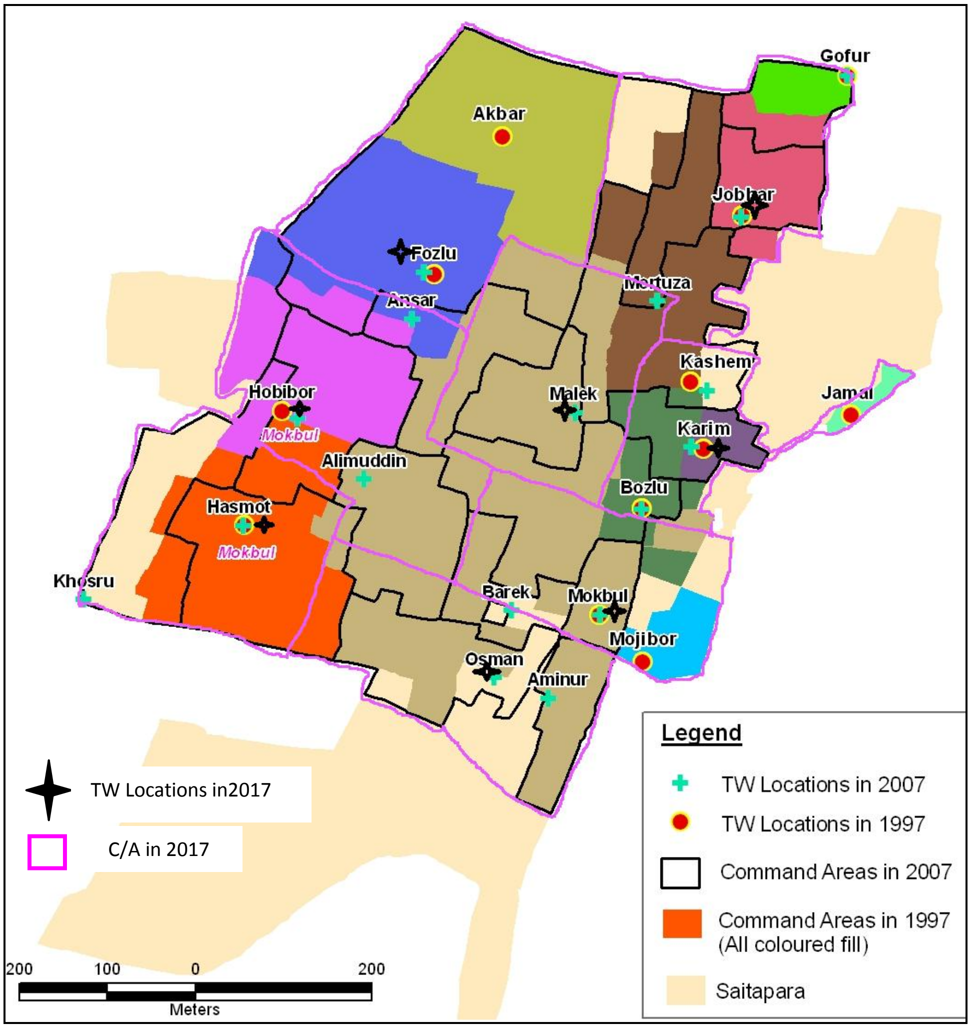


Figure 5.3: Comparison of command areas under different STWs among 1997, 2007 and 2017.

Case study: Mr. Akbar and Mr. Fazlu were the STW owner and their command areas were adjacent. Akbar was known as a bad tempered person and thus he had no good relationship with the farmers (water buyers). He was selling water but did not listen to complaints from the water buyers. So farmers moved to other STWs day by day. Finally he had to stop his STW irrigation business as no body wanted to buy water from his STW. On the other hand, Mr. Fazlu was in disadvantages position in terms of land elevation variations i.e. the command area of Akbar was in the lower elevation rather than of Mr. Fazlu (Figure 5.3 and 5.4). Due to gravity force, naturally irrigation water seepage / passed from upper elevation to lower elevation. Therefore, Mr. Fazlu had to more irrigate due to water loss. But when Mr. Akbar stopped his irrigation business, then Mr. Fozlu has increased command area comparatively less fuel cost from 4.11 to 9.56 hectares by utilizing the land slope from 1997 to 2007 respectively.

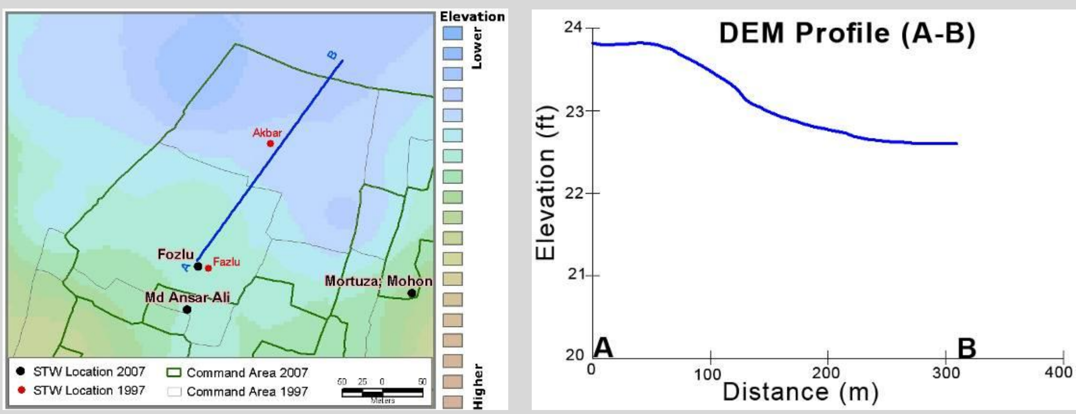


Figure 5.4: Digital Terrain Model (DTM) showing the slope profile between two STW.

5.3.3 Land use pattern of Saitapara Mouza

Plot-wise land use is prepared from mauza map of 1997 (Mandal, 1997) and also plot-wise land use map of 2007 (Hossain and Moududi, 2009) and plot-wise land use map of 2017 is prepared from the field survey of January 2017. Here it is needed to mention that land use pattern of 2007 and 2017 were the same. There is no significant change found in land use (Figure 5.5) of the Saitapara mauza over last twenty years since 1997. Only two small plots went under irrigation area in 2007, which were previously covered by sand.

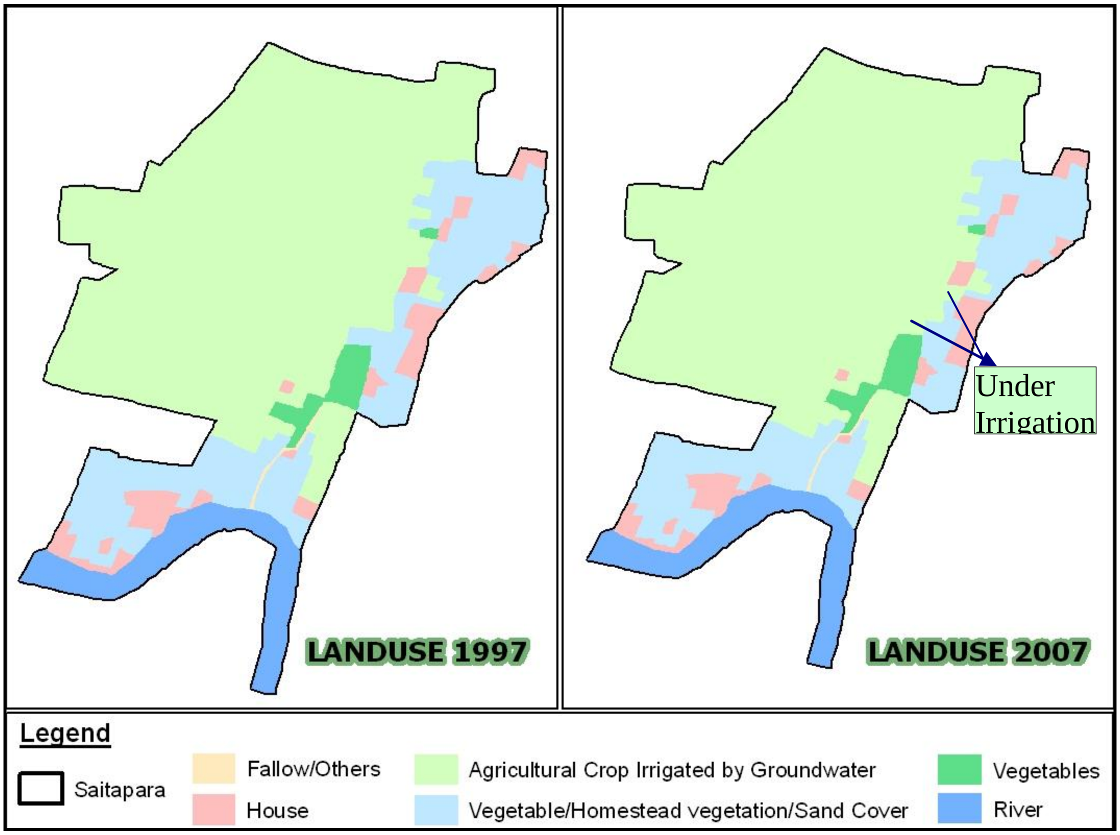


Figure 5.5: Landuse pattern of Saitapara mauza since 1997

5.3.4 Cropping Pattern Analysis of Kurmurshi Mouza

In Kurmushi mauza, Mortuz Ali has a STW covering about 4.4 hectares of land consisting 56 plots. There are seven different cropping patterns (Figure 5.6) found in 2016 cropping year in such a small command area. The main cropping patterns were Boro-B.Aman-Mustard and Boro-T.Aman-Mustard in the study area. The variations are due to the different land elevations, where the western part of the command area is higher and the eastern part is lower. Vegetables are grown on higher lands and Boro-Aman are grown on lower lands. Even where Aman is grown, comparatively higher lands are used for growing transplanted Aman and lower lands for broadcast Aman. Such diversified cropping pattern is also due to different soil type. The western and south-western parts of the command area which are near to the STW are mostly composed of sandy soil and this type of soil is good for vegetables. This sandy soil mainly comes from the abandoned sand bars of the nearest Kalidaha River. On the other hand, the eastern part of the command area is mostly composed of Silty clay and that is good for paddy cultivation. The small part of the village has such micro variations. This influences the irrigation, initial investment and also cash flow. The intensity and management of irrigation of the command area is not uniform. Mostly one irrigation and in some cases two irrigations are needed for vegetables to grow over the cropping period. The cost of irrigation for vegetables is BDT 100-200 per irrigation per plot, whereas it is one-fourth share of the crop for Boro rice.

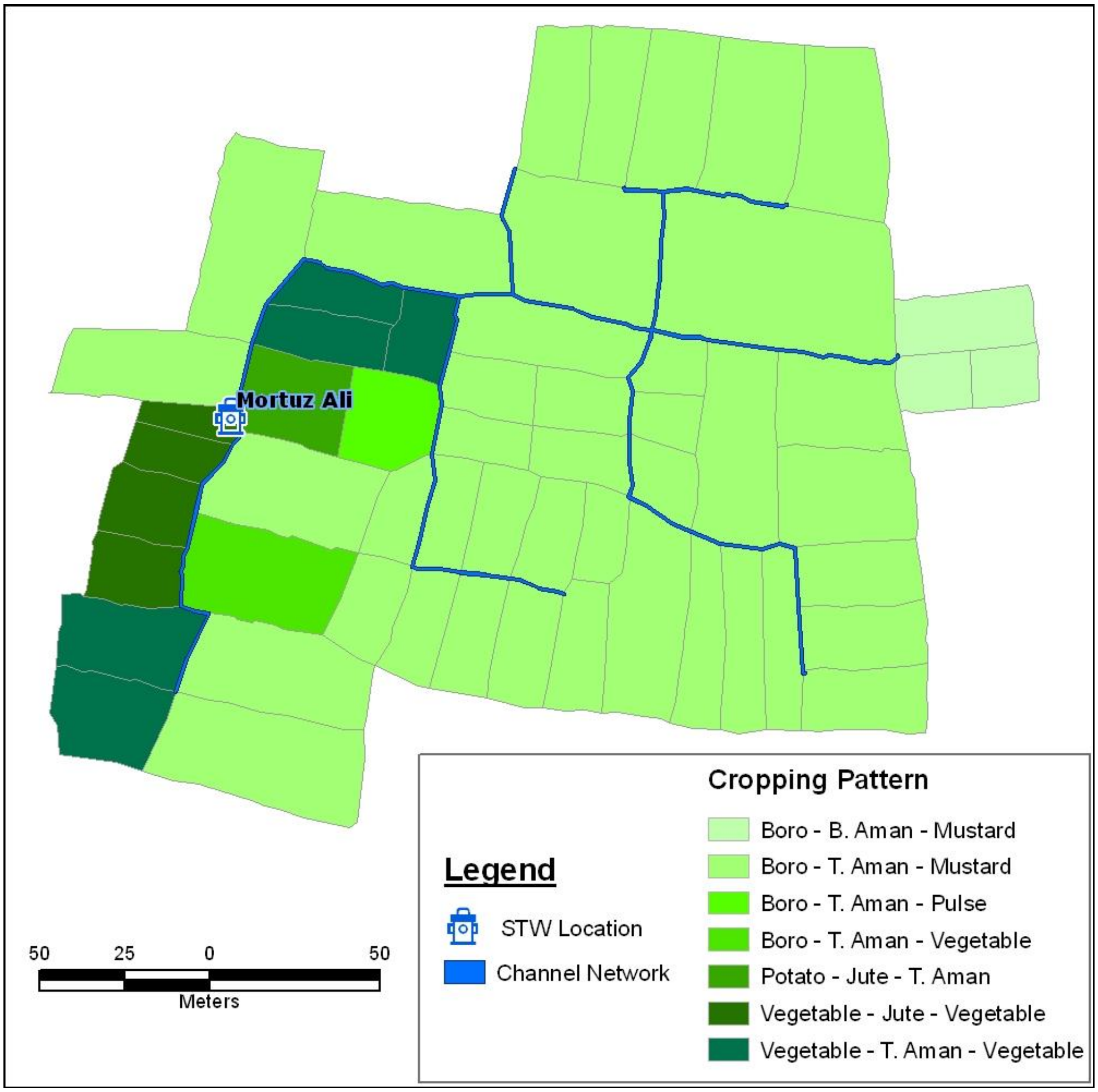


Figure 5.6: Cropping pattern of a command area in Kurmushi mauza in 2016

5.3.4 Cropping Pattern Analysis of Saitapara Mouza

There is also simple cropping pattern present at Saitapara mauza of the study area. For example, A STW of Bozlu in Saitapara covers about 2.19 hectares of land which consists of 20 plots in the command area. The cropping pattern of the command area is Boro-B.Aman-Mustard in normal flood year. Such a small command area has land elevation variation. Flood water was a little bit higher in the last year (2016) and that is why broadcast Aman paddy was damaged in the lower elevated lands but the crop on the higher elevated land survived. Figure 5.7 shows that four plots do not have direct connection with the water distribution channel of the STW. Actually these plots are lower in elevation than the other plots of the command area and thus do not have channel connection but get irrigation water by seepage and overflow through higher elevated lands.

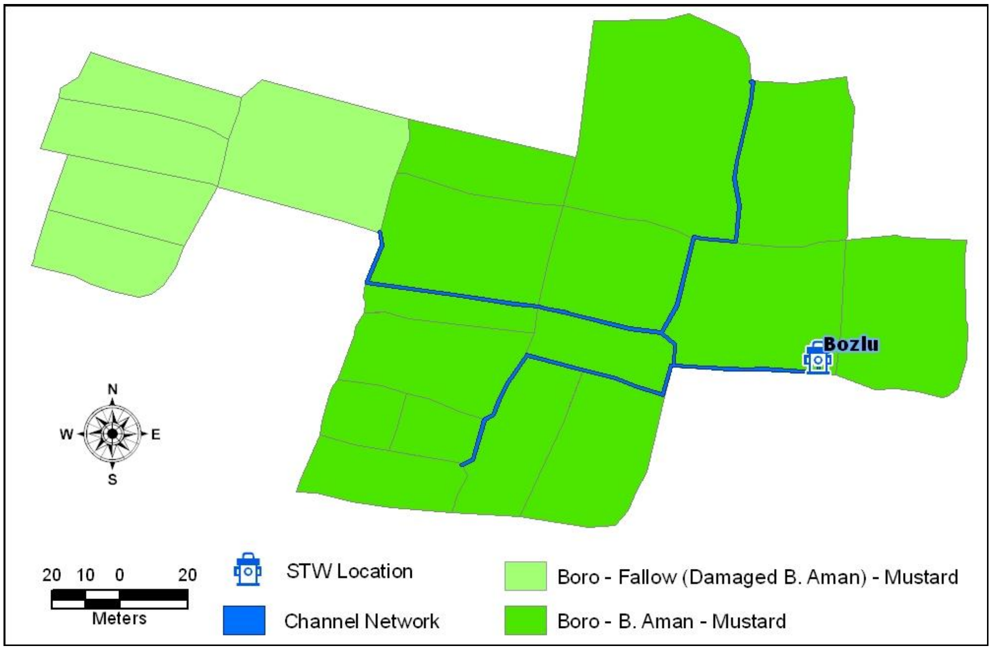


Figure 5.7: Cropping pattern of a command area at Saitapara mauza in 2016

5.4 CONCLUSION

This research study concluded that mainly two types of irrigation equipment used to abstract groundwater for the Boro paddy cultivation in the study area in the past up to 2007. They were diesel operated STW (DOS) and electricity operated STW (EOS). But at present (2017), there was no exists of DOS in the study area, only EOS is running. The study revealed that in 1997, DOS was 76% and EOS was 24%, while in 2007 those were 46% and 56% respectively and in 2017 those were 4% and 96% respectively. The last twenty years since 1997 using of DOS has been decreased and using of EOS has been increased 40% respectively. In addition, STWs location and command areas were changed little bit and there was no significant change found in land use pattern over last twenty years since 1997 in the study area. The research findings also showed that there were seven different cropping patterns found in the study area. Main cropping patterns were Boro-T. Aman-Mustard and Boro-B. Aman-Mustard. Diversified cropping pattern was found in the study area due to the different soil type and the different land elevations.

It was observed during field survey of this study that most of the farmers are using Chinese motor, though there are some other motor from different country's origin. It may be due to fewer prices of Chinese motor and available spare parts in the market. It also may be due to high price of diesel cost and less operation cost of electricity STWs. However these should be studied for further validation. In this perspective, further study is needed to be conducted to investigate 1) why most of the farmers were using Chinese motor, 2) the characteristics of those motors and 3) hydraulic, agricultural and economic performance of STWs. Therefore, further research focuses about evaluation of STW equipment characteristics and performance (hydraulic and agricultural) of EOS in Chapter 6 and financial analysis in Chapter 8.

Chapter 6

EVALUATION OF STW EQUIPMENT CHARECTERISTICS AND STW IRRIGATED SCHEMES USING PERFORMANCE INDICATORS

Chapter 6

EVALUATION OF STW EQUIPMENT CHARECTERISTICS AND STW IRRIGATED SCHEMES USING PERFORMANCE INDICATORS

6.1 INTRODUCTION

Three classes of irrigation systems like (i) publicly managed major flood control, drainage and irrigation projects, (ii) privately owned and operated minor irrigation schemes, and (iii) non-mechanized and traditional indigenous systems exists in Bangladesh. Minor irrigation systems comprise of deep tube wells (DTWs), shallow tube wells (STWs) and low lift pumps. The DTWs operate on force mode with submersible pumps in the wells and have a normal design discharge capacity of 57 l/s. The STWs operate on suction mode with centrifugal pumps above ground surface and have a normal design discharge capacity of 14 l/s (DAE, 1994 and Mandal, 1997). The DTWs are generally 100 m deep, require rigs for installation and were installed by the government in the past. They have now been privatized and owned as well as operated by cooperative basis. The STWs, on the other hand, are generally 40–60 m deep, manually installed and privately owned and operated. Both, DTWs and STWs, generally pump from the same aquifer, but because of larger investment cost and intricate operation and management, the number of active DTWs has steadily declined after privatization (Mandal, 1997).

The contribution of minor irrigation to total irrigated area (3.8 million ha) during 1996-97 was about 91% (3.4 million ha). Out of this, 2.2 million ha (63%) was irrigated by about 630,000 STWs and 0.5 million ha (14%) by about 25,000 DTWs and the rest by low lift pumps (NMIDP, 1998). Both, DTWs and STWs, use groundwater for irrigation and the performances of most of these tube wells in the past have not been satisfactory because of poor layout, construction and maintenance and consequent water losses in the canal system and institutional constraints (Biswas and Mandal, 1982). Much research had been conducted in Bangladesh to evaluate the performance of minor irrigation systems. From the review of literatures (Mirjahan, 1984; Akteruzzaman et al., 1993; DAE, 1994; IIMI-BSERT, 1996; Rashid and Mridha, 1997), however no evidence was found that an orderly and analytical procedure or methodology was followed in evaluating the performance of these projects. The approach was taken in the evaluation studies, heavily biased towards socio-economic aspects with attention to agronomic issues. Again no evidence was found regarding mis-match among STW components or equipments. It is often asserted that, because of the import liberalization policy, engines and motors of different BHP are being imported and this equipment is being used by farmers without consideration to the actual power requirements under the prevailing field conditions (IIMI-BSERT (1996), which leads the poor efficiency of the STW performance. With increasing population and demand for food, sustainable increases in production from irrigated agriculture must be achieved. So, this study was taken up for a holistic evaluation of some STW irrigated schemes using a set of standard performance indicators. The specific objectives of this study were: to evaluate the STW equipment characteristics and the mis-match among the STW components, to evaluate the performance of STWs selecting a practical and useful set of indicators for the study area.

6.2 MATERIALS AND METHODS

6.2.1 Study area

The experimental site or study area was within Dighalkandi union, which was under Ghatail Upazila of Tangail district in Bangladesh. The study area comprises of five Mauzas of Dighalkandi union namely Kagmari Beltail, Saitapara, Kurmushi, , Kaijalipur and Shekh Shimul (Fig. 4.1).

6.2.2 Performance indicators

Performance of a system was represented by its measured levels of achievements in terms of one or several parameters, which were considered as indicators of system's goals. The process of performance evaluation consists of specifically measuring the extent to which the goals were being met at the end of a given time and, thus requires that all the relevant inputs and outputs were evaluated. This evaluation was done through performance indicators. Evaluation of performances of the selected DOS and EOS schemes was carried out using a standard set of performance indicators. Before selecting the indicators, the performance indicators suggested by Abernethy (1989), Molden and Gates (1990), Bos *et al*. (1993) and Molden *et al*., (1998) were thoroughly reviewed. The indicators, thus, selected were broadly classified as hydraulic, agricultural and socio-economic.

6.2.2.1 Hydraulic indicators

Hydraulic indicators deal with the lifting, conveyance and delivery of irrigation water from the source (tube wells) to the farmers' fields by management of irrigation facilities. The hydraulic indicators used in the performance evaluation were as mentioned below:

Delivery performance ratio (DPR): The simplest and probably the most important hydraulic performance indicator is:

$$DPR = \frac{\text{actual discharge}}{\text{target discharge}}$$

Target discharge of a tubewell was the standard design discharge of its pump and was taken as 14 l/s for STW (DAE, 1994). The target discharges were based on pump horsepower and drawdown-discharge–efficiency relationship.

Water delivery performance (WDP): Over a sufficiently long period of time (at least an irrigation season), it was more useful to modify the DPR by changing discharge into total volume of water pumped during the season. This results in a slightly different indicator:

$$\text{WDP}=\frac{\text{actual volume of pumped}}{\text{target volume of pumping}}$$

Since, no data on target volume of pumping during irrigation season was available; MPO (1985) reported national average seasonal operating hour was multiplied by the target discharge to obtain target volume of pumping.

Conveyance loss ratio: This ratio, which indicates the relative amount of water loss in a canal reach due to canal seepage, leakage, over flow, etc., was defined as:

$$\text{Conveyance loss ratio}=\frac{(\text{inflow}-\text{outflow})}{\text{inflow}}$$

Inflow and outflow from a canal reach may be in either discharge or volume units.

Overall reliability: The pattern in which water was delivered over time may significantly affect the overall adequacy of water delivered and, hence, had a direct impact on crop production. The rationale for this was that water users may be less efficient in water use if there was an unpredictable variation in volume or timing, and they may not use other inputs, such as fertilizer in optimal quantities if they were more concerned with crop survival than crop production. The indicator used for measuring reliability is a composite of two different elements, the water delivery performance indicator and the reliability of timeliness. This was expressed as:

$$\text{Overall reliability}=\frac{(\text{volume delivered})}{(\text{target volume})}\text{X}\frac{(\text{actual duration of supply})}{(\text{target duration of supply})}$$

Equity: Two simple indicators, tail:head and tail:middle equities of depths of water delivered, were used in the present study to evaluate the equity performance of the selected STW schemes.

6.2.2.2 Agricultural indicators

Agricultural indicators measure the contribution of irrigation activity to the economy in relation to consumption of the increasingly scarce resource, water. The main outputs (actual irrigated area, crop yield and crop production) of the major inputs (water, land and finances) in an irrigated agricultural system were directly reflected by these indicators. The agricultural indicators used in the performance evaluation were as following:

Irrigated area ratio: This indicator becomes more important where water is a limiting resource towards irrigation development. The indicator was expressed as:

$$\text{Irrigated area ratio}=\frac{(\text{actual irrigated area})}{(\text{target irrigated area})}$$

Potential command areas (target irrigated areas) had been computed by DAE (1994) based on pump capacities and crop water requirements and for STWs target irrigated areas was computed 8 ha.

Yield ratio: This indicator becomes more important, where land was a limiting resource towards irrigation development. The indicator was expressed as:

Yield ratio= $\frac{\text{actual yield}}{\text{target yield}}$

The potentially achievable yield of 6 t/ha for high yielding variety (HYV) rice based on optimum inputs and favorable climate had been taken as the target yield (DAE, 1994).

Production ratio: This was the most useful agricultural indicator to evaluate irrigated agricultural systems, where both water and land were limiting resources towards irrigation development. The indicator was the multiplication of the area and yield indicators and was expressed as:

Production ratio= $\frac{\text{actual production}}{\text{target production}}$

Target yield of Boro rice was multiplied by the target command area to obtain target production and actual yield was multiplied by the actual command area to obtain actual production.

6.2.2.3 Socio-economic indicators

The socio-economic indicators relate to long term impacts of pursuing a particular set of operational and agricultural strategies. Their main utility is to address concerns that may have greater value to policy makers than to irrigation system managers. The socio economic indicators used in the performance evaluation were as mentioned below.

Total financial viability (TFV): This describes the overall financial viability of the irrigation system. In recent years, there has been increasing concern over the level of recurrent costs required to keep irrigation systems functioning and substantial efforts have been made to raise revenues from water users to meet operation and maintenance (O&M) costs and often some or all of the capital costs. The indicator is defined as:

TFV=$\frac{\text{irrigation fees imposed}}{\text{total O} \& M\ cost}$

In the present study, the local market price of the share of paddy (usually one-fourth) taken by the pump owners from the farmers as irrigation fees was taken as irrigation fees imposed. Seasonal capital recovery cost and O&M cost together constitute the total O&M cost.

Fee collection performance: This indicator is used where the irrigation agency collects money from farmers as irrigation fees. The indicator is expressed as:

Fee collection performance=$\frac{\text{irrigation fees collected}}{\text{irrigation fees imposed}}$

Profitability of farmers: This indicator deals with the profitability of farmers at the individual farm level. The indicator is defined as:

$$\text{Profitability of farmers} = \frac{\text{incremental benefit of irrigation per ha}}{\text{irrigation fee per ha}}$$

Incremental benefit of irrigation is the difference in net benefit between an irrigated rice crop and a non-irrigated non-rice crop (for example, wheat). The non-rice crops are not present in any irrigation scheme under study. They are grown in non-irrigated lands, which are similar and adjacent to the schemes under study.

Sustainability of irrigated area: This is the basic indicator on which strategic management depends. Looking at the trend of the indicator over a period of time (a few years), relevant agency/person can take necessary interventions to tackle problems (if any). This indicator is expressed as:

$$\text{Sustainability of irrigated area} = \frac{\text{current irrigated area}}{\text{initial irrigated area}}$$

6.2.3 Field data collection procedure

The primary data were collected through questionnaire surveys (interview schedule) from STW owners and direct measurement from field level in 2016 and 2017 Boro season (December-May). A field survey was carried out to evaluate the STWs equipment's characteristics of the study area. In this regard, data / information were collected about nominal brake horse power (BHP), nominal revolution per minute (RPM) and country of origin of the prime movers (engine and motors) and pumps, capacity of pump, pipe size, boring depth etc. were collected through a prescribed questionnaire and levelling plate attached with the engine/motor. But in many cases investigator didn't find it due to old and aged engines and pumps. Actual RPM of the pump (using a tachometer) were measured in the field during survey.

The STW owners were interviewed through a prescribed questionnaire in order to gather additional information on the frequency and nature of breakdown, energy (diesel or electricity) consumption per hour by the prime movers. For diesel engines specific fuel consumption was calculated by total used diesel dividing diesel used per hour by nominal brake horse power. The STW owners were also asked about their opinion on the quality of the equipment and on their preference between different brands. Besides this, a focused group discussion was made through three set of checklist with different stake holders such as pump owners and irrigators, STW installer, STW operators/drivers/managers, STW mechanics and Electric motor mechanics, irrigation equipment traders, complementary import dealers and support service providers in order to obtain different types of information regarding STW irrigation technology and profitability of Boro rice production.

The questionnaire was reviewed and revised after field testing during the 2015-2016 dry season. To assess business in both DOS and EOS and also to assess the hydraulic performance and agricultural performance of STW, firstly 12 STWs were selected randomly from all including 2

DOS and 10 EOS. Equal representation of farmers from the head, middle and tail end of each scheme was ensured during the sampling of farmers.

To assess hydraulic performance of STWs different indicators such as delivery performance ratio (DPR), water delivery performance (WDP), conveyance loss ratio, overall reliability, equity were measured in the field level through direct measurement. To assess agricultural performance of STWs different indicators such as irrigated area ratio, yield ratio, production ratio, water productivity and land productivity were measured in the field level through direct measurement.
To investigate the irrigation channel characteristics (dimensions), data were also collected through direct measurements from selected 20 STWs irrigated schemes of the study area and data were analysed. Pearson Correlation test/analysis was done to assess the implication of mismatches between engines and pump capacity, between discharge and engine capacity (BHP), between discharge and size of distribution channel in operating the irrigated schemes,.

Data on discharges of STWs, conveyance losses in the irrigation canals, flow velocity and surface area and cross section of irrigation canals were collected through direct measurements in the field. Pump discharge was measured by volumetric method. For this purpose a 240 litres capacity of container and a stop watch to calculate time elapsed to fill the container were used. In addition discharges were measured with the propeller type current-meter. Area–velocity method with one point velocity measurement was used to compute discharges at 0.6 depths. To find conveyance losses in the irrigation canals, the inflow–outflow method was used with generally 50 m sections for STW schemes.

The secondary data were collected from Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC), Center for Environmental and Geographic Information Services (CEGIS) and Department of Land Records and Survey (DLRS), Department of Agricultural Extension (DAE) etc. In addition different published journals, different reports, books, articles, News paper and internet were also taken as a crucial source of secondary data.

6.3 DATA ANALYSIS, RESULT AND DISCUSSIONS

6.3.1 Technical Characteristics of STWs irrigation Equipment

There was almost similar characteristics pump-engine in the study area. Most of the STW owners were used generally 1 cusec pump and 5.5 HP to 7.5 HP motor/engine for irrigation purpose. They were habituated to use such type of pump-engine. In few cases there had been seen 8-10 HP motor/engine for irrigation purpose; however their command area was little bit bigger. Most of the engines are Chinese and Japanese.

All STW owners were used 4 inch diameter pipe in delivery side. In some cases, there was same diameter pipe both in suction side and delivery side. But most of the cases, STW owner installed or bored 5 inch diameter pipe, but using T they have used 4 inch diameter pipe in suction side. To get sufficient water in pump casing and to avoid cavitations they followed such type of technique.

6.3.1.1 Brake Horse Power (BHP)

In the study area, the Brake Horse Power (BHP) of the engines and motors were investigated. My survey data revealed that BHP varied a great deal. For diesel engines the horse power ranged from 5 to 7.5 hp for STW (Table 6.1a). Similarly, electric motor power for this system ranged from 5 to 10 hp (Table 6.1b). These wide ranges would indicate a somewhat indiscriminate selection of prime mover power.

Table 6.1a: Nominal Brake Horse Power (BHP), Revolutions Per Minute (RPM) and fuel consumption by diesel operated STWs in the study area.

BHP range (HP)	**Country of Origin**	**Average nominal RPM**	**Average diesel consumed (liter/hr)**
5.0-6.0 (2)	China (2)	2041	0.568

Note: Figure in parenthesis indicates number of engine.
(Source: Field survey, 2015-2016).

Table 6.1b: Nominal Brake Horse Power (BHP), Revolutions Per Minute (RPM) and electricity used by electrically operated STWs in the study area.

BHP range (HP)	Country of Origin	**Average nominal RPM**	**Average electricity consumed (kwh/hr)**
5.0-6.0 (20)	China (12)	1426	6.00
	Japan (2)	2500	8.00
	England (1)	1465	8.00
	Unknown (5)	1417	7.00
6.5-7.5 (20)	China (10)	1440	8.00
	Japan (2)	2500	6.00
	England (4)	2200	7.00
	Unknown (4)	-	7.00
8.0-12.0 (5)	China (4)	1448	5.12
	Unknown (1)	1500	7.00
Unknown (3)	Unknown (3)	1500	7.00

Note: Figure in parenthesis indicates number of motor.
(Source: Field survey, 2015-2016).

6.3.1.2 Nominal RPM of Prime Movers

The speeds of the engines varied widely. The investigation revealed that the nominal RPM of the diesel engines ranged 2041 (Table 6.1a). The nominal RPM of the electricity engines / motors ranged from 1417 to 2500, which was more or less similar to that of the diesel engines (Table 6.1b).

6.3.1.3 Energy Consumption

The choice of engines of different horse powers would normally lead to different levels of fuel consumption. It was desirable to maintain low fuel consumption for efficient burning, optimal heat energy and keeping within a satisfactory range of specific fuel consumption (SFC) between 0.21 to 0.29 liter/bhp/hr (Micheal and Khepar 1992).

The average fuel consumption of different engines for STWs was calculated based on the information collected from STWs owners. For the diesel engine, the range was from 0.56 liter/hr to 1.13 liter/hr (Table 6.1a). Fuel Consumption of Chinese and Japanese engines (operated by diesel) was on average 0.86 and 1.02 liter/hr respectively. The Chinese engines' low or comparable fuel consumption, coupled with their much lower price, can be expected to induce farmers to purchase Chinese engines. The electricity consumption of the STWs varied from 5.12 to 8.00 kwh/hr with an average of 7.00 kwh/hr (Table 6.1b). The Chinese electric motors, because of their smaller size, consumed a lower amount of electricity as compared to others.

6.3.1.4 Breakdown of the Engine

The breakdowns of engines may occur during irrigation period and it may be either major or minor depending on which part broke or malfunctioned. In the study area, failure of bearings or breakage of crankshaft and replacement of piston assemblies were the major ones and affected irrigation. Minor breakdowns were replacement of oil seals, nozzles, plungers etc. and it was happened frequently. A study also stated that minor breakdowns were happened frequently. The repairs of major breakdowns were often delayed due to lack of availability of workshop facilities in the rural areas. The repairs of minor breakdowns were easily repairable by the rural mechanic subject to availability of replacement parts in the market (IIMI-BSERT, 1996). It was revealed from my questionnaire survey that availability of spare parts as well as mechanics was not a constraint towards regular maintenance of STWs. It was also reported that electric motor's break down occurred less frequently than diesel engines and repairing of electric motor required longer time than diesel engine which hampered irrigation. From the Focussed Group Discussion (FGD), it was observed that the aged Japanese engines had broken down more frequently than the cheaper (but newer) Chinese engines. The average breakdown duration was 2-3 days for diesel engines.

6.3.1.5 Country-wise share of engine in the study area

Country-wise share of engine in the study area was shown in the Table 6.2. The Chinese engine/motor was widely used in the study area as well as all over the country. The reason for high popularity of Chinese engine/motor is its early availability and cheaper price. Field survey data revealed that although Japanese and English STWs engines were preferred by pump owners (if price was not considered). Equipment purchasers have gone for cheaper engine/motor, even with a perceived lower level of durability and a higher rate of breakdown.

Table 6.2: Country-wise share of engine in the study area.

Origin of Prime Mover	Diesel operated	Electrically operated	Total	Percent
China	2	26	28	56
Japan	0	04	04	08
England	0	05	05	10
Unknown	0	13	13	26
Total	2	48	50	100.00

(Source: Field survey, 2015-2016)

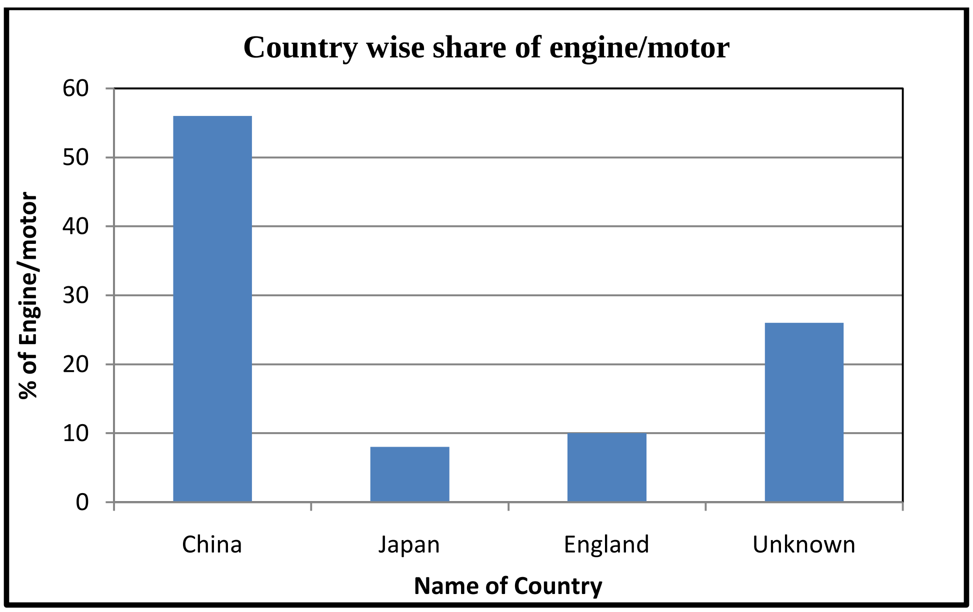


Figure 6.1: Country-wise share of engine in the study area.

6.3.1.6 Command area (C/A) under different engine capacity

Average Command area under different engine capacity was shown in Table 6.3. Table 6.3 showed that engine capacity ranged from 6.5 to 7.5 HP belonging higher C/A comparatively others and field survey data revealed that most of these engines are electrically operated providing with partnership. Mandal (1997) also stated that small farmers' share of STW ownership has increased significantly over the years in Bangladesh. Those farmers who were unable to get electric connection to their engine due to high charge of electric connection fee and also not potential in social, they were running their business by low capacity engine (5.0 to 6.0 HP) comprising less average command area.

Table 6.3: Average Command Area (C/A) under different engine/motor capacity.

BHP range (HP)		Average C/A (ha)
5.0-6.0	(22)	3.55
6.5-7.5	(20)	4.25
8-12	(5)	3.75
Unknown	(3)	2.72

Note: Figure in parenthesis indicates number of engine/motor.
(Source: Field survey, 2015-16)

6.3.2 Technical Performance of STWs

6.3.2.1 Hydraulic Performance

6.3.2.1.1 Delivery performance ratio (DPR)

Average discharges of DOS and EOS during 2016 Boro season (January-May) were 15 and 16 l/s, respectively. Target discharge of a tubewell was the standard design discharge of its pump and was taken as 14 l/s for STW (DAE, 1994). The average DPR was found to be 1.07 for DOS and 1.14 for EOS schemes. National average discharges of DTWs and STWs were 46 l/s and 12 l/s, respectively (MPO, 1985). This indicates that the present average discharges of both DOS and EOS of the study area were well above the then respective national averages.

The average pump discharge of the 12 STW was 15.5 liter/sec measured in January-May, 2016. The discharge range of 12 STWs was 10.00 to 26.72 liter/sec in the study area based on pump-engine capacity. Both discharges were similar due to similar characteristic aquifer in the study area, which was discussed in chapter 4. Though same BHP of engine and same diameter of installation pipe, discharge may be varied due to strainer length and position (vertically), type of aquifer, height of drawdown etc. To determine pump discharge volume method was followed[1]. The rate of flow was measured by the following formula:

$$\text{Discharge rate (litres/sec)} = \frac{Volume\ of\ container}{Time\ required\ to\ fill}$$

1 Firstly, we tried to measure pump discharge using X-Y coordinate method, but it was not possible due to wide spreading of water from the delivery pipe. Then we tried to measure pump discharge by Velocity-Area method. Due to low water depth and narrow channel, Velocity-Area method also was not appropriate at the field condition. For this reason, we measured pump discharge by volumetric method. We used a 240 liter capacity of container and stop watch to calculate time elapsed to fill the container. Pump discharge of 12 STWs were measured in the study area.

Figure 6.2: Showing measurement of pump discharge in the study area.

6.3.2.1.2 Water delivery performance (WDP)

Average seasonal operating hours of DOS and EOS were found to be 1127 h and 1054 h respectively, in the study area. Earlier, the average seasonal operating hours were 1223 h for DTWs and 1216 h for STWs (MPO, 1985). This indicates that averages of the seasonal pumping hours of both DOS and EOS of the study area were below the then respective national averages by about 100 h and 160 h, respectively. WDP was found to be 0.85 and 0.98 for DOS and EOS, respectively. WDP of EOS was better than that of DOS because the actual discharge of EOS was higher than its target discharge.

6.3.2.1.3 Conveyance loss ratio

Conveyance loss in the irrigation canal depends upon whether it was lined or unlined. In STWs (both for DOS and EOS), which were unlined, the average loss per 100 m was 2.75 l/s (18.33% of the discharge). In a study, Dutta (1993) found an average conveyance loss of 4.5 l/s per 100 m length of canal for four DTWs and 2.6 l/s for four STWs. Thus, the average conveyance loss found in the present study was comparable with that of the past studies.

6.3.2.1.4 Overall reliability

Overall reliability of water deliveries was found to be 0.86 and 0.82 for DOS and EOS, respectively. So, in both the DOS and EOS schemes of the study area the volume of water supplied and the duration of the supply are close to their respective targets and the schemes can be considered as reasonably dependable.

6.3.2.1.5 Equity

To evaluate the equity of water deliveries, three farmers from head, middle and tail ends of each irrigation scheme were interviewed three times during 2016 Boro season (January-May) regarding the availability of water in terms of depth. The equities thus obtained are given in

Table 6.4. Equity or spatial uniformity in water delivery was not met for both DOS and EOS schemes. This happened because of frequent electric disruptions, inadequate canal lengths and inadequate maintenance of irrigation canals (lack of timely cleaning of vegetation from supply canals, non-closing of rat holes and cracks that developed in the canal embankments, inadequate canal section resulting in overtopping of embankment, etc.), which hampered the supply of water to the tail end farms. The average irrigation canal density was more or less similar which 58 m/ha for DOS and 60 m/ha for EOS. Dutta (1993) found an average canal density of 190 m/ha for DTWs and 206 m/ha for STWs.

Table 6.4: Head:tail and middle:tail equities of DOS and EOS schemes

Type of tubewell	Tail:head equity	Tail:middle equity
DOS	0.50 (0.45–0.57)*	0.52 (0.50–0.54)
EOS	0.45 (0.36–0.54)	0.55 (0.53–0.57)

*The values within the brackets indicate range.

6.3.2.2 Agricultural performance

6.3.2.2.1 Irrigated area ratio

Average command areas for DOS and EOS were found to be 2.80 and 3.30 ha respectively in the present study. Irrigated area ratio was found to be 0.35 and 0.41 for DOS and EOS respectively. In the past, average command areas of STW were 4.3 ha (MPO, 1985). Another study, an average command area of 3.4 ha per STW was reported by NMIDP (1998). So, the average command areas in the present study were comparatively low the respective national average command areas. As per Halcrow and Partners, (1998) and BADC (2002), the C/A per STW was constant (4 hectare) for the years 1982-83 to 1992-93, but has continuously declined since then. From 1993-94 to 2000-01 there has been a continual decrease in the C/A per STW and over 8-years above period, the C/A per STW has been reduced by about 34% over the country. As per Minor Irrigation survey Report of BADC (2011), area irrigated per STW was 2.26 hectare. So, there was found similarity between present and past in terms of C/A in the study area.

6.3.2.2.2 Yield ratio

Average yield of HYV Boro rice of the study area during 2016 Boro season (January-May) was given in Table 6.5. The yields of 2016 Boro season (January-May) were more than the average national yield. Average national yield of 4.13 t/ha of HYV Boro rice was reported by Bangladesh Bureau of Statistics (BBS, 1997). The higher yield was due to the application of high doses of urea (fertilizer), adequate and dependable irrigation water deliveries, favorable weather, less insect attack, etc. However, the yield was less than the target yield at national level (6.0 t/ha). Yield ratio during 2016 Boro season (January-May) was found to be 0.76 for DOS and 0.86 for EOS.

Table 6.5: Average crop yields of STW schemes during 2016 Boro season

Type of Tube wells	Average yield in 2016 (t/ha)	Average national yield of HYV Boro rice (t/ha)
DOS	4.935	4.13
EOS	5.581	

(Source: Field survey, 2016)

6.3.2.2.3 Production ratio

The production ratio during 2016 Boro season (January-May) was 0.35 and 0.41 for DOS and EOS respectively.

6.3.2.2.4 Land Productivity (LP)

Land Productivity (LP) or Yield may be defined as the production of any crop from a unit area of land. Average LP of 12 STW (2 DOS and 10 EOS) has shown in the following Table 6.6 and it seemed to be similar. However, an individual LP of 12 STWs scheme has shown in the Annexure-6. The average Land Productivity of the study area was 5483 Kg/ha. For diesel engine, the average Land Productivity was 4935 Kg/ha and for electric engine, the average Land Productivity was 5593 Kg/ha (Table 6.6) which were more or less similar with a study by Zahid (2006). Zahid research finding stated that the average land productivity or average yield of the Boro rice by STW irrigation was 5152 Kg/ha. However, LP depends on many factors such as required amount fertilizer application in proper time, fertility of land, quality of seed, required irrigation application in proper time etc.

Table 6.6: Average Land Productivity of 12 STWs in the study area.

Type of Engine	Total C/A (ha)	Total Production (kg)	Land Productivity	
			kg/ha	t/ha
Diesel	5.64	27834	4935	4.935
Electric	35.72	199360	5593	5.593

(Source: Field survey, 2016)

6.3.2.2.5 Water Productivity (WP)

To determine water productivity (WP), it was needed to know the total hours of operation of an engine/motor in a whole season. The hours of engine operation depends on many factors, such as capacity of engine-pump, availability of electricity, availability of diesel, planting time duration within a command area, rainfall, size of command area etc. The exact number of hours of operation was almost impossible to derive from the STW owners or drivers. But, it is possible to determine how much water was applied in a season, based on the quantity of fuel consumed and discharge by a STW in a season. For electricity operated STWs, the operation time was a little bit higher than that of diesel engine, because of there was no metering system.

WP may be defined as the ratio between amounts of water applied and amount of crop produced from a land in a season. In other words, WP means the amount of water needed to produce one unit of crop. Average WP of 12 STW (2 DOS and 10 EOS) has shown in the following Table 6.7. However, an individual WP of 12 STWs has shown in the Annexure-7. The average WP of the study area was 3.271 M^3/kg. For diesel engine, the average WP was 3.148 M^3/kg and for electric engine, the average WP was 3.298 M^3/kg (Table 6.7). Zahid (2006) research finding stated that the average WP for *Boro* rice by STW irrigation was 3.70 M^3/kg, which is more or less similar with this study. Moya and Rust (1985) noted that the average yield efficiency was 0.23 kg of rice per cubic meter of water applied at the farmer's field in the Philippines. It is seemed that my study result is less than the Moya and Rust and more or less similar result.

Table 6.7: Average WP of 12 STWs in the study area.

Type of Engine	Water Productivity (M^3/kg)
DOS	3.148
EOS	3.298

(Source: Field survey, 2016)

From the above table, it was seen that WP for electric engine was higher than for diesel. The reason was pump owner had to pay fixed bill to the electricity supplying authority based on pump-engine capacity. For this reason, they run their engine longer time compared to diesel engine and they always try to store sufficient water in the field and to avoid any breakdown of engine/motor which hampers pumping of water.

6.3.2.3 Socio-economic performance

Total financial viability (TFV): The irrigation business in the study areas was highly profitable in the present situation (2017) because IRR was quite higher than bank rate (10 percent). Details are shown in Chapter 8. Though, the IRR of DOS was 34 % which was much lower than the IRR estimated in other study (IIMI-BSERT, 1996), but the IRR of EOS was 363 % which was much higher than the IRR estimated in study (IIMI-BSERT, 1996). This indicates that the STW owners of the study area are highly benefited by selling irrigation water.

The lower IRR rate for DOS in present situation clearly proved that the IRR rate decreased over time mainly due to increase of diesel price and repairing costs. On the other hand, lower electric charges compared to fuel and lubricant costs and coverage of higher command area by EOS promoted the irrigation business, which proved to be more profitable than DOS.

Fee collection performance: Fee collection performance was exactly 100% for both DOS and EOS schemes, since a share (usually one-fourth) of rice is harvested by the pump owners directly from farmers' fields as irrigation fee.

Profitability of farmers (Boro rice production): Data of sector wise input cost, labor cost, irrigation cost and net benefit of growing HYV Boro rice is shown in Table 8.5 (Chapter 8). The analysis shows that amongst the four categories Table 8.6 (Chapter 8), when all inputs including land and labor are hired (category 1), production of irrigated rice was not profitable. Production of irrigated rice was highly profitable when grown by farmer in his own land with family labor (category 4) (Table 8.6 and Figure 8.6). In this case, returns to family labour were Tk. 560 per man-day in 2017, which was quite higher than normal wage and it indicated that Boro rice production was a competitive business in rural market and was strongly able to compete with other business. In cases of all inputs hired except labor (category 2) and all inputs hired except land (category 3), irrigated rice was reasonable profitable and marginally profitable to the farmers respectively.

Sustainability of irrigated area (SIA): Average SIA was found to be 0.91 and 0.96 for DOS and EOS, respectively. Also, it was found that though the DOS and EOS were on an average 11 and 12 years old, yet the tube wells were performing well and the sustainability of irrigated area for both DOS and EOS can be considered as satisfactory.

6.3.3 Water Distribution System

6.3.3.1 Channel Characteristics

There is almost trapezoidal characteristic of channel in the study area. All field channels in the study area were Kutccha (made by clay soil) and it was sufficient to carry the water for irrigation purpose. There was not observed any overtopping during the operation of the pump. However, in some case it seemed that distribution channel in terms of surface area or cross-section area was higher than the required area.

6.3.3.2 Dimension of Field Channel

The field channel measurement and flow velocity of 20 STWs (20 command area) were taken in the study area. The channel length depends on command area and shape of command area. The average command areas of 20 STWs were 3.32 hectares. The average flow velocity was measured 0.614 m/sec. The average dimension of channel was shown in Table 6.8a. However, individual channel measurements of 20 STW's command area of the study area are shown in Annexure-8.

From the measured field data, it was observed that the length of channel ranged from 302 to 648 m with an average 424.92 m, top width of channel ranged from 0.48 to 0.63 m with an average 0.56 m, average width of channel ranged from 0.46 to 0.52 m with an average 0.5 m, and channel height ranged from 0.15 to 0.23 m with an average 0.18 m (Table 6.8a). From the above field data of the channel showed that the channel is capable to carry 0.055 m^3/sec of water which is greater that measured discharge (0.01913 m^3/sec)

Table 6.8a: Average channel length, surface area and X-section area in the study area.

Average C/A (ha)	Surface Area of Channel			X-section area of Channel			Estimated Discharge (m^3/sec) Area X velo
	Length (m)	Top width (m)	Area (m^2)	Av. Width (m)	Av.ht (m)	Area (m^2)	
3.32	424.90	0.56	237.94	0.5	0.18	0.09	0.055
Remarks: 0.055 m^3/sec > 0.01913 m^3/sec (measured discharge)							

(Source: Field survey, 2015-16)

There is scope for improvement of channel dimension to save land as well as water losses by reducing width of distribution channel, which was shown in Table 6.8b. Table 6.8b shows that if it is reduced 50% of top width or average width of the existing channel, then that channel would be sufficient for flowing of the measured discharge and 118.97m^2 lands would be saved for rice cultivation which leads to the production. Thus it was possible to save potential cultivated land and water loss by reducing width of distribution channel.

Figure: 6.3: A view of channel dimension measurement in the study area.

Table 6.8b: Showing scenario if reduced average channel width, surface area and X-section area in the study area

Average C/A (ha)	Average Channel Dimension			Channel X-section area (m^2)			Estimated Discharge (m^3/sec) Area X velo
	Length (m)	Top width (m)	Area (m^2)	Av. Width (m)	Av.ht (m)	Area (m^2)	
3.32	424.90	0.28	118.97	0.25	0.18	0.045	0.027
Remarks: 0.027 m^3/sec > 0.01913 m^3/sec (measured discharge)							

(Source: Field survey, 2015-16)

6.3.3 Mis-match among STWs Equipment

The technical parameters among the STW equipments setting of the study area was shown in Table 6.9 by Pearson correlation test. From the Table 6.9, it is evident that mis-match among different parameters [between engine or motor and pump capacity, between discharge and engine capacity (BHP), between discharge and water distributional channel] of STW equipments were happened. Field survey data revealed that the overall mis-match mainly occurred due to lack of technical knowledge and information of the STW owner, mechanics, farmer, equipment traders and installers.

Table 6.9: Pearson Correlation Coefficients among Engine Capacity (HP), Pipe Diameter, Pump Discharge and Surface Area of Channel

Variables	Discharge (m^3/sec)	Engine capacity (HP)	Pipe diameter (m)	Surface area of channel (m^2)
Discharge	1.00	-	-	-
Engine capacity	0.03	1.00	-	-
Pipe diameter	- 0.08	0.25	1.00	-
Surface area of channel	- 0.32	0.11	0.33	1.00

(Source: Field survey January, 2016)

From the table, the following mis-matches were observed in the study areas:

a) It was observed that mis-match between engine/motor and pump capacity was happened. In many cases, the nominal RPM of many engines/motors were much higher than the designed capacity of the coupled pumps resulting lower discharge. To save the pump or to avoid any breakdown of pump blade, the owners had to be fixed the engine speed considerably. As a result, the engines could not run with a full load capacity which delivered lower discharge.

b) Mis-match between discharge and engine/motor capacity (BHP) was found quite higher because of engine/motor's BHP were higher than the required BHP of pump, which indicates misuse of energy and the owners used their pump & engine/motor for different durations, which might be reduced pump and engine/motor efficiency. As a result, the pump & engine/motor could not deliver designed discharge as per engine/motor capacity (BHP).

c) Mis-match between discharge & water distribution channel was happened due to the lack of awareness of the farmers. Pump owner made the channel on the others farmer land with out any consideration regarding potential cultivated land loss and valued water loss and farmer had no complained about channel making. Most of the channel were made widely which cross-sectional area was almost double than the designed discharge. As a result, potential cultivated land loss and valued water loss occurred.

d) A remarkable matching between HP and pipe diameter was found in the study area, though it was mis-match practically (r=0.25).

6.3.5 Electricity Connections and Supply

6.3.5.1 Electricity connections issues

Though recently most of the STW owners were shifted from diesel engine to motor engine (which is operated by electricity), but there was some problem in this system. For example, to get electricity connections the STW owners or farmers had to face different problems. From the field survey, it was reported that they had to follow many formalities to get this connection; even they had to pay extra money, otherwise it was not possible to get this line. 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 or local Rural Electrification Board (REB) office which was also known as Palli Biddut Samity (PBS) office. EOS owners stated that they got electricity connection with the help of middle man, who had good linkage with some of the PDB or REB officials. Middle man charged fixed cash to arrange electricity connection, but the charges also varied depending on relationship between the STW owners and the middle man and the distance of STWs from the main electric line. The owners claimed that the major portion of electricity connection charges goes to middle man and PDB officials. Miah and Mandal (1993) and Hossain and Moududi (2009) also reported that the STW owners had to pay bribes to the concerned officials for getting electricity connections.

6.3.5.2 Electricity supply issues

The farmers were happy with electricity supplies during irrigation period as comparatively 10 years ago. There was some times voltage fluctuation which caused of motor burned or caused of non-uniform flow. They faced trouble little bit load shading particularly in peak season (March-April). In dry season (March-April), the load shading was reached extreme condition, but due to this load shading there was no hampered on irrigation. After load shading when electricity would come, all engines/motors were started together. As a result due to poor quality of wire and transformer, some times it could not carry the load of electricity. At that time, few motors were burned and the irrigation system was hampered. Finally, crop production was reduced due to load shading and voltage fluctuation.

6.3.5.3 Service of electricity organization

In some cases of the study area, EOS irrigation scheme was delayed to start due to lack of service from PDB or REB office. Farmers did not get good service in proper time during peak season. When wire or transformer burned, then farmers have to organize to get service for repairing transformer or any other problems. Otherwise it would take much time to solve any problem. Moreover, in some places of the study area the infrastructure for this system was not so good. The wire was pulled from one place to another place by bamboo, which is the matter of risky and dangerous. The farmers were not happy with quality of wire and transformer also.

Figure: 6.4: A view of electric wire was pulled by bamboo in the study area.

6.3.5.4 Cost of electricity, billing and payment system

Though there was the standard rate of metering bills system (Table 6.10) in the study area, which was collected from PDB office, but it would not followed in all cases in practical in the study area. From the field survey, it was observed that there was no any metering system for electrically operated engine and the cost of electricity was made on motor horsepower basis, i.e. the bill was flat tariff (Tk/horsepower/season). PDB officials informed that in case of non-metering system they prepared the electric bills on the basis of HP. Electric bill has to pay the STW owner after harvesting the crop. They think that it was one of the advantages in case of electric engine, rather than diesel engine.

Table 6.10 Standard billing system of Power Development Board (PDB) office.

<table>
<tr><th>Motor Capacity (HP)</th><th>Unit (Kwh)</th><th>Vat and Service charge</th><th>Total cost (Tk)</th></tr>
<tr><td>5.0-6.0</td><td>3500</td><td rowspan="3">@ Tk. 2.97 per unit and 5% vat of the bill</td><td>10915</td></tr>
<tr><td>7.0-7.5</td><td>4000</td><td>12474</td></tr>
<tr><td>8.0-12.0</td><td>5000</td><td>15593</td></tr>
</table>

(Source: PDB official data, 2017)

6.3.5.5 Farmer's perception about metering and non-metering system

From the field survey, it was observed that some STW owner did not know on what basis PDB made their electric bill, whatever based on motor horsepower or command area or any other else. Some EOS owners claimed that they paid higher electric charge due to non-metering system. Again they blamed about illegal practice between some EOS owners and PDB officials. They think that in most of the case, the electric bill depends on relation between bill maker and STW owner. The STW owners with large HP motor and big command areas had hidden negotiation for preparing electricity bills at lower rate. Farmers informed that they want metering system, because they think that in metering system their neighbour mauza's STW owner was paying comparatively less electric bill to REB. They believe that in metering system their electric bill would become less than the present system. As a result their cost would be saved a great extent.

STW owners' opined that they were paying double money due to non-metering system. They stated for example, A 5 HP motor's bill was Taka 15000 in metering system, while the bill was Taka 30000 in non-metering system. However, most of the farmers and STW owner opined that electric bills were made, mainly depending on different motor's capacities (HP) and command areas on an average. The correlation coefficient of electric charge with both motor capacity and command area also supported the farmers' perception (Table 6.11).

Table 6.11: Pearson correlation among engine power (HP), electric charge and command area

Item/Parameter	**Electric charge**	**Level of significant**
Motor capacity (HP)	0.592	0.000
Command area (Hectare)	0.527	0.001

6.4 CONCLUSIONS

The characteristics of STW equipments were evaluated using some parameters such as BHP, RPM, fuel consumption, break down and country of origin. These study findings showed that most of the engines were Chinese and Japanese in the study area. Engines or motors belonging to wide ranges of power were found in use in the study area. Smaller engines/motors were found to be more popular in terms of capacity utilization. It was observed in the field that engine BHP used in STW irrigation system usually higher than the required indicating wastage of power and energy. In addition, the nominal RPM of many engines/motors were much higher than the designed RPM of the pumps and the farmers had therefore to reduce the engine speed considerably. As a result, the engines could not run with a full load, resulting in poor specific fuel consumption and lower discharge.

The research findings showed that mis-match among different component or parameters of STWs [between engine/motor & pump capacity, between discharge & engine capacity (BHP), between discharge & water distribution channel] were observed in the study area. The overall mis-match mainly occurred due to lack of technical knowledge and information of the STW owner, mechanics, farmer, equipment traders and installers.

The research findings showed that the command area of the STWs does not depend on the BHP of the engines. As a result, cheaper and smaller engines were favoured and as such Chinese engines have taken control of the markets and replaced the more expensive engines (from Japan). Data revealed that fuel consumption for smaller engines, whether of Japanese or Chinese origins were reasonably satisfactory. It indicates good performance of the engines with their pumps. Finally, it can be concluded that pump discharge of both engines (diesel and electric motor) considering same as BHP are little bit similar. Water productivity and land productivity of both engines (diesel and electric motor) were similar.

The performances of selected 12 STW schemes were evaluated using some standard hydraulic, agricultural and socio-economic indicators. The results showed that the schemes are now performing better than in the past. This was happened mainly because of higher pump discharges compared to the respective national averages, higher rice yield due to the application of high amount of chemical fertilizer, pesticides and good water management practices. The performance evaluation can be further improved by including indicators on environmental sustainability, income and employment generation and poverty alleviation.

It was observed during field survey that some owners run their STW singly; some owners run their STW with partnership and equal or different share. That's why it is needed to further study how the farmers manage their business, how they form their partnership and why, etc. Therefore, further research focuses about management issues of STWs irrigation system in Chapter-7.

Chapter 7

SHALLOW TUBE WELL IRRIGATION MANAGEMENT SYSTEM IN BANGLADESH AGRICULTURE

Chapter 7

SHALLOW TUBE WELL IRRIGATION MANAGEMENT SYSTEM IN BANGLADESH AGRICULTURE

7.1 INTRODUCTION

From the historical chronology of minor irrigation system, it was observed that the STW irrigation management system in Bangladesh is important and critical issue about its sustainability. It is noticed that in the beginning of privatization STW irrigation system, the farmers used STW singly to irrigate their own land. Following over time, farmers used STW jointly to irrigate their own land. Consequently, they also sell water to other farmers. It was reported that farmers (STW owners) sell water commercially to the farmers (water buyer for Boro rice production) to earn profit like in other businesses (Mandal and Parker, 1995). So, it can be said that different stake holders are associated with this STW irrigation business and there is a strategic management system to run this business. The aim of this study is to understand how the farmers manage their STW irrigation system / business, though there is a lot of problem with this business such as command area formation and settlement, fund management, sharing arrangement, partnership and ownership formation as well as conflict arising anytime (before or during running of STW irrigation) between STW owner and water buyer or between two STW owner or any other factors that influence STW irrigation management in Bangladesh agriculture.

7.2 APPROACHES AND METHODOLOGIES

7.2.1 Study area

The study area was Dighalkandi union, which is under Ghatail Upazila of Tangail district of Bangladesh. The study area comprises five Mauzas of Dighalkandi union namely Saitapara, Kurmushi, Kagmari Beltail, Kaijalipur and Shekh Shimul (Fig. 4.1).

7.2.2. Field data collection procedure

Primary data was collected from the field survey through prescribed questionnaire to understand the management system of STW irrigation technology of the study area and then these data were analyzed in tabular and graphical form. Here, management system includes types of ownership, partnership formation, sharing arrangement, operational cost management system, fund management, command area formation and settlement, conflict mitigation or any other problem arising during irrigation.

The primary data were collected through two sets of interview schedule from STW owners and water buyers in 2016 and 2017 Boro season (January-May). Additionally, Focussed Group Discussions (FGD) were made with STW/motor mechanics, STW operator/driver/manager, spare parts sellers, STW installer, local workshop owners, complementary input dealers, irrigation equipment traders and support service providers through three sets of checklist to collect concern primary data. In addition, some case studies have been collected from different stake holders regarding STW irrigation business management system, STW mechanic (rural mechanic) and motor mechanic of STW, coping with changing diesel prices, cooperation helps to earn more income in STW irrigation business, non-cooperation in STW irrigation business and social power influence on STW irrigation business.

The secondary data were collected from Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC), Center for Environmental and Geographic Information Services (CEGIS) and Department of Land Records and Survey (DLRS), Department of Agricultural Extension (DAE) etc. In addition different published journals, different reports, books, articles, News paper and internet were also taken as a crucial source of secondary data.

7.3 DATA ANALYSIS, RESULT AND DISCUSSIONS

7.3.1 STW Ownership Formation, Relationship among Partners & Sharing Arrangement

7.3.1.1 STW Ownership Formation

Both single and partnership arrangements were available in the study areas to perform the STW irrigation business. Majority of STWs owners (60 percent) had partnership and 40 percent STWs owners had no partner; it means 40 percent STWs owners are single ownership which is shown in Table 7.1 and Figure 7.1. 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. STW partnership among brothers was also formed due to distribution father’s assets by law of inheritance.

Table 7.1 STW ownership patterns in the study areas

No. of partner	No. of owner	%
One	20	40
Two	17	34
Three	6	12
Four	5	10
Five	2	4
Grand Total	**50**	**100**

(Source: Field data, 2016)

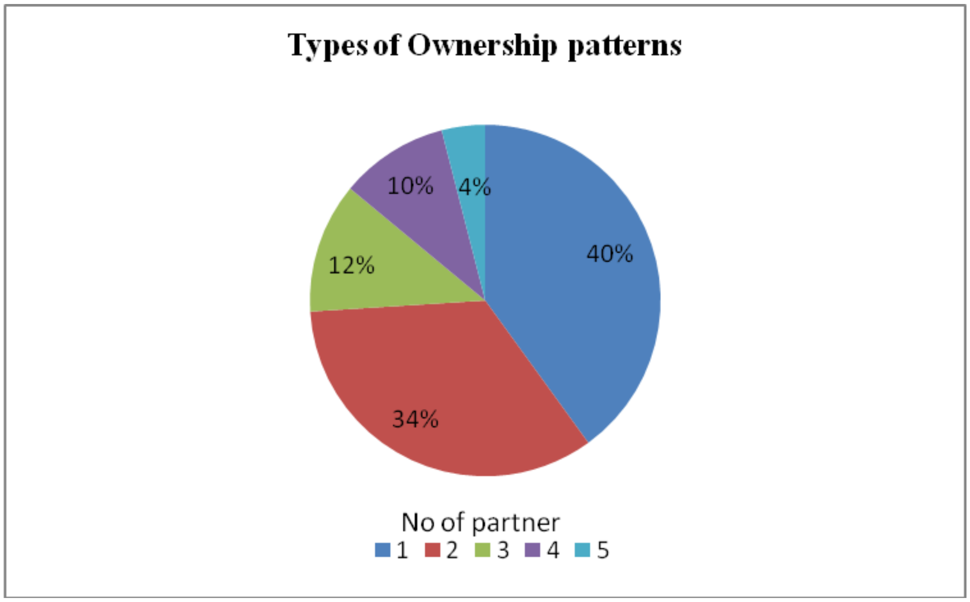


Figure 7.1: STW Ownership patterns in the study areas (Source: Field data, 2016)

7.3.1.2 Relationship among Partners

Partnership was formed within family members, close relatives and also among neighbours (Table 7.2). Most of the partners gave opinion that they jointly operated their business for increasing control over command area and for sharing the investment and maintenance costs. Farmers form partnership also to mobilize capital, to shift from diesel to electric operated STW, to increase command area, to share management functions and to minimize business risk. It was also observed that some owners preferred sharing STWs business with others because of good social relationship and spreading risk. The absentee STW owners were continuing their business by negotiating with partners with the help of his other family members (wife, son and brother). They also communicated with partners by physical visits occasionally (who stay within country) or through mobile phone (who stay outside the country). The partners commonly selected from the members of the extended family, neighbours and relatives (Table 7.2).

Table 7.2 Relationship among partners

	No. of owner	Percentage
Respondents	29	35
Family members	11	13
Relatives	22	27
Neighbour	20	24
Total	**82**	**100**

(Source: Field data, 2016)

7.3.1.3 Sharing Arrangement

There were several types of sharing arrangements observed in the study areas. Majority of the partners had 50 % of share. One-fourth (1/4) share was also observed in a greater extent in the same areas. Some unequal distributions of shares were also found in field survey (Table 7.3 and Figure 7.2). 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. Some of the small share partners had also their own land in their command areas.

All of the partners contributed the investment and operating costs according to their shares of STWs. The manager's/drivers/operator of the STW was appointed by the owners and their salaries were paid only for *Boro* season (about 4-5 months). Generally, an operator is appointed for whole Boro season (4-5 months) as contract basis and payment was paid as Tk. 7000 to Tk. 8000 per month. However, some where payment for operator was paid as consolidated Boro rice (1200-1280 kg) for the period of irrigation season. Some partners performed as STW manager (Case study-1) alternatively in a seasonal or weekly or monthly or yearly basis. The partner who worked as manager was also paid the same rate. 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 irrigation business.

Table 7.3 Sharing arrangement among STW partners

Percentages of share	Number of partners	Percentage
Up to 25	36	44
26 to 50	42	51
51 and above	4	5
Total	**82**	**100**

(Source: Field data, 2016)

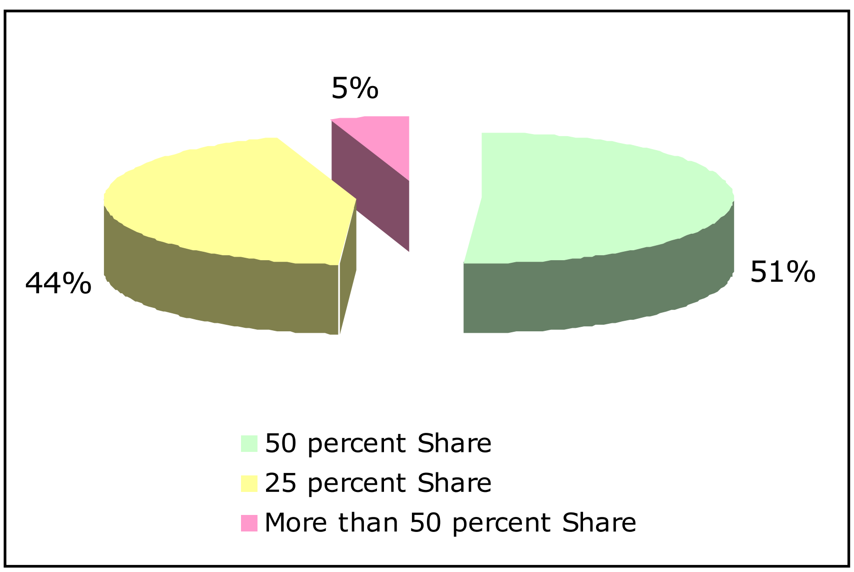


Figure 7.2: Sharing arrangement among STW partners (Source: Field data, 2016)

Case study 1: Partner performed as STW manager

During the last *Boro* season (2016), Mr. Mortuz and Mr. Barek operated their Electricity Operated Shallow Tubewell (EOS) themselves by rotation without employing any driver (manager/operator). They operated STW in a weekly basis. Mr. Mortuz's son helped him when required and Mr. Barek himself performed the driving task. Their STW motor perfectly operated in last season without any technical difficulties. They maintained proper rotation in irrigating all plots without any biasness, because of crop sharing system was as irrigation charge.

7.3.2 Education and Occupational Status of STW Owner

7.3.2.1 General and technical level of education

It is generally expected that the educated STW owners would do better in their business through better management and control of resources. But the real scenario was not always true in the study areas. The average year of schooling was low for both single and partner owners in the study areas (Table 7.4). Only a few STW owners were highly educated. One owner, however, was a university graduate. Single STW owners were more or less equally educated as in the case of STW partners (Table 7.4).

The level of technical knowledge was classified into three categories, such as good, fair and poor. Table 7.5 reveals that most of the STW owners (70 %) 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 (also known as STW mechanics) repaired diesel engines only. The required spare parts were provided by owners or sometime mechanics buy spare parts from shops on behalf of the owners. Mechanics 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 for electric motors, that's why their own technical knowledge seems to be low.

Table 7.4 Educational Background of STW owner

Education level	Single	Partner	Total
Year of schooling	5.4	4.1	4.5
Standard deviation	4.7	4.2	4.4
Co-efficient of variation (%)	88	103	98

(Source: Field data, 2016)

Table 7.5 Level of technical knowledge

Type of technical knowledge	Single		Partner	
	No.	%	No.	%
Good	3	15	6	7
Fair	6	30	19	23
Poor	11	55	57	70
Total	**20**	**100**	**82**	**100**

(Source: Field data, 2016)

7.3.2.2 Occupational Status

Most of the owners, either single or partners were directly involved in agriculture/farming activities. Their main earning sources and rural livelihoods were directly depended on agriculture. Few STW owners were involved in business and services as their main occupations. But interesting thing was that the equal number (6 %) of STW partners did jobs abroad and within country (Table 7.6). All STW owners who worked abroad run their businesses through partnership arrangements.

Table 7.6 Main occupation of STW owners

Occupation	Single		Partner	
	No.	%	No.	%
Agriculture	17	85.0	66	80.5
Business	2	10.0	6	7.3
Service (in country)	1	5.0	5	6.1
Service (Abroad)			5	6.1
All	**20**	**100.0**	**82**	**100.0**

(Source: Field data, 2016)

7.3.2.3 STW owner’s 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. About 20 % of STW owners had no own land in their command areas (Table 7.7 and Figure 7.3). Therefore, it appeared 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 land holding 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. Either single STW owner or partnership owner increased their command area by irrigating land from their kinship, clan and neighbours.

Table 7.7: Distribution of own cultivable land under self command area

Land area	No land	1-50 decimal*	51-100 decimal	101-150 decimal	Above 150 decimal	Grand Total
Single						
%	9	23	34	23	11	100
Average size (dec)	0.0	15.8	72.4	122.5	202.5	79.6
Standard deviation	0.0	10.5	12.1	7.6	45.0	63.3
Co-efficient of variation		67	17	6	22	80
Partnership						
%	24	29	24	16	6	100
Average size (dec)	0.0	27.9	71.0	122.9	350.0	66.3
Standard deviation	0.0	11.5	14.1	12.7	114.5	88.1
Co-efficient of variation		41	20	10	33	133
Total						
%	20	27	27	18	8	100
Average size (dec)	0.0	24.9	71.5	122.8	284.4	70.3
Standard deviation	0.0	12.3	13.2	10.8	115.6	81.5
Co-efficient of variation		50	18	9	41	116

Source: Field data, 2016 (Note: * 100 decimal = 1 acre)

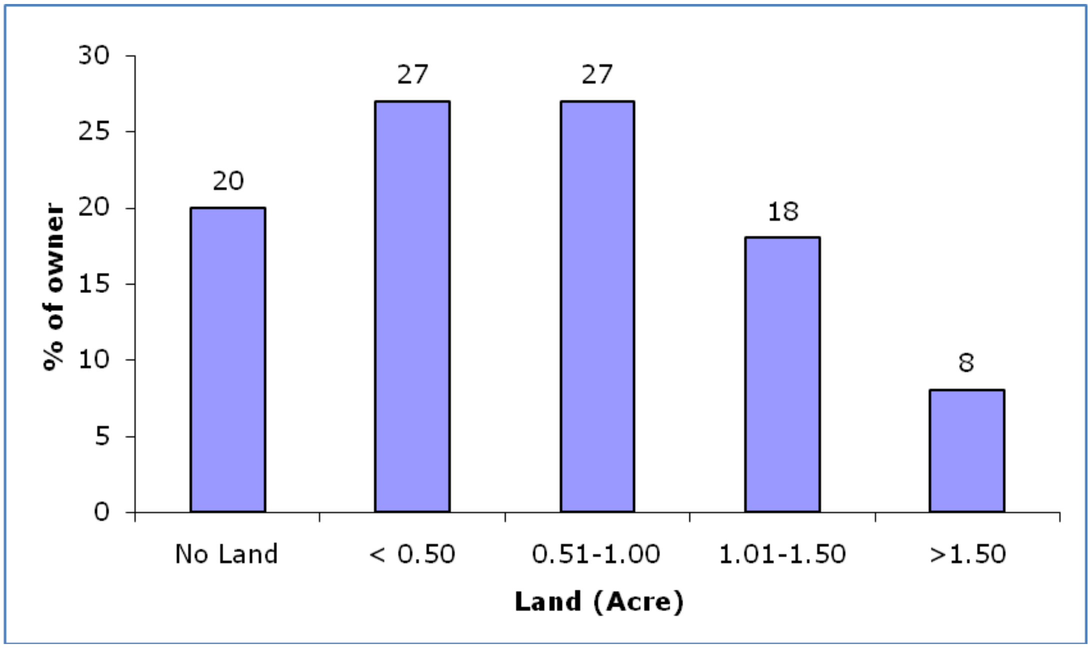


Figure 7.3: Distribution of own cultivable land under self command area
(Source: Field data, 2016)

7.3.2.4 Ownership Type and Energy Uses

STWs were operated by diesel and electricity in the study areas. Higher percentages (almost all) of STWs were operated by electricity in each mauza; but exception was found in Saitapara mauza, where only two STWs were operated by diesel (Table 7.8). Mauza wise distribution of STW and their energy type is shown in Table 7.8.

Table 7.8 Mauza wise distribution of STW and their energy type

Name of Mauza	Diesel		Electricity	
	No.	%	No.	%
Kagmari beltail			4	100
Kaizalipur			12	100
Kurmushi			11	100
Saitapara	2	25	6	75
Shekhsimul			15	100
All	**2**	**4**	**48**	**96**

(Source: Field data, 2016)

Most of the single owned STWs were operated by diesel, whereas most of the partnerships STWs were operated by electricity and it is shown in Table 7.9 and Figure 7.4. Here, one thing is clear that partners accumulated their capital for paying the larger fees for getting the electric connection. Again they could also arrange and increase their command areas negotiating land from kins, close relatives assuring more reliable water supplies. 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 (GoB) increased diesel prices several times, although diesel price in world market is going down. The GoB did not provide any subsidy to the farmers or respective diesel cost. So, irrigation business was facing challenges to cope with the rising diesel prices. For this reason, diesel operated STW owners have been shifted to electric operated STW. They were trying to take in more partners or 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 7.9 and Figure 7.4 showed that 60% EOS operated by partner ownership and 40% EOS operated by single ownership.

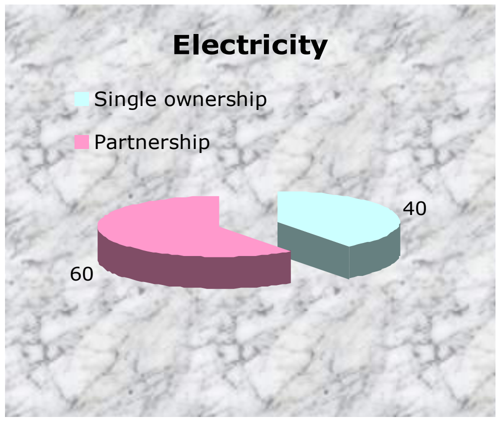


Figure 7.4: Ownership Type and Energy Uses (Source: Field data, 2016)

It was reported from the field survey that electricity operated STW (EOS) irrigation system was the higher profitable than diesel operated STW (DOS) which was proved from Table 8.1c under Chapter 8. Research findings of Miah and Hardaker (1988) also showed that EOS was more profitable than DOS.

Table 7.9 Relationship between ownership and sources of energy

Sources of energy	Single		Partner	
	No.	%	No.	%
Diesel	2	10		
Electricity	18	90	30	100
Overall	20	40	30	60

(Source: Field data, 2016)

7.3.2.5 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 leader) settle through village litigation. After fixing command areas for particular STWs, there was little scope to change within short period of time. In most of the command areas, water buyers came from neighbourhood of the STWs. In few cases water buyers committed to irrigate their land under the selected STW command area formalized through some form of written contact (Kaijalpur muaza). Again irrigation charges in the form of crop-share were settled by the *samaj* (community) 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 chase STW owners for irrigating their plots. Moreover the crop sharing system reduces the conflict between water buyer and seller. Continuation of one-fourth (1/4) crop sharing system for three decades, obviously indicates its sustainability.

The community approved new entrepreneur for running STW business in his own land. They discouraged new entrepreneur to take any 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 shallow tube wells (EOS) (Case study 2).

Case study 2: Coping with changing diesel prices

Mr. Md. Abdul Kader had a diesel operated STW in Sheksimul Mauza. He purchased this STW in 2010 from Mr. Md. Abdul Hanif. Mr. Hanif sold his diesel engine to meet financial needs for continuing business and also to bear the expenses of his daughter's marriage. Mr. Kader operated his DOS with irrigating 4.8 acres of land till 2015. Last year (2016), he was unable to operate the diesel engine due to higher fuel prices and financial crisis. Again he neither could arrange new partners (sharing business) nor manage capital required for changing DOS to EOS. Moreover, he tried his best to be a partner of Mr. Latif's electric operated STW but Mr. Latif and his existing partners denied him of any partnership in their business. After long discussion and with the help of samaj (community leader) they settled new type of arrangement, where Mr. Kader had paid Tk. 6000 to Latif and his partners for irrigating 4.8 acres land of his (Mr. Kader) STW command area. In addition he paid Tk 2000 as driving/management cost and also Tk. 2000 for channel making and repairing cost. Mr. Kader as usual had taken 1/4 share of crop for his STW command areas like as before without operating his diesel engine. From this arrangement Mr. Kader benefited greatly (Tk. 9000 as Gross margin), though he doubted about the sustainability of this arrangement. Latif and his partners (Mr. Akter and Mr. Ezaz) were also happy with the new arrangement due to non metering electric billing system. So, this case study illustrates the coping strategy of running diesel operated STW with increasing diesel prices. (Note: 1 US$=78.00 Taka)

It was reported in the field that 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). Collected data showed that 47% STW command areas decreased and only 6% command areas increased over time. About a half of command areas remained unchanged. However, increase of command area was observed mainly for EOS. The following Figure 7.5 shows the partnership STWs command area formation.

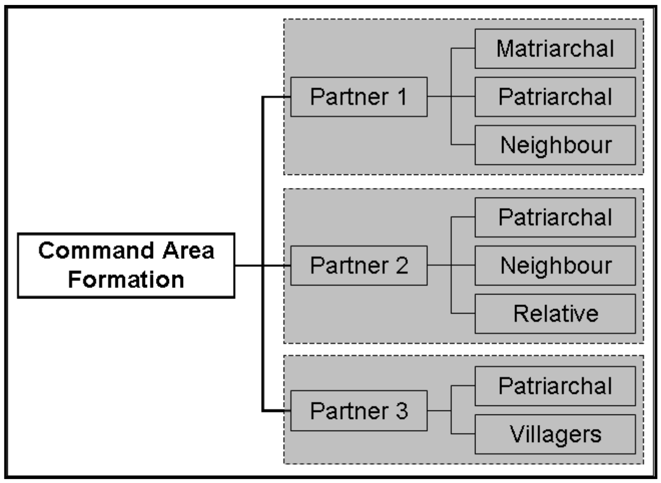


Figure 7.5: Diagram of partnership command area formation

7.3.2.6 Fund Management

It is very essential for accumulating capital before starting any kind of new business. Most of STW owners managed their capital by themselves or from other funding sources for bearing investment and maintenance costs (purchasing diesel engine or electric motor, fuel, spare parts etc). There were 102 farmers involved in STW irrigation business in selected 5 mauzas. Among them 20 farmers were single owners and most of them (about 90%) received loan for investment cost from formal sources and only 10% managed investment cost by themselves. Majority of them financed their business from own sources. Temporary loans from close relatives without interests were expressed as own investment. It is interesting that no partnership STW owners had loan from bank. It appears that getting loan from bank was difficult due to high transaction costs and various complex formalities.

Thirty (30) partnership STWs were found in the study areas and these STWs were shared among 82 farmers (Table 7.10). Most of them managed capital by themselves. The NGOs were more preferable to other funding institutions by the partners to borrow. Very few of them also managed fund by selling own or mortgaging out land. Besides supports from relatives growing cash crops and the inflow of remittance from in-country and abroad were the major sources of self-finance.

Table 7.10 Different sources of fund for purchasing STWs by the owners

Funding sources	**Single**		**Partnership**	
	No.	**%**	**No.**	**%**
Bank	2	10	3	4
Cooperative	1	5	2	2
Gift	1	5		
Land sale /mortgage out	1	5	3	4
NGOs	5	25	14	17
Own (including relatives)	10	50	60	73
Grand Total	**20**	**100.0**	**82**	**100.0**

(Source: Field data, 2016)

7.3.2.7 Social Power and Status of the STW owners

Social Power and Status of the STW owners for this study considered Union Parishad, School and Madrasha as formal social institutions and samaj (community), Gusthi (lineage), masque, bazar/hat , local samitee, graveyard, eid field, play ground as informal social institutions. STW owners were involved both of formal and informal social institutions in the study areas. Comparatively, single STW owners hold more positions of social institutions, compared to STW partners (Table 7.11). 57% of single STW owners were involved with different formal and informal social institutional committee. On the other hand, only 22% for STW partners were involved with such social institutions. Generally they settled 1/4 crop share as irrigation charge but a few exceptions were found in the case of low laying plots. The lower plots were irrigated from Beels or ponds at the beginning of crop cultivation. But a few of them paid 1/8 crop share as irrigation charge for such plots.

Table 7.11 Involvement with social institutions by STW owners

Committee type	**Single**	**Partner**	**All**
Union Parishad	8	3	7
School committee	7	3	8
Madrasa committee	6	2	6
Bazar committee	2	2	3
Mosque committee	15	3	9
Samitee	3	1	2
Others (Eid field, graveyard, play ground, journalist foundation)	16	8	10
All	**57**	**22**	**45**

(Source: Field data, 2016)

7.3.2.8 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 land holders as they were not allowed 1/4 crop share as irrigation charge. Some conflicts among STW owners were observed, particularly in redistribution of command area plots to new STWs. Some irrigation channels were also controlled mostly by powerful STW owners. Most of the problems were mitigated by the *samaj* and even by the local union parishad representatives (Case study 3).

Case study 3: Problems mitigated by the *samaj* and the local union parishad representatives

Shirin had a DOS at Kurmushi mauza. She irrigated 4.30 acres of land. But this *boro* season (2016), Jabbar forcedly tried to take over 30 decimal lands from her command area by irrigating at the beginning of irrigation season. In the circumstances, she contacted with her uncle (matriarchal) who possess higher social status and also live in the same village. Then her uncle came along with the water buyer and held meeting with the local social power holders to solve the problem. The local leaders called Jabbar and asked him, why he has irrigated the plots without permission of concerned person that were not under his command area. He could not answer the question. Then the 30 decimal lands resettled to be under the command area of Shirin. Therefore, the *samaj* (community) resolved the problem by settling command area as before.

7.3.3 Determinants that influenced the farmers to participate in STW irrigation business.

An attempt was taken to identify main factors influenced the participation in STW irrigation business. In this regard, some variables such as education level, main occupation, household income, income from business and remittance were assumed as influencing factors for participation in the STW 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. After statistical analysis, the following results (coefficients of variables) have been found as per Table 7.12.

Table 7.12: Factors that influenced to participate the farmers in STW irrigation business (Probit model)

Variables	Coefficient
Education level (year)	0.053 (0.026)**
Occupation (1=Agriculture, 2=Others)	- 0.841 (0.176)***
Income (Tk. in lac)	0.650 (0.163)***
Business income (1=Yes, 0=No)	- 0.755 (0.297)**
Remittance (1=Yes, 0=No)	- 0.572 (0.367)
Regression estimates	
Number of observations	110
Log likelihood function	-93.38
Restricted log likelihood	-109.69
Chi-squared	32.62
Degrees of freedom	4
Significance level	0.000
Corrected prediction	64%

Note: ** and *** significant at less than 5% and 1% level respectively

7.3.3.1 Educational Level

To run the STW irrigation business, it is essential to understand the technical aspects and business strategies. It was assumed that farmers having higher level of education may have higher technical and business knowledge and they might be involved with the STW irrigation business. The coefficient of education level of farmers indicates that higher educated farmers were involved with STW irrigation business and the significant level strongly supports the educated farmers to participate in STW irrigation business.

7.3.3.2 Occupation:

The STW irrigation business is directly related to crop production. It was assumed that farmers who are intensively involved in agriculture might be involved with STW irrigation business. The coefficient of occupation (for agriculture) also supports the assumption and the significant level strongly supports the agriculture farmers to participate in STW irrigation business.

7.3.3.3 Household Income

Higher amount of investment is needed to start STW irritation business, even good amount of operating capital is essential to run the STW irrigation business during irrigation season. It was assumed that the rich farmers having higher earnings (income) may come to this business. The coefficient of rich farmers having higher earnings (income) shows that rich farmers encourage STW irrigation business and the significant level strongly supports the rich farmers (higher income) to participate in STW irrigation business.

7.3.3.4 Business

It is already mentioned in above that huge capital is needed to invest in the STW irrigation business. Currently in rural areas a significant amount of household income comes from business. That's why it was assumed that the farmers having business income might be encouraged to join in the STW irrigation business. But the assumptions for business income were quite inversely related. The coefficient of the farmers who were intensively involved with other business, may not be involved with STW irrigation business and the significant level strongly supports the farmers not to participate in STW irrigation business.

7.3.3.5 Remittance

Already mentioned in above huge capital is needed to invest in the STW irrigation business. Currently in rural areas a significant amount of household income comes from remittance. That's why it was assumed that the farmers having remittance income might be encouraged to join in the STW irrigation business. But the assumptions for remittance income were quite inversely related. The coefficient of the farmers who were intensively involved with remittance income from abroad does not indicate any significant for participation to the STW irrigation business. Moreover, the significant level strongly supports the farmers (who were intensively involved with remittance income from abroad) not to participate in STW irrigation business.

7.4 CONCLUSIONS

This study demonstrated that both single and partnership arrangements were available in the study areas to perform the STW irrigation system and business. Majority of STWs owners (40 percent) had no partner. The partnership was formed by 2-5 farmers. This study concluded that there were several types of sharing arrangements in the study areas. Majority (51 percent) of the partners had 50 % of share. The research findings showed that average level of education was slightly higher for single owners than STW partners. Data revealed that most of the STW owners (70%) did not have adequate technical knowledge. The findings showed that most of the STW owners (80%) were involved in agriculture activities as their main occupation. The equal number (6%) of STW partners did jobs abroad and within country. The STW owners who worked in abroad, running their businesses through partnership arrangements.

This study also concluded that about 20% of STW owners had no own land in their command areas. The study revealed that STWs were operated by diesel (4 %) and electricity (96 %) in the study areas. Most of the single owned STWs were operated by diesel, whereas partnerships STWs were operated by electricity. Data also showed that comparatively single STW owners hold more positions of social institutions compared to STW partners. The research findings indicated that the command area formation was usually settled in negotiating with surrounding STW owners, but if there is any dispute for command area plots, *samaj* (community and its leader) settled through village litigation. The research findings also indicated that most of the

STW owners managed their investment and maintenance costs from formal credit sources as well as by selling or mortgaging out their land and in a few cases they arranged funds from themselves or relatives. Finally, misunderstandings and conflicts among the partners, owners and water buyers were handled and mitigated by community institution (samaj) with participation of stakeholders from different gusthi (lineage).

The study also demonstrated that higher education, occupation in agriculture and higher income earning may encourage the farmers to participate in the STW irrigation business and the significant level strongly supports it. The farmers, who were intensively involved with other business and remittance, may not be involved with STW irrigation business and the significant level strongly supports not to participate in STW irrigation business.

From the above mentioned management issues in this chapter, it was observed that STW irrigation business is associated with different type of cost involved. On the other hand, to whom irrigation water is selling for Boro rice productions, what is the condition for them, i.e. are they growing rice with profitable or not? This should be cleared by further validation. In this regard, further study is needed to be conducted to investigate about profitability of both STW owner and water buyer (irrigator) considering changing input and output price regime and uncertain situation. Therefore, further research focuses about profitability of both STW irrigation business and Boro rice production in the next Chapter 8.

Chapter 8

PROFITABILITY OF STW IRRIGATION BUSINESS AND BORO RICE PRODUCTION UNDER STW IRRIGATION SYSTEM IN BANGLADESH

Chapter 8

PROFITABILITY OF STW IRRIGATION BUSINESS AND BORO RICE PRODUCTION UNDER STW IRRIGATION SYSTEM IN BANGLADESH

8.1 INTRODUCTION

Surface water and ground water are two major sources of irrigation water in Bangladesh (Rahman and Parvin, 2009). Low Lift pump (LLP), Canal and Traditional (Dhone and Swing basket) are used as a means of technology for surface water irrigation while Deep Tube Wells (DTW), Shallow Tube Wells (STW) and Hand Tube Wells are used for ground water irrigation. Before 70s, irrigation was mainly dependent on surface sources and in the mid-seventies government emphasized on groundwater irrigation with DTW projects (Rahman and Parvin, 2009). But government soon shifted to STW because of it's suitability to socio-economic status of the farmers (less investment cost, small land holdings, availability in the market, withdrawing restriction on import and STWs spacing rules). STWs coverage about 62 percent of total irrigated area in Bangladesh (BBS, 2008). The total irrigation coverage was increased 1726 to 5898 thousand hectare within the period of 1981-82 to 2006-07 (242 percent) whereas irrigation potential is estimated at 7550 thousand hectares (Ernest, 2007). There is still possibility to expand 22 percent of irrigated area according to irrigation potentiality.

STW irrigation system involved cost of money during whole Boro season. STW equipments have different spare parts; component and different types of cost are associated with this system. It has mainly investment cost and operation and maintenance (O & M) cost. On the other hand, farmers (water buyer/irrigators) have to invest input cost (labor for land preparation, tillage, seeding, transplanting, weeding, application of fertilizer, insecticides and pesticides, harvesting and drying etc), purchasing of seed, fertilizer, insecticides and pesticides, water charge, land rent (for marginal farmer or tenant) etc for Boro rice production.

Hence, in this chapter the study intends to acquire an integrated understanding of the economic aspect of STW irrigation system both for STW owner and water buyer, i.e. whether water selling business by STW is economically viable or not both for Diesel Operated Shallow Tube Well (DOS) and Electric Operated Shallow Tube Well (EOS), how much cost on food grain production and benefit / return per hectare from this system. Therefore, an attempt was taken to understand how profitable irrigation business for STW owners (both for DOS and EOS) considering present situation and changing input-output price regime and how profitable of Boro rice production to the farmers.

8.2 APPROACHES AND METHODOLOGIES

8.2.1 Study area

The study area was as same as previous Chapter 7 that comprises five Mauzas namely Kagmari Beltail, Saitapara, Kurmushi, Kaijalipur and Shekh Shimul of Dighalkandi union under Ghatail Thana of Tangail district as shown in Fig. 4.1.

8.2.2. Field data collection and analysis procedure

To assess economic performance of STWs irrigation business and Boro rice production different indicators such as total financial viability (TFV), internal rate of return (IRR), fee collection performance, benefit-cost ratio and profitability of STW owner and farmers were determined. In this chapter, an attempt was taken to understand how profitable the STW irrigation business and Boro rice production for STW owner and irrigators (water buyer) respectively. In this regard data on investment cost, fuel/energy cost, operation and maintenance cost and return / benefit of STW irrigation technology both for DOS and EOS were collected. Again, for Boro rice production cost per hectare, data on irrigation input cost (labor for land preparation, tillage, seeding, transplanting, weeding, application of fertilizer, insecticides and pesticides, harvesting and drying etc), purchasing of seed, fertilizer, insecticides and pesticides, water charge, land rent (for marginal farmer or tenant) etc and return / benefit (production and market price) from farmers (water buyers / irrigators) were collected. All these primary data were collected during the field survey in 2016 and 2017 Boro season through formatted questionnaire from both for STW owner and irrigators (water buyers). In addition, focused group discussion were made with the pump managers/operators/drivers, installers, mechanics to collect primary data such as pump operation time, operation and maintenance cost of pump-motor, availability of spare parts and mechanics in the locality, etc.

Secondary data were collected from different organizations. Moreover, published articles, journals were also taken as a crucial source of secondary data in this connection. After collecting necessary data, they were analyzed using tabular, graphical and econometric techniques. Microsoft Excel and SPSS program were applied for analyzing data in a meaningful way. Moreover, sensitivity analysis was also conducted considering both certain and uncertain situations for the STW irrigation technology. Investment in STW irrigation technology is made for a long period and for this reason to estimate the profitability of STW irrigation business the project appraisal method was followed. Thus, discounted measures such as internal rate of return (IRR), benefit-cost ratio (BCR) and net present value (NPV) were used in this study. In the recent past 10 percent discount rate was usually used for financial project appraisal in Bangladesh. In this study, 10 percent discount rate was also used in the sensitivity analysis.

8.3 DATA ANALYSIS, RESULT AND DISCUSSIONS

8.3.1 Investment Cost of STW

Investment cost of STW included purchase of diesel engine/electric motor, pump, pipe and strainer, STW installation, construction of STW shed, irrigation channel making, registration fee for electric connection, switch board, connection cable, iron / wood made base, electric light etc. Investment cost of STW both for DOS and EOS is shown in Table 8.1a and item wise detail description is given below.

Table 8.1a: Investment cost of STW irrigation technology, 2017.

Cost Item	DOS		EOS	
	Tk.	US$	Tk.	US$
a. Purchase of diesel engine/electric motor	12800	164	12000	154
b. Purchase of pump, pipe and strainer	6000	77	7780	100
c. Installation	1400	18	1700	22
d. Construction of STW shed	2050	26	2590	33
e. Irrigation channel making	2145	28	2750	35
f. Others (Registration fee for electric connection, switch board, connection cable, iron / wood made base, electric light)	3000	38	20000	256
g. Total investment cost [a+b+c+d+e+f]	**27395**	**351**	**46820**	**600**

Source: Field Survey (2017)
*Taka 78.00 = US$ 1.0

8.3.1.1 Purchasing cost of diesel engine and electric motor

Purchasing cost of both diesel engine and electric motor were about the same in the study areas (Table 8.1a). Some owners bought second-hand diesel engine and electric motor at lower price from local markets. Recently some of them also bought old electric motors collected from ship. Local mechanics helped them to purchase the motor from Chittagong (350 km distance from study area). Most of the brands of electric motors are imported from China and these were cheaper than the brands from other countries. A few diesel engines made in Japan were comparatively older, but were more costly than electric motors. The diesel engines were purchased long ago when the engine price was lower compared to present price (2017). Although the life span of engines and motors varied due to variation of uses by owners, however 10 years average life span is assumed for both engine and motor.

8.3.1.2 Cost of pump, pipe and strainer of STW

About the same quality of pumps for both diesel and electric STWs were used by the owners. A large number of owner used the pumps made by local industries due to its' cheaper price. Most of the owners used plastic pipe in their STWs, although a few of them used iron pipe also. Though, three types of strainer made of plastic, iron and bamboo were used in the study areas, the owners widely used the plastic strainer for their STWs. The cost of bamboo made strainer was about a half compared to plastic strainer, but owners were not generally interested with it because it was not possible to re-bore bamboo strainer when needed. Due to higher price, very few owners used iron strainers. Generally the owners used more depth of boring for EOS than DOS, which resulted in higher cost to install EOS (Table 8.1a).

8.3.1.3 Installation cost of STW

The installation cost is shown in Table 8.1a and from this it can be said that the installation cost of EOS was little bit higher than DOS due to boring depth was higher in case of EOS rather than DOS. The installation person charged higher price from EOS owners because they used longer and larger pipe dia. According to farmers' opinion and mechanics views, it was assumed that the STW was needed to re-install every 5 years, although it varies from STW to STW. In that case, the cost of re-installation was higher than initial installation because the cost included both de-installation and installation of pipes at the same time.

8.3.1.4 Cost for construction of STW shed

Each STW owner temporarily made STW shed in the field during *Boro* rice cultivation period. The average initial cost of new shed making is shown in Table 8.1a. The cost varied from one owner to another because some owners used tin (corrugated iron sheet) only and some of them used both bamboo and tin as materials. However, most of the sheds were made by tin and bamboo. Other cost such as rope, iron pin, human labour, earth work etc. were also incurred for constructing new shed. At the end of *Boro* season, STW owners packed the shed materials and kept the materials to use in the next season.

8.3.1.5 Irrigation channel making cost of STW

In the study areas, whole irrigation channel networks of command areas of all STWs were katcha (made of earthen). Human labour was the only cost for making irrigation channel. Before start of *Boro* season, STW owner made or repaired irrigation channel. The average cost for making irrigation channel for DOS and for EOS is shown in Table 8.1a. 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.

8.3.1.6 Other investment cost 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 other investment costs of EOS were higher than DOS. Specially, the electricity connection fee was much higher than other investment cost. From the field data revealed that the owners truly felt additional fees were charged illegally by the officials in the name of electricity connection fees.

8.3.2 Operation and Maintenance (O & M) cost of STW

Operation and Maintenance (O & M) cost of STW included fuel (diesel or electricity), mobil, spare parts and mechanics fee, operator’s salary, irrigation channel repairing, STW shed repairing, labor for collection of rice from field etc. O & M cost of STWs both for DOS and EOS is shown in Table 8.1b and item wise detail description is given below.

Table 8.1b: O & M cost per season of STW irrigation technology, 2017.

Cost Item	DOS		EOS	
	Tk.	US$	Tk.	US$
a. Diesel cost [450 liter/season@65 Tk./liter]	29250	375	-	-
b. Mobil cost [10 liter/season@250 Tk./liter]	2500	32	-	-
c. Electricity cost		-	30000	385
d. Spare parts and mechanics fee	1800	23	800	10
e. Operator’s salary	32000	410	31000	397
f. Irrigation channel repairing	1000	13	1100	14
g. STW shed repairing	900	12	1150	15
h. Others (Labor for collection of rice from field)	17116	219	16673	214
I. Total O & M cost (Tk.) [a+b+c+d+e+f+g+h]	**84566**	**1084**	**80723**	**1035**

Source: Field Survey (2017)
*Taka 78= US$ 1.0

8.3.2.1 Power, fuel and lubricant cost of STW

The average fuel cost per season for DOS is shown in Table 8.1b, although fuel consumption of DOS varies with different types of engines powered by different horse power (HP). The diesel price varied between owner to owner due to purchase of diesel from different sources such as local diesel shop, Upazila level diesel shop and diesel selling pump. Electric charge of EOS varied a great extent in the study areas based on pump capacity. According to the mechanics opinion, on an average each STW needs about 12 litres of lubricating oil (like mobil) per season but the owners used about 10 litres of lubricating oil (mobil), which obviously decreases engine life and capacity. Variation of lubricating oil (mobil) prices was quite high because the owners purchased lubricating oil (mobil) of different qualities from different retail sellers.

8.3.2.2 Spare parts and mechanic fee

Most of the DOS owners paid mechanics fee as a consolidated rice (80-120 kg) per STW for a season. The mechanics fees, 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 every year. On the other hand, the EOS owner did not pay any fixed payment for mechanics. They paid mechanics in cash when they repaired their STWs. Some electric motor did not give any trouble during the entire *Boro* season. The EOS owner also opined that burning of motor cable was the main trouble. They brought the troubled motors in mechanic's shop to repair and they paid mechanics fee in cash. Table 8.1b showed that spare parts and repairing of DOS was costlier than EOS.

8.3.2.3 STW Operator's /Driver's salary

STW operator is also known as lineman / driver (who maintain supply of irrigation water to the line/channel) in the study area. The payment varied from operators to operators due to differences in their experiences and relationship between STW owner & operator. Generally, an operator is appointed for whole Boro season (4-5 months) as contract basis and payment was paid as Tk. 7000 to Tk. 8000 per month. However, some where payment for operator was paid as consolidated Boro rice (1200-1280 kg) for the period of irrigation season. The main task of STW operator was to operate & maintain STW machine/engine and to maintain distribution route for irrigation irrigator's plots to avoid any conflicts among the irrigators. He was also responsible to care about collection of rice from the irrigators' fields as irrigation charge. There was no significant difference between operator's salaries with respect to DOS and EOS (Table 8.1b).

8.3.2.4 Irrigation Channel and Shed repairing cost of STW

Generally, STW owners repaired the old irrigation channel and made STW shed before starting irrigation system. They also have been used some old corrugated sheets as well as old tin from previous season to build the tube well shed. Human labour 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 needed. Repairing cost for irrigation channel and shed in the case of EOS were slightly higher than for DOS due to longer irrigation channel to serve for larger command area of EOS and to protect motor respectively (Table 8.1b).

8.3.2.5 Other operation and maintenance (O & M) cost of STW

Most of the STW owners appointed contract labour to collect rice from plots to owners' house when harvesting started. Some STWs needed bamboo pillars to be connected with electricity transformers. Some times, the DOS owners used grease in the moving parts of the engine to keep smooth the engine. Other O & M cost incurred by the STW owners in the study areas are shown in Table 8.1b.

8.3.3 Return or Benefit from STW irrigation system

Return or benefit included Boro rice and Boro straw of STW Irrigation system which is shown in below Table 8.1c. STW owners charged one fourth share of total production of Boro rice as irrigation charge from irrigators in these study areas. Straw of Boro rice was also shared at the same rate. As payment of water charge, DOS owner got on average 15.45 ton rice @ Tk. 21620 per ton considering 2.82 ha command area and 5.48 t/ha yield, while EOS owner got 19.56 ton rice at the same rate from per STW per season; though it depends on command area to a large extent. Additionally, DOS owner got Boro rice straw of Tk. 10000 while EOS owner got Tk. 11115 (Table 8.1c). 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 the electricity connection is cut off from Power Development Board (PDB) after Boro rice harvesting. Total return from DOS was lower than EOS in the study area due to smaller command area.

The STW owners felt that a good amount of salvage value is possible to get from their STWs when these will not run. The salvage value of EOS was higher than DOS (Table 8.1c). EOS included the salvage value of electricity cables, which would have high value in the present market.

Table 8.1c: Return or Benefit per season of STW irrigation technology, 2017.

Return or Benefit Item	DOS		EOS	
	Tk.	US$	Tk.	US$
a. Value of rice (5.48 t/ha@21620Tk./t*CA/4)	83527	1071	105741	1356
b. Straw from rice	10000	128	11115	143
c. Charge for watering the vegetables plots and others	1000	13	500	6
d. Total return (Tk./season) [a+b+c]	**94527**	**1212**	**117356**	**1505**
aa. Salvage value of STW	6600	85	8250	106

Source: Field Survey (2017 Boro season)
*Taka 78= US$ 1.0

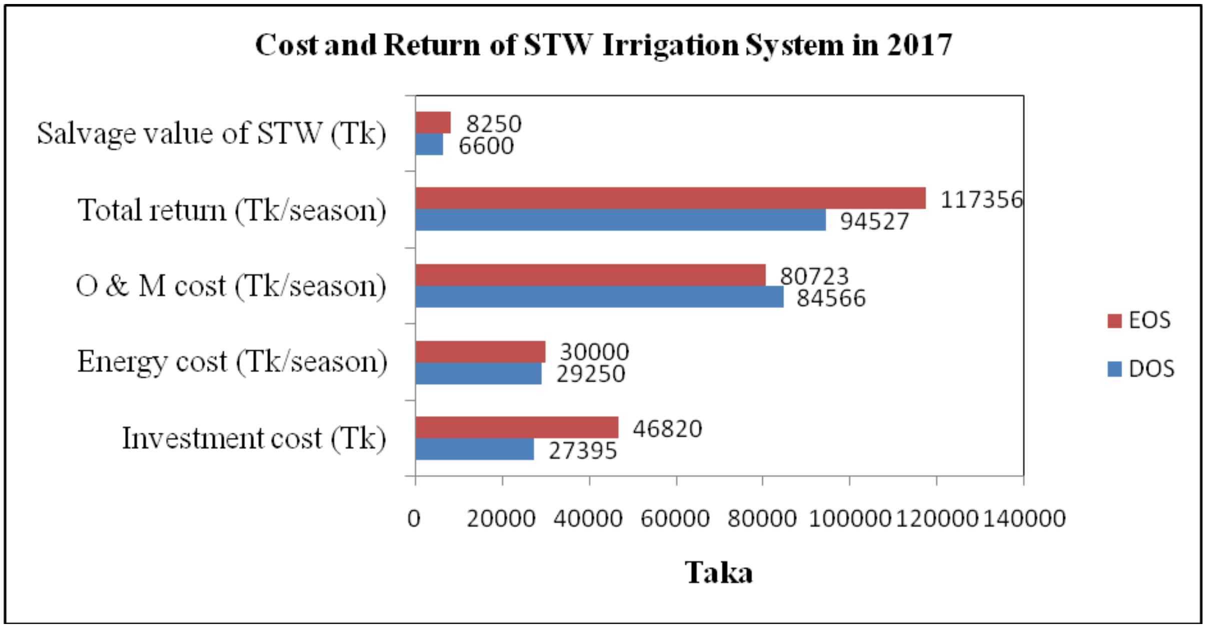


Figure 8.1: Comparison between cost and return of DOS and EOS irrigation system.

8.3.4 Sensitivity analysis of STW irrigation system (business)

Sensitivity analysis with Benefit-Cost ratio was calculated (Table 8.2) from investment cost, operation & maintenance cost and return or benefit mentioned in Table 8.1a, Table 8.1b and 8.1c. Details analysis was shown in Annexure 9, Annexure 10, Annexure 11, Annexure 12, Annexure 13, Annexure 14, Annexure 15, Annexure 16 and Annexure 17. Table 8.2 and Figure 8.2 showed that the irrigation business in the study areas was highly profitable in the current situation (2017) because Internal Rate of Return (IRR) was quite higher than bank rate (10 percent). Though the IRR of DOS was 56 % (higher than bank rate), but it was much lower than the IRR estimated in other study (Mandal and Parker, 1995). This lower IRR rate in present situation clearly proved that the IRR rate decreased over time mainly due to increase of diesel price and maintenance cost. Again, lower electric charges compared to fuel & lubricant cost and coverage of higher command area by EOS promoted the irrigation business, which proved to be more profitable than DOS.

During the recent past, both diesel and electricity price and output price was up and down in Bangladesh. In this regard sensitivity analysis was done considering the both certain and uncertain situations. Sensitivity analysis showed that for a 10 % increasing of operation and maintenance (O & M) cost or 10% decreasing of benefit when other cost remain the same, DOS business runs as unprofitable, while the EOS business still remains profitable (Table 8.2 and Figure 8.2). The main reason for lowering of profit from DOS was the significant increase of diesel price. Again, other things remaining the same, only diesel price increased by 10% will still give a marginal profit for the DOS owners (IRR 32%) (Table 8.2 and Figure 8.2). Moreover, if both diesel and rice price increased by 10% keeping other thing remaining the same; the irrigation business will be profitable. If diesel price increased by 20% and output price increased by 20%, the STW business will be even more profitable (Table 8.2 and Figure 8.2). Hossain and Moududi (2009) also did sensitivity analysis and made same comments about STW irrigation system or business.

Table 8.2: IRR, NPV and BCR of STW irrigation technology in different uncertain situations

Different certain and uncertain situations	Diesel operated STW			Electricity operated STW		
	IRR (%)	NPV (Tk)	BCR	IRR (%)	NPV (Tk)	BCR
In 2017 (current situation)	56	38499	1.07	360	184288	1.34
If O&M cost increased by 10%	-6	-14521	0.98	156	134692	1.23
If benefit decreased by 10%	-12	-20896	0.96	113	111866	1.21
If diesel price increased by 10%	32	19465	1.03	-	-	-
If diesel and output price increased by 10%	151	77797	1.14	-	-	-
If diesel price increased by 20% and output price increased by 20%	526	118158	1.20	-	-	-

Source: Field Survey (2017 Boro season)

*Taka 78.00 = US$ 1.0, NPV indicates Net Profit Value, BCR indicates Benefit-Cost Ratio.

Note: Table data calculated from Annexure 9, Annexure 10, Annexure 11, Annexure 12, Annexure 13, Annexure 14, Annexure 15, Annexure 16 and Annexure 17.

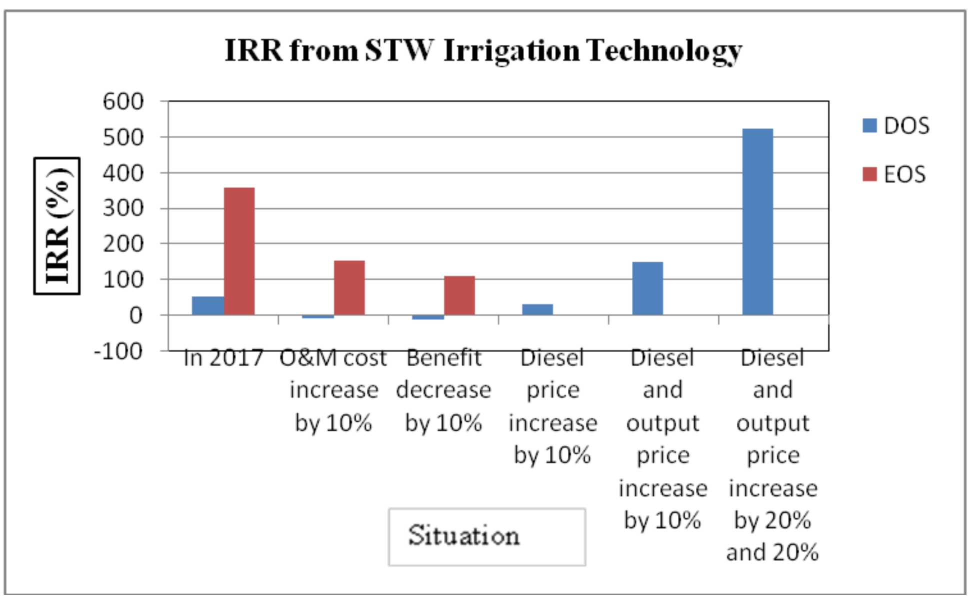


Figure 8.2: IRR from STW irrigation technology under different uncertain situation.

8.3.5 Profitability of Boro Rice Production with STW irrigation

Boro rice production involved different type of costs and returns which are shown in Table 8.3. Among the cost items for producing modern variety (MV) Boro rice, human labor was the vital one. Irrigation cost was the second highest which is essential for MV Boro rice production. The yield of MV Boro rice was quite satisfactory in the study areas. Per hectare cost and gross return for producing MV Boro rice under STW irrigation system is shown in Table 8.3. Item wise details cost and return has been described in below.

8.3.5.1 Cost of Boro Rice Production

Labour: Human labour cost was one of the most important and largest cost items in the production process of MV *Boro* rice. It required for different farm operations like land preparation, seedling, transplanting, weeding, application of fertilizers and insecticides, harvesting and carrying, cleaning, drying, storing, etc.

Both family and hired labour were used to cultivate Boro rice in the study areas. To cultivate one hectare land of Boro rice 156 man-days labour was required. Survey result revealed that 100 man-days hired labour and 56 man-days family labour were required to cultivate one hectare land of Boro rice. The average wage was different in 2016 and 2017. The average wage was US$ 6.41 (Tk. 500.00) per man-day in 2017, although it varied during different intercultural operations within the irrigation season (Table 8.3). Farmers generally paid higher wages during transplanting and harvesting time. The marginal farmers, who produced Boro rice in rented land mainly, used family labor to cultivate their plots. But the rich farmers were highly dependent on hired labour.

Tillage cost: The use of power tiller for land preparation has been increased rapidly in the study villages. Most of the farmers used hired power tiller. There was a competitive ploughing rate of power tiller in the study areas as a good number of power tillers were rented to plough the crop fields. Average per hectare tillage cost was US$ 32.00 (Tk. 2470.00) for two cross ploughings by power tiller or tractor in 2016. But in 2017 it was increased US$ 63 (Tk. 4940).

Seed and Seedlings: Farmers used both home supplied and purchased seedlings. Though, the seedling price varied US$ 0.44 t0 US$ 0.77 per kg (Tk. 35-60)) over the years. There was available seed in the market of 10 kg packet, which price was US$ 4.48 to US$ 5.12 (Tk. 350-400). There was different opinion about required amount of seed per unit area of land. As farmer’s opinion above mentioned 10 kg packet is required for 1 Bigha (33 decimal), but as per block supervisor 10 kg packet is sufficient for one acre (100 decimal). So, based on farmer’s opinion the amount of required seed per hectare was calculated. It was found that per hectare cost of MV *Boro* rice seedlings was US$ 33.00 (Tk. 2600.00) in 2016 which constituted 1.82 per cent of total cost (Table 8.5).

Fertilizer: Most of the farmers mainly used three types of fertilizer namely Urea, Tripple Super Phosphate (TSP) and Muriate of Potash (MP). The prices of fertilizers were US$ 0.20 (Tk. 16.00) per kg for Urea, US$ 0.19 (Tk. 15.00) per kg for MP and US$ 0.28 (Tk. 22.00) per kg for TSP both in 2016 and 2017. The farmers used 148 kg, 74 kg and 148 kg of Urea, MP and TSP respectively, which represent 1.66, 0.78 and 2.28 per cent of total cost in 2016. Farmers had to use lower doses of fertilizer in the plots which were used for mustard cultivation just before *Boro*. Normally there has been a residual effect of fertilizer on the *Boro* rice as the farmers usually apply higher doses of fertilizer in mustard cultivation. Some farmers used zinc and gypsum for getting better yield and per hectare US$ 25.64 (Tk. 2000.00) is needed in this connection, which represents 1.40 per cent of total cost in 2016. 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 at the rate of US$ 0.64 (Tk. 50.00) per quintal as some rice mill sold ash at this rate.

Insecticide and herbicide: Majority of the farmers in the study areas did not use any insecticide and herbicide in their plots to save the environment. Only a few farmers used insecticides in producing MV *Boro* rice in the study area. Almost all the selected farmers, who used insecticides for their MV *Boro* rice, were not sure about the name, brand, quantity and 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 cost incurred by farmers for purchasing insecticides from the dealers or retailers. It was found that per hectare cost of insecticide and herbicide was US$ 8.97 (Tk. 700.00), which was 0.49 per cent of total cost in 2016. Major farmers in the study areas did not use any insecticide and herbicide in their plots.

Irrigation: Irrigation was a leading input for MV *Boro* production. The cost of irrigation water was the main cost item of Boro rice production and it was a fixed share (usually one-fourth) of rice that is harvested by the pump owners directly from farmers’ fields as irrigation fee. Thus the per hectare water charge for irrigation was US$ 332 (Tk. 25920) in 2016 for MV *Boro* cultivation under STWs which represent 18.15 per cent of total cost.

Land rent: In the study area as well as all over the country, the marginal farmer who produced Boro rice in rented land mainly, or tenant who produced Boro rice in other land owner provided paying to the land owner. The rent of land was different for different plots depending upon location and topography of the soil. Land use cost considered on the basis of the land renting arrangement prevailed in the study areas. In the study area, for renting one Bigha (33 decimals) of land only for *Boro* season, tenant had to pay Tk. 5000 or 200 kg of rice to the land owner and for renting one Bigha (33 decimals) of land for one year (when farmers grow two or three crop in a year), the farmer had to pay US$ 79.74 to US$ 153.84 (Tk. 7000.00 to Tk. 12000.00) depending upon location, topography and type of the soil/land.

Capital Interest: Interest on operating capital (OC) included all cost in the process of growing MV *Boro* rice excluding which interest had already been charged. Interest on OC was estimated considering 10 percent bank interest rate. The rate was also used recently by several researchers (Sarwer, *et. al*., 2008; Nargis, 2008). The Interest on OC on an average was US$ 41 (Tk. 3218) for MV *Boro* rice production, which cover 2.06 percent of total cost in 2016.

8.3.5.2 Return from Boro Rice Production

Rice and straw: Per hectare yield of Boro rice was 5.48 ton in both year 2016 and 2017 and average price of Boro rice at harvesting period was US$ 1329 (Tk. 103682) and US$ 1616 (Tk. 126040) in the study areas in 2016 and 2017 respectively. From the field study it was observed that rice straw from one hectare of land was valued as US$ 143 (Tk. 11115) (Table 8.3).

Table 8.3: Production costs and returns of Boro rice per hectare in successive two years

Cost and Return item	In 2016			In 2017		
	Tk.	US$	% of total cost	Tk.	US$	% of total cost
Cost						
A. Family labour cost (56 Man-day@ Tk. 400-500 / man-day)	22400	287	15.69	28000	359	16.97
B. Total variable cost (Sum of sl. no 1 to sl. no 10)	**117474**	**1506**	82.26	**133643**	**1713**	81.00
1) Hired labour (100 Man-day@ Tk. 400-500 / man-day)	40000	513	28.01	50000	641	30.31
2) Tillage cost	2470	32	1.73	4940	63	2.99
3) Seedling	2600	33	1.82	2600	33	1.58
4) Urea@Tk. 16/kg	2368	30	1.66	2368	30	1.44
5) MP@Tk. 15/kg	1110	14	0.78	1110	14	0.67
6) TSP@Tk. 22/kg	3256	42	2.28	3256	42	1.97
7) Zinc and gypsum	2000	26	1.40	2000	26	1.21
8) Insecticide and herbicide	700	9	0.49	700	9	0.42
9) Water charge (1/4 th share)	25920	332	18.15	29619	380	17.95
10) Land rent	37050	475	25.94	37050	475	22.46
C. Interest on operating capital	2937	38	2.06	3341	43	2.03
D. Gross cost [A+B+C]	**142811**	**1831**	**100**	**164984**	**2115**	**100**
Return						
Rice 5.48 ton @ Tk. 18920-23000 / ton	103682	1329	Net return and BCR is determined considering hired labor and hired land.	126040	1616	Net return and BCR is determined considering hired labor and hired land.
Rice straw	11115	143		11115	143	
E. Gross return	**114797**	**1472**		**137155**	**1758**	
F. Net return [E-D]	**-28015**	**-359**		**-27829**	**-357**	
G. BCR [E/D]	**0.80**	**0.80**		**0.83**	**0.83**	

(Source: Field Survey in 2016 and 2017 Boro season)
*Taka 78.00 = US$ 1.0

8.3.5.3 Profitability analysis of Boro Rice Production

It was reported/observed that in the study area, the marginal farmers or tenant produced Boro rice in rented land and they generally used family labour to cultivate their plots. There were four categories farmers in the study areas (Table 8.4), they are:

1) When all inputs including land and labour were hired (category-1),
2) When all inputs hired except labour (category-2),
3) When all inputs hired except land (category-3), and
4) When all inputs hired except labour and land, i.e. when Boro rice is grown by farmer in his own land with family labour (category-4).

Therefore, profitability of Boro rice production would be different for different category. During the farmer's survey, data on irrigation input cost (labour, irrigation, fertilizer, fuel, land rent etc) and benefit (production and market price) were collected and the item-wise input cost and benefit are shown in Table 8.3. The analysis showed that amongst the four categories presented in Table 8.4, when all inputs including land and labour were hired (category-1), production of irrigated Boro rice was not profitable. Production of irrigated Boro rice was higher profitable when grown by farmer in his own land with family labor (category-4) (Table 8.4 and Figure 8.3). In this case, returns to family labour were US$ 6.41 (Tk. 500) and US$ 7.17 (Tk. 560) per man-day considering the year 2016 and 2017 respectively, which was quite higher the then normal wage and it indicated that Boro rice production was a competitive business in rural market and was strongly able to compete with other business. In cases of all inputs hired except labor (category-2), Boro rice production was reasonably profitable and all inputs hired except land (category-3), irrigated Boro rice production was marginal profitable to the farmers.

Table 8.4: Profitability of Boro rice production by STW per hectare

Category	For the year 2016			For the year 2017		
	Gross cost (US$)	Gross return (US$)	Benefit-cost ratio	Gross cost (US$)	Gross return (US$)	Benefit-cost ratio
1. All hired input	1831	1472	0.80	2115	1758	0.83
2. All hired input except labor	1031	1472	1.43	1115	1758	1.58
3. All hired input except land	1356	1472	1.09	1640	1758	1.07
4. All hired input except labor and land	556	1472	2.65	640	1758	2.75

Figure 8.3: Profitability of Boro rice production by STW per hectare.

8.3.6 Household income of STW owners

Annual household income of STW owners is shown in Table 8.5. Water selling, Boro rice production and remittance income was the major sources of income for STW owners. Table 8.5 clearly showed that the income from water selling had a significant role in total household income of STW owners. About 23 percent of total income was earned by STW owners from water selling, which was the second highest income. Remittance income from abroad (35 percent) was dominant in household income in the study areas. The STW owners earned 16 percent of household income from Boro rice which was much higher than Aman rice. However, Aman production was lost in 2016 due to uncertain flood and heavy rainfall. Farmers reported that the Aman production is hampered once in every 2-3 years. But Boro production is normally free of natural risks and gives a certain significant amount of income. EOS owners earned slightly higher income than DOS owners from water selling, but the difference was not statistically significant (t-statistics is 0.29 and $P \geq 0.05$).

Table 8.5: Annual household income of STW owners

Sources of income	DOS		EOS		All types	
	US$	**% of total**	**US$**	**% of Total**	**US$**	**% of Total**
Aman rice	32.95	2.40	26.79	1.36	26.92	1.62
Boro rice from own plots	254.26	18.54	286.74	14.51	268.72	16.12
Water selling	381.42	27.82	397.97	20.14	416.67	25.00
Aus rice, mustard, pulses, jute and sugarcane	38.45	2.80	49.79	2.52	43.59	2.61
Vegetables	21.28	1.55	35.37	1.79	27.67	1.66
Livestock, poultry and fisheries	26.35	1.92	50.40	2.55	37.24	2.23
Services	59.35	4.33	81.35	4.12	67.95	4.08
Business	169.60	12.37	97.71	4.94	134.62	8.08
Remittance	293.77	21.43	897.44	45.41	512.82	30.76
Others (trees & labour selling and rickshaw pulling etc.)	93.67	6.83	52.92	2.68	130.77	7.84
Total	1371.09	100.00	1976.49	100.00	1666.96	100.00

Source: Field Survey (2017)

*Taka 78= US$ 1.0

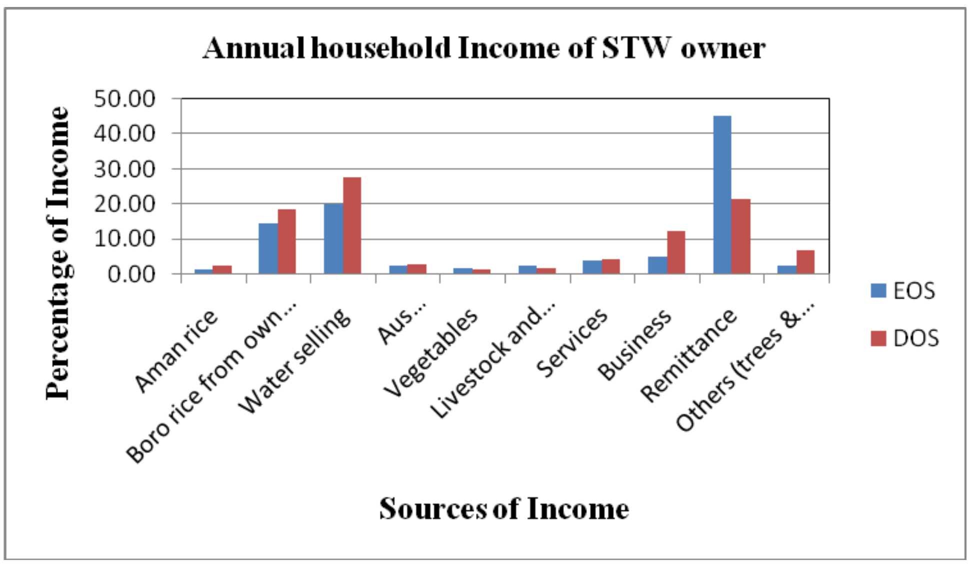


Figure 8.4: Annual household income (%) of STW owners from different sources.

8.3.7 Household Income of Water Buyers

Boro rice production and remittance were the main sources of income for the water buyers. Annual household income of water buyer is shown in Table 8.6. They earned the highest income from Boro rice (31%). Table 8.6 revealed that household income of water buyers prominently depends on Boro rice. Remittance also was one of the main sources of household income for water buyers, which was similar to water sellers. Small but countable amount of incomes came from business, services and labour selling and rickshaw pulling. Aman rice is also one main source of household income but the crop is susceptible to flood damages and the income from this crop is sometimes uncertain. The respondents opined that water buyers lost their aman rice in the year 2016 due to flood and heavy rainfall and got 2.2 % of total household income, which was insufficient. Average household income of water buyers was much lower than water sellers, who included tenant, small and marginal farmers.

Table 8.6: Annual household income of water buyer

Sources of income	Taka	US$	% of Total
Aman rice	1800	23	2.16
Boro rice from own plots	25820	331	31.00
Water selling	3511	45	4.22
Mustard, pulses, jute, wheat and sugarcane	2600	33	3.12
Vegetables	2000	26	2.40
Livestock, poultry and fisheries	4487	58	5.39
Services	5014	64	6.02
Business	7863	101	9.44
Remittance	20100	258	24.13
Others (trees & labour selling and rickshaw pulling etc.)	10100	129	12.13
Total	**83295**	**1068**	**100.00**

Source: Field Survey 2017
*Taka 78= US$ 1.0

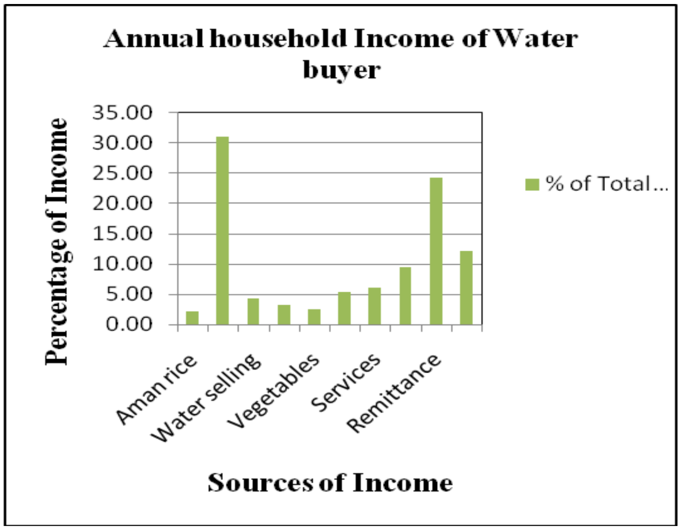


Figure 8.5: Annual household income (%) of water buyer from different sources.

8.4 CONCLUSION

This study demonstrated that 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 cost of STW irrigation system. Energy (diesel, petrol or electricity) price was the main operating cost of STW irrigation system. The DOS owners were anxious about increase of diesel price over the time because they were in break-even stage of this business. If diesel price increases continue, it would be very difficult to run STW irrigation business with marginal profit. This study demonstrated that STW irrigation business was marginal profitable in current price (2017) of inputs and output, but the business will unprofitable for DOS in uncertain situation considering 10 percent increasing of O & M cost or 10 percent decreasing of benefit or 10 percent increasing of diesel price (though it is marginal profit).

Boro rice production was higher profitable when farmers grown it in his own land with family labor. In this case, returns to family labour were US$ 6.41 (Tk. 500) and US$ 7.17 (Tk. 560) per man-day considering the year 2016 and 2017 respectively, which was quite higher the then normal wage. When all inputs including land and labor are hired, Boro rice production was not profitable. In cases of all inputs hired except labor, Boro rice production was reasonably profitable and all inputs hired except land, Boro rice production was marginal profitable to the farmers. Finally, this study concluded that STW irrigation system depends on social, economic and management issues to become profitable by the owners and irrigators.

Chapter 9

GENERAL DISCUSSION

Chapter 9

General Discussion

Groundwater is a precious and the most widely distributed resource for irrigation in the world. From a study it is reported that nearly one fifth of all the water used in the world is obtained from groundwater resources (Raghunath, 1987). Groundwater exploitation and utilization have become important throughout the country as water use in agriculture is increasing day by day. In Bangladesh, 65% groundwater is abstracted by STW for irrigation (BBS, 2015).

The focus of this thesis has been chosen to examine the structure of STW irrigation system, i.e. who are the associated with this system or how many stakeholders are associated with this system; to examine how the farmers run or manage their business, i.e. how they manage their fund, why they form partnership, how they mitigate their conflict raised during irrigation period; to examine the technical and economic performance of STW equipment; i.e. how perform (efficiency) STW perspective discharge, yield and how profitable the Boro rice production both for STW owner as well as water buyer. The yield performance of Boro rice was compared between DOS and EOS system (Chapter 6 and Chapter 8). Only Boro season (winter / dry season) was selected for this study. The key finding of the study are: a) STW irrigation business (water selling business) was profitable at the current (2017) high food grain prices, although irrigators paid one-fourth crop share as payment for water and EOS irrigation system was comparatively more profitable than DOS irrigation system. b) Production of irrigated Boro rice was reasonably profitable when it was grown by farmer in his own land with family labor. A number of additional issues relating to the STW irrigation system were discussed in this chapter.

9.1 Rationale of selection of study theme

Bangladesh, the most densely populated country in the world suffered from food deficiency for a long time. And it was the major challenge of government since liberation for increasing food grain production to meet up the growing demand. Following the over time, Bangladesh has made impressive progress in agriculture sector in the last three decades and has almost become self-sufficient in food grain production (Rahman and Parvin, 2009). This is a tremendous achievement owing to its small territory and huge population and this was achieved through agricultural mechanization and modernization. Irrigation is one of the leading inputs has direct influence to increase yield, food grains production and plays vital role for ensuring food security in Bangladesh. Various system / technologies have been used for irrigating crops which have contributed to rapid expansion of irrigated area. The conventional irrigation methods (Low Lift Pump, Dhone, Swing Basket, Treadle Pump etc.) were replaced by modern methods (i.e Deep Tube Well and Shallow Tube Well). In addition, surface water irrigation also sharply declined, losing its importance due to lack of new surface irrigation project and the ineffectiveness of earlier project. According to Rahman and Parvin (2009), groundwater covered 77 percent of total irrigated area and major (62%) extractions occurred through Shallow Tube Wells (STWs). The rapid expansion of ground water irrigation by STWs have been occurred / happened due to government's withdrawal on restrictions on tube well setting rule, encouraging private sector and the cost effectiveness of Chinese engine which have been affordable to the small and medium farmers. Before 70s, irrigation was mainly dependent on surface sources and in the mid-seventies government emphasized on groundwater irrigation with DTW projects. But government soon shifted to STW irrigation system because of it's suitability to socio-economic status of the farmers due to less investment cost, small land holdings, availability in the market, withdrawing restriction on import and STWs spacing. There are two types of STW, one is diesel operated Shallow Tube Well (DOS) and other is electric operated Shallow Tube Well (EOS) in the study area as well as all over the country.

Normally, approximately 20% of the geographical area of Bangladesh is affected by flooding and 80% land of the country is plain (Singh *et al.* 2013). For this reason STW irrigation system was selected as most suitable system for Boro rice production in winter season. Further, climate change did not affect on both DOS and EOS irrigation system regarding its sustainability. This was also reason to select of these two irrigation system / technology. In addition life cycle of these two techniques was very much similar. That's why both DOS and EOS were selected as a testing irrigation system.

9.2 Trend line of STW energy type in the study area

In Chapter 5, it was observed that last 20 years (from 1997 to 2017) DOS has been decreased from 76% to 04% and EOS has been increased from 24% to 96% (Fig. 9.1). It can be said that DOS is in abolition stage and EOS has been reached tends to 100%. That means due to availability of electricity supply, EOS has been increased. So, government should be taken necessary action to ensure uninterrupted power supply and metering system. Also electricity price should be maintained reasonably so that production cost is not increased.

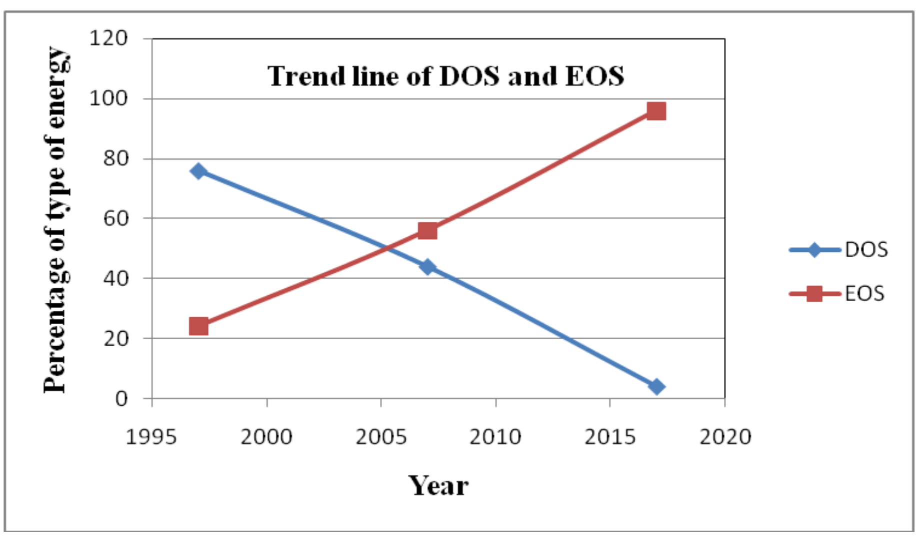


Figure. 9.1: Increasing and decreasing of type of STW energy.

9.3 Household income of STW owners and Water buyers

In Chapter 8, it was observed that the income from water selling (STW irrigation business) and Boro rice production had a significant role in total household income of STW owners and water buyer respectively. About 31 percent of total income from remittance, 25 percent of total income from water selling and 16 percent of total income from Boro rice production was for the STW owners, which was the first, second and third highest income respectively. On the other hand, Boro rice production was the main sources of income for the water buyers. They earned the highest income (31%) from Boro rice production and second highest income (24%) from remittance. Income from Boro rice was much higher than Aman rice. Farmers reported that the Aman production is hampered once in every 2-3 years due to uncertain flood and heavy rainfall. But Boro rice production is normally free of natural risks and gives a certain significant amount of income. Since STW irrigation business and Boro rice production is the major sources of income of the farmers and most of the farmers (80% people of the country) depended on Boro rice cultivation; that's why government should take care about Boro rice production to survive the peoples of the country as well as to meet up the food demand and for the development of the country.

Farmers earned a significant profit from MV Boro rice. Field survey data showed that specialized, experienced and educated farmers earned comparatively higher profit than those of other diversified, less experienced and lower educated farmers. Specialized farming, knowledge sharing and education of the farmers could be the ways of increased farm profit. Only one fourth of the young farmers were engaged in Boro production, so impressive extension works could involve more number of youths which would create a seasonal employment in the country. In such way, the farmers earn a handsome amount which contributed around 31 percent of total household income. Boro rice contributes highest percentage of total rice production. So, increase of Boro rice production would be a significant possible way to remove food deficiency in the country. Irrigation is the vital input for Boro rice cultivation in Rabi season in Bangladesh. So, developments of STW irrigation facilities are the crucial issue to increase and sustain MV Boro rice production.

9.4 Income and capital mobilization

Mustard and vegetables were the main crops cultivated by the farmers before of Boro season in the study areas. Although some farmers cultivated vegetables, about 25 percent of them did not make profit as per their expectation. Generally, income earned from mustard and vegetables production was mobilized to purchase inputs used for Boro rice production. But in 2016, the farmers failed to mobilize sufficient capital from mustard and vegetables for Boro cultivation due to loss of former crops. About 59% farmers borrowed money from relatives, neighbours, friends, NGOs etc. All borrowers did not use money for Boro cultivation; however one-fourth of borrowed farmers invested their money to purchase the inputs of Boro cultivation.

9.5 Observations during field visit and data collection

Approximately 100% farmers cultivated their land for Boro rice through STW irrigation system, no any other means and 80% crop area is covered by Boro rice in the study area. The farmer (water buyer) got water timely and adequately from the water seller, unless there is occurred any technical problem or any inconvenient situation is created. The farmer can complain to the water seller regarding poor quality of water supply (timeliness or adequacy) if any and the water seller listen to and take care of farmer complain. Since water charge is in terms of crop share, so water seller always tries to better irrigate in all plot. More production, more crops will get water seller. Based on this principle, it is duty of water seller how water would be allocated among buyers. Water seller (operator/driver of STW) take care about who (which plot) will get water and when. It was reported that last 10 years (from 2007 to 2017) diesel price has been increased from 35 to 65 Taka per litre respectively. By the by production cost has also been increased with diesel price increasing. For this reason, most of the STW owners (almost 100%) already shifted from diesel engine to electric engine. They opined that electric engine system was less operation cost, easy to irrigate larger command area. Moreover, electricity charge has to pay after harvesting crop and comparatively electricity charge was less than diesel engine in metering system. So EOS along with metering system would be reduced the production cost and thereby it would be more profitable.

9.6 Lessons from the focused group discussion (FGD)

Focused group discussion (FGD) was made with different type of stake holders associated with the STW irrigation business and Boro rice production. The different type of stake holders were STW owner, farmer, mechanics, driver / manager / operator, installer, worker in workshop, spare parts seller, social worker, politician, union councillor, social community etc. From the focused group discussion (FGD) with mechanics and spare parts seller, the investigator was informed that there were ten workshops within three markets near the study areas for repairing of STWs. Among these three markets, there were 12-15 shops engaged in STWs spare parts selling including pipe, strainer, cable, switch board etc. The distance from Union to Thana varied from 5 to10 km. There were only 6 mechanics in the selected 5 mauzas and they repaired only diesel operated STW (DOS). Each mechanic involved with a number of DOS depending on their experiences and quality of works. On the other hand, the EOS owner did not pay any fixed payment for mechanics. They paid mechanics in cash when they repaired their STWs in mechanic's shop. Both diesel and electric mechanics, they had no institutional or formal education or training; they learned it through doing the work in practical. There was no any training centre or any formal institution near the study area for mechanics, farmer, driver, installer and trader. All stake holders think that there should have training centre or formal institution at Union or Thana level for the development of their skillness.

Figure 9.2: A view of investigator was discussing with different stake holders

From the focused group discussion, the investigator was informed that some of the STW owners operated the machine by them and some of the STW owner hired the driver or the operator for operating the STW machine in Boro season (4-5 months). The payment varied from operators to operators due to differences in their experiences and relationship between STW owner and operator. There were two type of payment system all over the country viz per month salary and consolidated Boro rice for the period of irrigation season.

From the focused group discussion, the investigator was informed that some of the farmers cultivate Boro rice his own land with family labour or hired labour, again some of the farmers (marginal or tenant) cultivate Boro rice in other's land or rented land with family labour or hired labour. Marginal farmers cultivate Boro rice in rented land. He had to pay the land owners for a certain time (may be for season or may be for one or several years) at a fixed rate. On the other hand, tenant farmers cultivate Boro rice in other's land also, but he had to pay half return or benefit to the land owner. In some areas or some cases land owner pay half tillage cost and half fertilizer cost to the tenant.

9.7 Profitability of STW irrigation business

The main operation cost of the STW irrigation technology or water selling business was fuel/electricity bill and driver salary. There was no metering system at all except few STW in the study area. Power development board (PDB) made electricity bill on an average based on motor horse power. The STW owner informed the investigator that this average bill was much higher than the metering system bill. For example, in metering system a farmer paid Tk. 15,000 in the last season for 5 HP motor, but in an average system for same HP motor the average bill was about Tk. 30,000, i.e. almost double. So they opined that metering system would be profitable for the STW owner. Again, some of the STW owners operated the machine by themselves. On the other hand, some of the STW owner hired the driver or the operator for operating the STW machine in Boro season (4-5 months) and all ancillary works is done by the driver (such as paddy harvesting, collection from the field and drying etc). For this STW owner had to be paid Tk. 30000 to 35000 as their salary. So, those STW owners hired driver, their total cost became about Tk. 65,000 to run a STW machine. On the other hand, ¼ share as an irrigation charge STW owner got about 100 maund paddy which is equal to 3700 Kg (1 maund=37 Kg) and during season the price of this paddy was Tk. 80000 (1 quintal@ Tk. 2162). That is total cost was about Tk. 65000 and total return was about Tk. 80000 at the end of the season. But here it is noticed that STW owner had to be invested about Tk. 40000 as investment cost of STW which average life span considered 10 years. So, it may be said that there was marginal profit for STW owner provided hired driver or operator. If STWs were operated by themselves, in other word if they did not hire driver then STW irrigation business would be reasonable profitable. It was reported from the field that due to requirement of food demand of the family and to make self employment and to be engaged themselves with the work, still farmers are doing this work as parental business.

For example one of the case studies may be cited here to understand / examine whatever the STW irrigation business was profitable or not. Mr. Md. Ajmat Ali, a STW owner of Kaijalipur mauza once upon a time he was 4 STW, but at present he has only one STW. Mr. Ali informed that in last Boro season (2017) he was a STW owner where command area was 40 Bigha (7.41 Bigha= 1 hectare) and his motor capacity was 10 HP. His total cost was Tk. 75300 (electricity bill was Tk. 47300 and driver salary was Tk. 28000). On the other hand, his total return was Tk. 75000 converting the Boro rice price in terms of money. That is total cost was Tk. 75300 and total return was about Tk. 75000 at the end of the season. It was observed from this case study that Mr. Ali did not get any net profit through this business. Mr. Ali opined that electricity bill was too much excess due to non-metering system. He also thought that the bill will be reduced to Tk. 35000 if it became metering system and in that case he could save Tk. 12300 and the business would become profitable little bit. Here it is clear that if STW owner performed as manager / driver / operator, then his business would become profitable. Mr. Ali also opined that without increasing of rice price, farmers both STW owner and water buyer could not sustain or survive themselves through STW irrigation business and Boro rice production respectively. He opined that the price of Boro rice should be increased at least Tk. 1200 per maund (1 maund= 37 Kg) or Tk. 3243 per quintal or Tk. 32430 per ton to make profitable STW irrigation business as well as Boro rice production.

9.8 Profitability of Boro rice production

From the Table 8.3 entitled "Production costs and returns of Boro rice per hectare in successive two years" under Chapter 8, it was observed that irrigated Boro rice production cost was increasing year to year. But return was increased little bit in terms of money. In the following year-wise cost and return of Boro rice per hectare are shown in Figure 9.3.

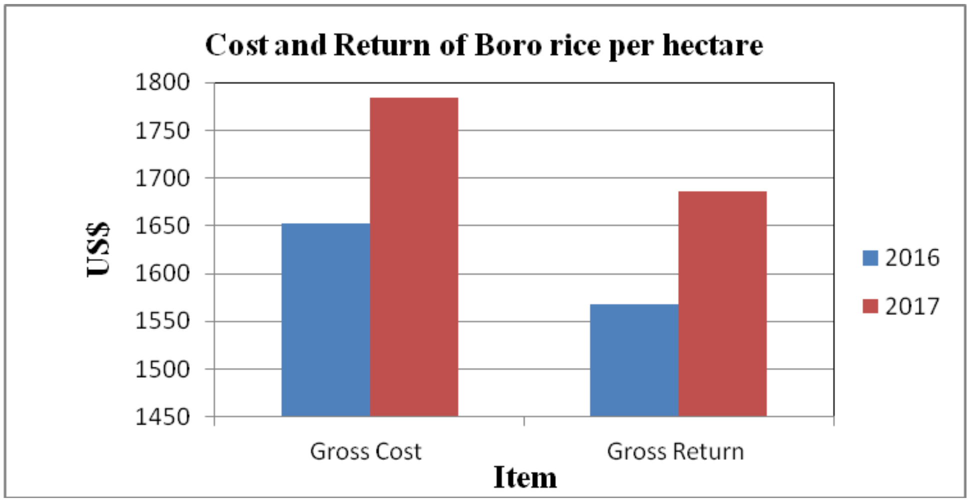


Figure 9.3: Year-wise Cost and return of Boro rice per hectare.

If we observed carefully the production costs and returns of Boro rice per hectare (Table 8.3 under Chapter 8) , we can see that there were mainly two types of cost involved viz 1) labor cost and 2) materials cost based on materials and non-materials. Labor cost includes different types of input cost such as land tillage, seedling, transplanting, weeding, application of fertilizer, pesticide and insecticide, harvesting, collection and drying of rice etc for Boro rice production. On the other hand, materials cost includes of seed, fertilizer, pesticide and insecticide. Besides the labor cost and materials cost, irrigation charge is an important item for Boro rice production.

In our country as well as in my study area most of the farmers were marginal and tenant. Marginal farmers cultivate Boro rice in rented land. He had to pay the land owners for a certain time (may be for season or may be for one or several years) at a fixed rate. On the other hand, tenant farmers cultivate Boro rice in other's land also, but he had to pay half return or benefit to the land owner providing that land owner pay half of production cost to the tenant.

Figure 9.4: A view of interview with a farmer by investigator

Farmers informed the investigator that those farmers who were growing Boro rice in their own land with family labour, in that case Boro rice production was higher profitable. Other wise Boro rice production was not profitable. They informed that production cost become higher than the total return if all input hired (specially labor and land). For example one of the case studies may be cited here. A farmer informed that to produce Boro rice per acre the total cost was Tk. 50000 and total return was 45 maund paddy (1maund=37 Kg) (after deduction ¼ share of irrigation charge) which was equal to 1665 Kg and during season the price of this paddy was Tk. 36000 (1 quintal @ Tk. 2162). That is total cost was Tk. 50000 and total return was Tk. 36000, that is Tk. 14000 was less than the production cost. So, it may be said that Boro rice production was not profitable in case of all input hired including labor and land.

If the farmer became tenant, then after deduction ¼ share of irrigation charge, the rice was divided into two parts of which one half got the land owner and the other half got the tenant. So, in above mentioned case studies, tenant and land owner got Tk. 18000 only for Boro season, but the cost of them each was Tk. 25000 which is more than the return. That means Boro rice production was not profitable in this system, especially for the land owner. It was reported that labor cost was 47% of total production cost of Boro rice (Table 8.3 under Chapter 8). So in this case study, labor cost was Tk. 23500 of which half paid by land owner and other half labor cost was adjusted by tenat farmer by devoted himself as a labor. He earned Tk. 18000 being invested

Tk. 13250 as materials cost. In this way tenant farmer survive themselves in practical situation. It was reported that land owner was not interested to grow Boro rice in his land in this system; he wanted to lease his land to the marginal farmer for getting cash money. The farmers opined that the price of Boro rice should be increased at least Tk. 1200 per maund (1 maund= 37 Kg) or Tk. 3243 per quintal to make profitable the Boro rice production at present situation.

9.9 Suitability and sustainability about STW irrigation system

Bangladesh is a land of 160 million inhabitants, where agriculture is still the major water using sector for surface and groundwater irrigation with rice cultivation for a long time, the single most important activity in the economy. In winter more than 70 percent of crop production is Boro rice. Boro rice is a major food crop which uses up a lot of water per hectare in the production process. According to a study it is 11500 m^3 per hectare (Biswas and Mandal, 1993). In this study, for Boro rice production water used 18222 m^3 per hectare.

From a study showed that irrigated area increased about three times and cropping intensity also increased from 154 to 176 percent within the period of 1981-82 to 2006-07 (Rahman and Parvin, 2009). The study revealed that Boro rice, an irrigated crop, consumed 73 percent of the total crop irrigation and contributed to a greater extent in total rice production in Bangladesh. Boro rice alone contributed to 55 percent of total food grain and was also highest production per unit area (3.44 MT per hectare) compared to Aus rice (1.66 MT per hectare) and Aman rice (1.99 MT per hectare). Consequently, the cultivated area of Boro rice increased by 1168 to 4068 thousand hectares within the period of 1980-81 to 2005-06 (Rahman and Parvin, 2009). The higher productivity of Boro rice has almost helped the nation to meet her food requirements (about 24 Million MT). Boro rice production was highly correlated (r=0.978) with irrigated area. Expansion of one hectare of irrigated area added 3.22 MT of Boro rice in Bangladesh (Rahman and Parvin, 2009). In this study, one hectare of irrigated area added 5.48 MT of Boro rice which is near to targeted yield. Here it is noticed that intensive land use is a pre-requisite to accelerate food production. Again intensive land use depends on the groundwater irrigation by STW which is one of the key factors in making the country self sufficient in food grain production. Farmers reported that the Aman production is hampered once in every 2-3 years. But Boro production is normally free of natural risks and gives a certain significant amount of income. In this point of view, the study entitled “Shallow Tube Well irrigation system in Bangladesh: perspective structure, management and performance” has great importance for the socio-economic development of Bangladesh due to its suitability and sustainability.

9.10 Effective use of STW irrigation system needs to be improved

Rice is the major staple food in Bangladesh and the majority of staple food grain comes from rice. About 80% of the cropped area of Bangladesh is used for rice cultivation, with annual production of 43.50 million metric tons in total land of 11.20 million hectare. The average yield of rice in Bangladesh is 3.88 metric tons per hectare (BBS, 2011). In this study, the average yield of rice was 5.48 metric tons per hectare in the study area. This yield of rice in Bangladesh is much lower than the existing world average. Rice production is currently in stagnant condition because farmers do not fully follow the improved techniques in an integrated way, which creates a yield gap. In this situation, farmers, researchers, and scientists are looking for new methods or technologies to get higher rice yield. To meet the increasing food demand, rice production must be increased and continued. Since Boro rice is produced completely under irrigation in winter or dry season by STWs, that's why the effective use of STW irrigation system also needs to be improved.

9.11 Improving management practice can increase productivity of STW

In our country most of our canals are earthen because of high initial cost for the construction of lined canals. The loss of water varies with the variation of soil characteristics. In sandy loam soil it is very high and in clay soil it is very low. It also depends primarily on season, water table, land topography, channel geometry and other flow characteristics. In minor irrigation project water loss through canal is of great concern. Since canals are earthen and irrigated lands are often located at a great distance, a large amount of water is lost as conveyance loss. Seepage and percolation are the processes by which considerable amount of irrigation water is lost. Irrigation water which is supplied in irrigation schemes, most of the time farmers could not be utilized properly. This loss in the field ranged from 15 to 50 percent of total water supply due to lack of proper management practices (Dutta, 1982).

Unlined earthen channels are frequently used to convey water in the farm. The advantages of earthen channels are that those are understood and accepted by the farmers. These can be built and maintained by unskilled labor and required no special equipment and materials. If improvement is made up in the channel network e.g. canal alignment, canal dimension, removing grass and compaction of channel, using lining material or polythene sheet, a considerable amount of pumped water can be saved. To meet up the food demand of increasing population, sustainable increased in production from irrigated agriculture must be achieved. It is possible to increase the productivity of shallow tube well by improving the management practices of soil, water and crop.

9.12 Numerous landless, marginal and small farmers

Continue decreasing per capita land in the country has been reached only 0.0542 ha (BBS, 2015). Landless farmer (less than 0.49 acre land owner) is 53%, marginal farmer (0.50-1.49 acre land owner) is 24%, small farmer (1.50-2.49 acre land owner) is 11%, medium farmer (2.50-7.49 acre land owner) is 11% and big farmer (greater than 7.5 acre land) is 1% of total farmer. So it is observed from the above information that the landless, marginal and small farmer is the highest number (88%). Most of the landless, marginal and small farmer of the country cultivates the land as a tenant especially Boro rice. Access of these farmers in STW irrigation system has been reached the country in self-sufficient in food grain production through self employment. That's why Bangladesh government should take necessary action for the development of the country through development of the STW irrigation system and Boro rice production.

Chapter 10
CONCLUSIONS, LIMITATIONS, RECOMMENDATIONS AND IMPLICATIONS OF THE STUDY

Chapter 10

Conclusions, Recommendations, Limitations and Implications of the Study

Rice is the main staple food grain in Bangladesh as well as part of the Asian countries and it covers about 80% of the total cropped area and it contributes over 90% of the total food grain production in Bangladesh. To meet up increasing food demand, the productivity of rice must need to be improved. Of the three types of rice viz Aus, Aman and Boro, Boro rice alone contributed the highest share of total rice production since 1998-99 to date. Boro rice alone contributed to 55 percent of total food grain and was also highest production per unit area. Thus, increased Boro rice production would be a significant possible way to overcome food deficiency in the country. Boro rice is produced in Rabi season (October to March) and it grows completely under irrigated condition by STW. Development of STW irrigation system / technology is playing a vital role for food security, livelihood and poverty alleviation. In order to grow more Boro rice, the effective use of STW irrigation technology needs to be improved. Therefore, the present study was undertaken 1) to estimate and examine cost and return both the STW owner's and farmer's from STW irrigation system and Boro rice production respectively, 2) to evaluate / understand how the STW irrigation system is running, managing, performing and contributing to the food security in Bangladesh. At the end of the research study, the following conclusions, limitations, recommendations and implications were summarised.

10.1 Conclusions of the study

1) This study demonstrated that the study area was suitable for Boro rice production as well as STW irrigation business due to geographical location, topography, lithology, aquifer characteristics and groundwater availability.

2) This research study concluded that two types of irrigation equipment were mainly used in the study area for groundwater abstraction. They were diesel operated STW (DOS) and electric operated STW (EOS). The study also revealed that in 1997, DOS was 76% and EOS was 24% in the study area, while in 2007 those were 46% and 56% respectively and in 2017 those were 04% and 96% respectively. Therefore, DOS is in abolition stage and electricity driven STWs increased a great extent near about cent percent.

3) The research findings also showed that there were seven different cropping patterns found in the study area. Main cropping patterns were Boro-T. Aman-Mustard and Boro-B. Aman-Mustard. Diversified cropping pattern was found in the study area due to the different soil type, the different land elevations and introduction of STW irrigation systems.

4) The study revealed that most of the engines / motors were imported from China and a quite few of them imported from Japan. However, some other countries like India and German made STW equipments were used in the study areas. Chinese and Indian engines were popular to the farmers due to cheaper, smaller and availability in the market, compared to more expensive Japanese engines. The farmers strongly felt that the smaller engines / motors were suitable for the smaller sizes of command areas due to fuel consumption were reasonably satisfactory and easy to irrigate the land whether of Japanese or Chinese or Indian origins, which indicated good performance of the engines with their pumps.

5) The study revealed that there were observed mis-match between pump and engines / motors, discharge with Brake Horse Power (BHP) and water distribution channel in the study area. Wide ranges capacities of engines or motors were used to irrigate Boro rice. Engine's / motor's BHP used in STWs usually were higher than the required BHP, which indicated misuse of energy due to lack of technical knowledge of the STW owners. The nominal revolutions per minutes (rpm) of many engines were much higher than the designed capacity of the pumps and the farmers had therefore to reduce the engine speed considerably. As a result, the engines could not run with a full load, resulting in poor fuel consumption and lower discharge.

6) The research findings showed that the command area of the STWs does not depend on the BHP of the engines. As a result, cheaper and smaller engines were favoured and as such Chinese engines have taken control of the markets and replaced the more expensive engines (from Japan). Data revealed that fuel consumption for smaller engines, whether of Japanese or Chinese origins were reasonably satisfactory. It indicates good performance of the engines with their pumps. Pump discharge of both engines (diesel and electric motor) considering same as BHP are little bit similar. Water productivity and land productivity of both engines were similar.

7) The performances of 12 STW selected schemes were evaluated using some standard hydraulic, agricultural and socio-economic indicators. The results showed that the schemes are now performing better than in the past. This was happened mainly because of higher pump discharges compared to the respective national averages, higher rice yield due to the application of high amount of chemical fertilizer, pesticides and good water management practices.

8) The study findings showed that the command area of the STWs did not depend on engine capacity alone, it is settled by a combination of factors such as pump capacity, availability of irrigable plots, soil types, slope of lands, land elevation variations, relationship among STW owners and irrigators (water buyer) etc.

9) The findings of this study indicated that the STWs were owned by single farmer or more than one farmer who was involved as a partner of STW irrigation business. Partnership was mainly formed by extended family members, kinship and neighbours. Most of the STWs were operated by partnership. Shares allocated among the partners were not necessarily equal and cost and return of their business were also shared according to their actual share.

10) Results of the study revealed that average level of education was slightly higher for single owners than STW partners. The findings showed that most of the STW owners were involved in agriculture activities as their main occupation. Most of the STW owners managed their investment and maintenance costs from formal credit sources (Bank, NGO, and Cooperative) as well as by selling or mortgaging out their land and a few cases they arranged funds from themselves. Most of the STW owners appointed drivers / operators as a manager and in some cases they performed as a manager (book keeping, serial maintaining for irrigating plots, taking care of engine / motor).

11) This study demonstrated that sometimes partners sit together and fixed or scheduled their management tasks of their irrigation business. Especially, diesel operated STWs owners resolved financial matters (repairing cost, predicted diesel cost and driver costs) before starting of the irrigation season. 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 or relocating command areas. Misunderstandings and conflicts were handled and mitigated by community institution (samaj) with participation of stakeholders from different gusthi (lineage).

12) From the statistical analysis data showed that higher education and higher income earning may be encouraged the farmers to participate in the STW irrigation business. The farmers, who were intensively involved with other business, may not be involved with STW irrigation business and the significant level strongly supports not to participate in STW irrigation business. The farmers having remittance income from abroad did not indicate any significant participation to the STW irrigation business.

13) This research study concluded that 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 irrigation business. Energy price was the main operating cost of STW irrigation business. The DOS was no more at all in the study area due to increasing of diesel price over the time and they were in break-even stage of this business.

14) The study showed that water selling, Boro rice production, and remittance income were the major sources of income for STW owners, while Boro rice production and remittance income were the main sources of income for the irrigators.

15) This research study also demonstrated that STW irrigation business was profitable in current normal price of inputs and outputs, when STW owners performed as a manager, but the business will unprofitable for DOS in uncertain situation considering 10 percent increasing of diesel cost or 10 percent increasing of total cost or 10 percent decreasing of benefit. It would be fairly unable to sustain the STWs irrigation business in severe uncertain situations with rising in diesel / electricity prices without commensurate rising in outputs (paddy) prices. The subsidy for diesel and electricity price and low tariff system for imported STW machine, spare parts can make the STW irrigation business sustainability.

16) Boro rice production was reasonably profitable at the current prices. The analysis showed that amongst the four categories of farmers, when all inputs including land and labor were hired (category-1), production of irrigated rice was not profitable. Production of Boro rice was highly profitable when grown by farmer in his own land with family labor (category-4). In this case, returns to family labour were US$ 7.17 per man-day, which was quite higher than normal wage (US$ 6.25/man-day), and it indicated that Boro rice production was a competitive business in rural market and was strongly able to compete with other business, which implies the sustainability of Boro rice production. In cases of all inputs hired except labor (category-2) and all inputs hired except land (category-3), Boro rice production was reasonable and marginally profitable to the farmers respectively.

10.2 Limitations of the study

In this study, certain small study area (5 adjacent mauza of Digholkandi Union under Ghatail Thana of Tangail district) was selected. It was a limitation of this study. But it would better if the study area considered all over the country. Then real scenario of the STW irrigation system in Bangladesh perspective structure, management and performance would be attained.

10.3 Recommendations of the study

The following recommendations were made to improve the quality of STW irrigation Business in Bangladesh:

1) Since most of the farmers concerned about the diesel price hike over time, they were keen to convert diesel operated STWs to electric operated STWs. In this regard, concerned

authority should give priority to facilitate electricity connections along with the provision of metering and billing systems.

2) Duty free import and free market distribution of irrigation equipments should be continued. Although Japanese and English STW engines were preferred by pump owners (if price were not considered), farmers have gone for cheaper engines, even with a perceived lower level of durability and a higher rate of breakdown. Therefore, the liberalized importation of smaller and cheaper engines should be continued. In this connection, Government can encourage the local concerned manufacturer for making at low cost (through without duties or restrictions etc).

3) Although rice production was profitable, the average yield was lower than in neighbouring countries. To increase yield government should increase investment in research for varietal improvement and on farm water management

4) Since, it is not possible to connect all STWs of the country with electricity connection in the short-term; some special subsidies should be ensured for coping with increasing diesel prices.

5) Since there was observed frequently a mismatch between engines and their pumps and systems in the study area, there should be an effort to remove it. Skill on matching engines with pumps and systems is important and there is scope for providing training and technical information for equipment traders, drillers and mechanics in regards to the selection of the right size of engine and pump and interpreting the physical system. This provision would help farmers minimize their costs of irrigation.

6) To keep the irrigation units (STWs) functioning smoothly, amongst other factors improvement of technical knowledge of rural mechanic through intensive training is very essential. The training facilities might enhance their work speed which may ensure the repairing of STWs quickly and also ensure uninterrupted irrigation for higher yield of Boro rice.

7) 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 due to shortage/unavailability of spare parts. This delayed repairing hampered crop production. This was a real problem in critical periods of crop growth. The increasing 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.

8) It was reported that due to uncertain supplying of fertilizers, farmers could not apply required fertilizers when needed and they had to drop from vegetations and mustard production. The Government should be ensured to supply fertilizers to the farmers in right quantity at right time and right price. This will help farmers to mobilize the earning coming from mustard and vegetables production to Boro crop cultivation.

9) Electricity operated STW owners earned higher profit than diesel operated STW owners. Conversely, DOS owners were sustaining with marginal profits. Diesel price should be subsidized to sustain irrigation water selling business by DOS. Otherwise, it would be fairly unable to sustain the STW irrigation business in severe uncertain situations like rising of diesel / electricity price without commensurate rising in paddy price.

10) Existing electricity connection procedure should be reviewed by the Government of Bangladesh (GoB) which might be improved the present situations about electricity connection and billing system. If diesel price increase and paddy price do not increase rationally, then the DOS owners will loss their spirit to run the STW and ultimately the crop production will be reduced in a large scale. To sustain this system, GoB should take a decision for continuing the existing subsidy system to the DOS owners.

11) Registration or electricity connection fee was quite higher which made some farmers unable to get electricity connection for their STWs. The higher fees are alleged to be charged illegally. The government should take steps to minimize cost of electricity connections fees and to ensure uninterrupted power supply for timely delivery of water to the field for improving yield

12) The EOS owners concerned about non-metering billing system. Non-metering rate of electricity would be rational if the rate could be billed on the basis of command area and not on the basis of engine capacity. Otherwise, the metering system would be recommended. In this regard, concerned authority should give priority to facilitate the provision of metering systems.

13) Shortage of diesel supplying and rising of diesel price in peak period of irrigation was reported in the study area. The government should monitor the diesel price and to ensure diesel supplying at the fixed price in time. Diesel price should continue to be subsidized to sustain irrigation water selling business as well as Boro rice production.

14) Potentials of the existing informal social institutions should be fully understood and utilized for improvement of command area level management of irrigation (i.e. allocation of plots, dispute settlement, field channel construction, etc).

15) Irrigation has direct influence towards farmer's socio-economic status, therefore further study could investigate the implication of irrigation on poverty alleviation in rural Bangladesh. Since total 7.41 mha lands is under irrigation and 54 percent irrigated land is under marginal and tenant farming for Boro rice cultivation, hence government should be kept in mind that the profit margins should have reasonable from Boro rice production for the marginal and tenant farmers.

16) The performance evaluation can be further improved by including indicators on environmental sustainability, income and employment generation and poverty alleviation.

10.4 Implications of the study

1) Irrigation is one of the leading inputs has direct influence to increase yield, food grains production and plays vital role for ensuring food security in Bangladesh. Groundwater irrigation covered 80 percent of total irrigated area and major extractions (62%) occurred through Shallow Tube Wells (STWs). In addition, different stakeholders are directly and indirectly associated with this STW irrigation system / business such as STW owners, water buyers, equipment traders, drillers, installers, mechanics, workshop etc. So, this business and Boro rice production lead to improve the socio-economic status of the farmers as well as different stakeholder's.

2) Eighty percent people of the country live in rural area and their livelihood is depends on agriculture. Through the STW irrigation technology and Boro rice production it is possible to alleviate poverty in rural area of Bangladesh.

3) Continue decreasing per capita land in the country has been reached only 0.0542 ha (BBS, 2015). Landless farmer (less than 0.49 acre land owner) is 53%, marginal farmer (0.50-1.49 acre land owner) is 24%, small farmer (1.50-2.49 acre land owner) is 11%, medium farmer (2.50-7.49 acre land owner) is 11% and big farmer (greater than 7.5 acre land) is 1% of total farmer. So it is observed from the above information that the landless, marginal and small farmer is the highest number (88%). Most of the landless, marginal and small farmer of the country cultivates the land especially Boro rice as a tenant. Access of these farmers in STW irrigation system has been reached the country in self-sufficient in food grain production through self employment. That's why Bangladesh government should take necessary action for the development of the country through development of the STW irrigation system and Boro rice production.

4) STW irrigation business as well as Boro rice production was highly profitable at the current high food grain prices. Higher return to management of human labour (US$ 7.17/man-day) was in fact able to compete with other business due to lower present wages (US$ 6.25/man-day), which implies the sustainability of Boro rice production. So, people can undertake this STW irrigation business as well as Boro rice production like other business or source of income.

5) This study demonstrated that EOS is more profitable than DOS. That's why EOS is increasing day by day in rural Bangladesh. In this regard, concerned authority should give priority to facilitate the provision of required electricity and should ensure uninterrupted supply of electricity properly through metering systems.

6) Since following over the time, STW irrigation has been established as a form of business in rural Bangladesh, it is essential to assess STW mapping in mauza map for the whole country for planning and decision making in holistic approach.

Chapter 11

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Chapter 11

REFERENCES

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Chapter 12

ANNEXURES

Annexure-1 (5 Pages)

STW Irrigation System in Bangladesh

Interview Schedule for STW Owner

STW ID: …………... *(Please take from STW list)* Sample ID: ……. Date: ……….

1. **Farmers Identification:**

Name:

Village	Mauza	Union	Upazila	District

2. **Types of farmer:**

STW Owner			Water Buyer	

3. **Types of STW ownership:**

Single			Partnership	

4. **If share, please give the following information:**

	Partner-1	Partner-2	Partner-3	Partner-4	Partner-5
Name of partners					
Formal education (year of schooling)					
Tech. knowledge (good/fair/poor)					
Main occupation					
Relationship with respondent					
% of share					
% of cost sharing					
Sources of fund (Own, Bank, Borrow, others)					
Land under command area (decimal)					
Residence distance from the STW					
Name of the Mauza/ village of his Residence					

5. **STW owner / partner involvement with social activities:**

Organization	Partner1	Partner2	Partner3	Partner4	Partner5
Union Parishad					
School committee					
Madrasha committee					
Bazar committee					
Mosque committee					

Shamity (Specify)					
Others (Specify)					

6. Technical aspects of the STW engine:

Depth of boring:		m

Types of pipe:	Iron		m	PVC		m

Types of strainer:	Bamboo		m	PVC		m	Iron		m

Depth of water table:		m

	T-pipe	Iron	PVC	Bamboo
Pipe dia: (cm)				
Pipe life span (year)				

7. Engine/pump characteristics:

Brand Name	Engine capacity (HP)	Pump/motor capacity (HP)	Life span (Year)	Years used

8. Source of energy for your machine ☐ Diesel ☐ Electricity

- *If diesel,* then how long did you operate? …………..years
- *If electricity,* then how long did you operate? …………..years
- *Before electricity* how was it operated? ☐ Diesel ☐ Others
- why did you shift from diesel to electricity?
  - ☐ Less operation cost
  - ☐ Easy to irrigate larger command area
  - ☐ Electricity charge has to paid after getting return from STW
  - ☐ Others

9. Command area characteristics:

Soil type:	Clay		clay loamy		Sandy	

Land type:	High		Medium		Low	

Area under command area (Bigha/acre/hectare):	
No. of farmers:	

Crops under command area (Bigha/acre/hectare) in 2015/2016/2017:

Boro rice	Wheat	Mustard	Vegetables	Others

Types of irrigation distribution channel:

Earthen		Plastic pipe		Pucca		Others (specify)	

Did your command area decrease over the year?

Yes		No	

If yes, what were the main reasons?

Irregular electricity supply/Diesel price increase		
New STW installation in previous command area		
Unable to bear operating costs of larger command area		
Others (specify)		

Did your command area increase over the year?

Yes		No	

If yes, what were the main reasons?

Due to merge with neighbor STW		
Due to shift from diesel to electricity		
Unable to run neighbor STW/DTW		
Others (specify)		

10. Benefit and cost of STW irrigation business:

Cost and Benefit	Year of purchase	Taka	Remarks
Investment cost:			
STW/motor purchase (Tk)			
Pump+pipe+strainer (Tk)			
Installation charge (Tk)			
House making for STW/motor (Tk)			
New irrigation channel making (Tk)			
Others (specify………..) (Tk)			
Operation and Maintenance (O & M) cost:			
Diesel (litre)			
Diesel price (Tk/litre)			
Electric bill (Tk)			
Mobil (litre)			
Mobil price (Tk/litre)			
Spare parts (Tk)			

Mechanics fee/charge (Tk)			
Driver /Line man/operator charge (Tk)			
Channel repairing (Tk)			
STW house repairing (Tk)			
Others (specify, ………..) (Tk)			
Benefit:			
Rice from share (maund/Kg/quintal)			
Rice price at harvesting period (Tk/maund or Kg or quintal)			
Straw (Tk)			
Income from other crops (Tk)			
- Mustard			
- Vegetables			
- Others			
Income from rice mill (Tk)			
Salvage value of STW/motor (Tk)			

11. Annual household income:

Sources	Taka	Sources	Taka
Non-irrigated Crops:		Cow	
- T. Aman		Goat/sheep	
- T. Aus		Chicken/duck	
- Mustard		Pigeon	
- Pulses		Fishery	
- Jute		Services	
		Business (profit)	
Irrigated crops:		Remittance	
- Boro rice		Labour selling	
- Wheat		Rickshaw/van pulling	
- Vegetables		Tailoring	
Trees selling		Mechanics	
Water selling		Others (specify)	
Power tiller service			

12. Characteristics of the main person managing the irrigation business?

Largest shareholder		
Who is highly technical about irrigation business		
Highly educated		
Better knowledge/experience about maintenance of STW		
Partner having largest area under command area		
Others (specify)		

13. Did you face any problem in construction of new irrigation channel?

Yes			No	

Did you face any problem to install/settle as a new STW owner?

Yes			No	

if yes, please mention the problems you have faced?

……………………………………………………………………………………

……………………………………………………………………………………

How did you solve the problem?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

14. Did you face any problem during irrigation of the plots?

Yes			No	

if yes, please mention, what type of problems did you face?
……………………………………………………………………………………

……………………………………………………………………………………

How did you settle the problems?

……………………………………………………………………………………

……………………………………………………………………………………

15. What is your suggestion to improve the STW irrigation business (if any)?
……………………………………………………………………………………

……………………………………………………………………………………

Thank you

Annexure-2 (4 Pages)

STW Irrigation System in Bangladesh

Interview Schedule for Water Buyers

STW ID: …………*(Please take from STW list)* **Sample no:**……. Date: ……………..

1. Farmers Identification

Name:

Village	Mauza	Union	Upazila	District

2. Types of farmer:

STW Owner			Water Buyer	

3. Please give the following information

Name of water buyer	
Formal education (year of schooling)	
Main occupation	
Subsidiary occupation	

Soil type:	Clay		clay loamy		Sandy	

Land type:	High		Medium		Low	

4. What crops were grown last year in your plots?

Rabi (2015-2016)	Kharif-I (2016)	Kharif-II (2016)	Plot area (decimal/acre/hectare)

5. Have you been cultivating your plots under same command area over the years?

Yes		No	

If no, what were the main reasons for cultivation under different command areas over year?

Irregular water supply	
New STW installation in closer place of the plot	
Conflict with STW owner	
Others (specify)	

6. a. Cost and return of main irrigated crops under the largest plot

Name of main crops						
Area of plot (decimal/acre/hectare)						
	No/Q	Tk/unit	Total	No/Q	Tk/unit	Total
Hired labor (man-day):						
Land preparation						
Transplanting						
Weeding						
Fertilizer application						
Herbicide application						
Harvesting						
Family labour (man-day):						
Land preparation						
Transplanting						
Weeding						
Fertilizer application						
Herbicide application						
Harvesting						
Power tiller/tillage (No.)						
Seed (kg)						
Urea (kg)						
TSP (kg)						
MP (kg)						
DAP (kg)						
Zinc (kg)						
Gypsum (kg)						
Insecticide (Tk)						
Herbicide (Tk)						
Irrigation (No.)						
Irrigation frequency (No.)						
Others (if any)						
Return:						
Main product (maund/Kg/quintal)						
Price (Tk/maund or Kg or quintal)						
By-product (maund/Kg/quintal)						
Price (Tk/…………….)						

b. Did you cultivate mustard in the same plot before planting Boro rice?

Yes			No	

7. Annual household income

Sources	Taka	Sources	Taka
Non-irrigated Crops:		Cow	
Aman rice		Goat/sheep	
Aus rice		Chicken/duck	
Mustard		Pigeon	
Pulses		Fishery	
Jute		Services	
		Business (profit)	
Irrigated crops:		Remittance	
Boro rice		Labour selling	
Wheat		Rickshaw/van pulling	
Vegetables		Tailoring	
		Mechanics	
		Trees selling	
		Water selling	
		Others (specify)	

8. Did you borrow money to purchase inputs regarding for Boro rice cultivation?

Yes			No	

If yes,

Amount borrowed (Tk)			Source:	

Total amount to be repaid (Tk):	Borrowed for (Months)	Interest rate (%)

9. Quality and quality of irrigation

a. How frequently did you get irrigation

Crop production stages	No. of irrigation
Land preparation	
Tillering (kushi expansion)	
Panicle initiating (growth)	
Flowering	
Grain filling	
Others (specify)	

b. Did you pay same water charge as others?

Yes			No	

If no, what was the water charge: …………. % of the total Boro rice production?

What were the reasons for difference in water charges?

………………………………………………………………………………………

………………………………………………………………………………………

c. Did you use any surface irrigation at the beginning?

Yes			No	

If yes, for how much land? ……………….. % of total land

What type of land was irrigated by surface water

Low			Medium	

d. How much of irrigation supplied by surface water? .... % of total irrigation

10. What are the major constraints you have faced in growing Boro paddy or what type of problems did you face? How did you settle the problems? (if any)?

……………………………………………………………………………………….

………………………………………………………………………………………

…………………..………………………. …………………………………………

11. What is your suggestion to improve the STW irrigation facility as well as Boro rice production cost could be minimized? (if any)?

……………………………………………………………………………………….

……………………………………………………………………………………….

Thank you

Annexure-3 (2 Pages)

STW Irrigation System in Bangladesh

Checklist for STW Mechanics /Workshop

1. How many number of mechanics worked in selected 5 mauzas (Saitapara, Kurmushi, Kaijalibeltail, Shekhsimul and Kagmari Beltail)?
2. Number and Location of workshops mainly used by STW owners from selected 5 mauzas.
3. How many STW machine / motor allocated / repaired by a mechanics and on what basis it depends?
4. What types of repairing activities are done / performed for STW?
5. Rate or payment or charging systems of STW machine, electric motor, pump, pipe and strainer repairing
6. How did you fix the rate of payment of machine/motor repairing?
7. How long did you provide services for STWs machineries under irrigation?
8. What types of services you mainly provide?
9. Life span of STW machine, electric motor, T-pipe, pipe and strainer made by iron, plastic and bamboo are used by STW owners.
10. Name of main brands are generally used by STW owners for electric motor, STW machine and pump.
11. Information about different types of pipes is used in a same STW boring.
12. What's about the mismatch among pipe diameter, pump and engine/motor capacity, discharge Vs distribution channel, HP Vs Command area?
13. Information about second hand electric motor and STW machine business in your area.
14. How you get spare parts during repairing of STW machine/ electric motors?
15. How STW owners inform you about machine or motor troubles?
16. Do you know the business about rejected machinery spare parts?
17. Problems or constraints during dealing with STW owners.
18. Have you any formal training or education as Mechanics?
19. What types of spare parts are made by workshops?
20. Do you think it is needed training and fund supply for providing better service?

STW irrigation System in Bangladesh

Checklist for STW Operator / Driver / Manager

1. What is your main work or duty?
2. What about your salary and how it is fixed?
3. When you receive your salary and do you face any problem to get salary?
4. Do you face any problems or constraints during irrigation period?
5. If yes, how did you solve it?
6. How many times you operate machine in a season and when you irrigate land?
7. How many diesel, mobil or fuel is needed for an engine for a season?
8. Do you have any suggestion for improving irrigation system?
9. Is there any mismatch among pump, engine BHP, discharge, pipe diameter, distributional channel etc. in the field?
10. What is your opinion about electricity supply in your irrigation area?

STW irrigation System in Bangladesh

Checklist for STW Installer

1. Numbers of shops are involved in boring of STWs in the selected 5 mauzas.
2. Rate or payment systems of boring the STWs.
3. How many people are associated for an installation group?
4. Support services for boring of STWs are purchased or rental basis.
5. Numbers of STWs are generally bored per irrigation season in the mauzas.
6. Information about bamboo made strainer.
7. What type of pipe mainly used for STW irrigation? i.e. plastic, iron or bamboo.
8. How long boring depth in your area?
9. Is there any relation between boring charge and boring depth?
10. How long time is needed of boring for a machine?

Annexure 4a: A detail lithology is shown for a bore-log GL93328001

Depth (m)	Thickness (m)	MaterialCode	Quality	Log
6.10	6.10	VSDSLTMIC	701505	
12.20	6.10	FSDVSDSLTMIC	70150505	
16.77	4.57	FSDMSDGVLSLTMIC	7015050505	
21.35	4.58	CSDVSDGVLMIC	70150505	
30.50	9.15	FSDVSDMIC	701505	
39.65	9.15	FSDMSDMIC	700505	
42.70	3.05	FSDMSDGVLMIC	55450505	
48.80	6.10	FSDMSDSLTMICGVL	7030050505	
53.38	4.58	FSDMSDMIC	554505	
64.06	10.68	FSDMSDMIC	554505	
67.11	3.05	FSDVSDSHLMIC	55450505	
71.69	4.58	FSDMSDCSDMIC	55451505	
74.74	3.05	FSDMSDGVLMIC	70150505	
80.84	6.10	MSDCSDMIC	701505	
83.89	3.05	FSDMSDCSDGVLMIC	5545150505	
86.94	3.05	FSDGVLMIC	700505	
93.04	6.10	FSDMSDGVLMIC	55451505	
96.09	3.05	FSDMSDVSDSLTMIC	5545150505	
102.19	6.10	MSDCSDGVLMIC	70150505	
106.76	4.57	FSDMSDGVLMIC	55450505	
107.37	0.61	FSDMSDCSDMIC	70150505	

GVL = Gravel
CSD = Coarse Sand
MSD = Mudium Sand
FSD = Fine Sand
VSD = Very Fine Sand
SLT = Silt
SH = Shale
MIC = Mica

Source: BWDB Borehole GL9328001, Birghatail, Ghatail, Tangail

Annexure 4b: A detail lithology is shown for a bore-log GL93328002

Depth (m)	Thickness (m)	MaterialCode	Quality	Log
4.88	4.88	PCLGVL	7030	
16.78	11.90	VSDSLTMIC	700505	
23.79	7.02	VSDFSDSLTMIC	70150505	
29.59	5.80	FSDVSDSLTMIC	55453005	
35.08	5.49	VSDFSDSLTMIC	55451505	
41.48	6.40	MSDFSDVSDSLTMIC	5545300505	
50.63	9.15	MSDSLTFSDPBLMIC	7030150505	
71.68	21.05	CSDGVLPBLMSD	50501505	
86.62	14.95	GVLVSDCLY	701505	
105.23	18.61	MSDFSDCLYSLTMIC	5545303005	
138.77	33.55	FSDSLTVSDMIC	70303005	
153.11	14.34	FSDVSDSLTMIC	55451505	

GVL=	Gravel
PCL =	Cobble
PBL =	Pebble
CSD =	Coarse Sand
MSD =	Mudium Sand
FSD =	Fine Sand
VSD =	Very Fine Sand
SLT =	Silt
SH =	Shale
MIC =	Mica

Source: BWDB Borehole GL9328002, Makrail, Deopara, Tangail

Annexure 4c: A detail lithology is shown for a bore-log GL93347001

Depth (m)	Thickness (m)	MaterialCode	Quality	Log
4.00	4.00	SLTCLY	7015	
10.98	6.98	VSDFSDSLTMIC	70150505	
23.18	12.20	VSDFSDSLTMIC	55450505	
59.48	36.30	FSDVSDMSDSLTMIC	7015150505	
76.86	17.39	CSDMSDGVLSLT	70151505	

Source: BWDB Borehole GL9347001, Elenga, Tangail

GVL =	Gravel
CSD =	Coarse Sand
MSD =	Medium Sand
FSD =	Fine Sand
VSD =	Very Fine Sand
SLT =	Silt
MIC =	Mica
CLY =	Clay

Annexure 4d: A detail lithology is shown for a bore-log GL93347002

Depth (m)	Thickness (m)	MaterialCode	Quality	Log
8.62	8.62	SLTVSDMIC	703005	
17.69	9.07	FSDMIC	7005	
28.98	11.29	FSDMSDMIC	701505	
48.80	19.83	MSDVSDMIC	701505	
57.34	8.54	MSDFSDSLTMIC	50500505	
70.15	12.81	MSDCSDSLTMIC	70050505	
83.88	13.73	FSDSLTMIC	700505	
93.03	9.15	MSDCSDSLTMIC	70050505	
107.36	14.34	FSDSLTGVLMIC	70150505	

GVL = Gravel
CSD = Coarse Sand
MSD = Medium Sand
FSD = Fine Sand
VSD = Very Fine Sand
SLT = Silt
MIC = Mica

Source: BWDB Borehole GL9347002, Kalihati, Tangail

Annexure 5: Twelve years monthly rainfall data of the Tangail rainfall station

Stn.	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Total	Total Dry Season	Total Wet Season
Tangail	2004	0	18	0	302	108	85	336	394	289	40	24	30	1626	374	1252
Tangail	2005	0	54	28	97	334	575	413	176	155	119	121	45	2117	345	1772
Tangail	2006	3	63	1	102	328	145	381	54	274	217	0	7	1575	176	1399
Tangail	2007	0	30	90	223	128	224	327	236	156	120	39	2	1575	384	1191
Tangail	2008	26	74	139	59	416	381	430	169	730	276	1	91	2792	390	2402
Tangail	2009	3	19	46	150	390	509	477	258	513	216	1	0	2582	219	2363
Tangail	2010	22	56	79	163	406	342	170	228	137	122	20	0	1745	340	1405
Tangail	2011	9	53	9	34	217	318	372	351	246	128	80	0	1817	185	1632
Tangail	2012	0	59	2	185	229	214	117	263	165	226	0	0	1460	246	1214
Tangail	2013	0	37	20	200	161	312	516	469	252	13	2	22	2004	281	1723
Tangail	2014	51	3	48	152	415	141	459	444	239	38	62	0	2052	316	1736
Tangail	2015	0	0	0	6	206	201	358	156	246	193	35	0	1401	41	1360
Average														**1896**	**275**	**1621**

Source: NWRD Database, CEGIS

Annexure 6: Details field data of Land Productivity (LP) of 12 STWs in the study area.

STW ID	Type of Engine (D/E)	C/A (ha)	C/A (Bigha) [Bigha= 33 decimal]	Production rate/Yield (maund/ Bigha)	Production rate/Yield (Kg/ Bigha)	Total Production (Kg)	LP (Kg/ha)	LP (MT/ha)
col (1)	col (2)	col (3)	col (4)= col (3)*2.47*3	col (5)	col(6)= col (5)*37	col (7)= col (6)* col(4)	col (8)= col (7)/col (3)	col (9)= col (8)/1000
SP01	D	2.52	18.67	18	666	12436	4935	4.94
SP02	D	3.12	23.12	18	666	15397	4935	4.94
SS12	E	4.55	33.72	18	666	22455	4935	4.94
SS13	E	3.60	26.68	22	814	21714	6032	6.03
SS07	E	4.00	29.64	21	777	23030	5758	5.76
KM01	E	3.50	25.94	22	814	21111	6032	6.03
KM02	E	2.72	20.16	22	814	16406	6032	6.03
KP01	E	3.25	24.08	22	814	19603	6032	6.03
KP02	E	3.20	23.71	19	703	16670	5209	5.21
KB04	E	4.50	33.35	21	777	25909	5758	5.76
KB05	E	3.20	23.71	18	666	15792	4935	4.94
SP03	E	3.20	23.71	19	703	16670	5209	5.21
Average=		3.45	25.54	20	740	18933	5483	5.48
Sum=		41.36	306.48			227194		

Annexure 7: Details of Water Productivity (WP) of 12 STWs in the study area.

STW ID	Type of Engine (D/E)	C/A (ha)	Diesel (L)/ Elect. Bill (Tk.)	Fuel consumed (L/hr)	Total operation Time (hr)	Discharge (L/s)	Total Vol. of Water (L)	Total Vol. of Water (M^3)	Total Production (Kg)	WP (M^3/Kg)
SP01	D	2.52	500	0.75	520	18.00	33696000	33696	12436	2.709
SP02	D	3.12	650	1.25	667	23.00	55227600	55228	15397	3.587
SS12	E	4.55	54700	-	1100	30.00	118800000	118800	22455	5.291
SS13	E	3.60	45000	-	800	23.00	66240000	66240	21714	3.051
SS07	E	4.00	50000	-	950	26.00	88920000	88920	23030	3.861
KM01	E	3.50	35000	-	750	20.00	54000000	54000	21111	2.558
KM02	E	2.72	30000	-	700	18.47	46544400	46544	16406	2.837
KP01	E	3.25	35000	-	725	20.00	52200000	52200	19603	2.663
KP02	E	3.20	30000	-	700	22.00	55440000	55440	16670	3.326
KB04	E	4.50	54000	-	1050	23.01	86977800	86978	25909	3.357
KB05	E	3.20	30000	-	700	17.00	42840000	42840	15792	2.713
SP03	E	3.20	30000	-	700	22.00	55440000	55440	16670	3.326

Annexure 8: Channel measurement of selected 20 STW's C/A of the study area.

STW ID	Command area (ha)	Channel Dimension			Channel X-section area (m^2)		
		Length (m)	Top width (m)	Area (m^2)	Av. Width (m)	Av.ht (m)	Area (m^2)
KB01	2.500	648	0.57	369	0.50	0.20	0.101
KB02	3.250	498	0.50	249	0.46	0.18	0.081
KB04	4.500	534	0.56	298	0.48	0.18	0.085
KB05	3.200	377	0.57	215	0.49	0.20	0.098
SP01	2.520	376	0.58	218	0.50	0.18	0.092
SP02	3.120	369	0.63	233	0.52	0.18	0.092
SP03	3.200	321	0.53	171	0.49	0.19	0.093
SP04	2.700	396	0.58	230	0.52	0.15	0.079
KM01	3.500	419	0.50	211	0.50	0.18	0.089
KM02	2.720	443	0.48	211	0.49	0.19	0.093
KM03	3.550	613	0.48	295	0.47	0.18	0.084
KM04	3.600	369	0.53	197	0.49	0.18	0.086
KP01	3.250	428	0.61	261	0.52	0.23	0.119
KP02	3.200	422	0.56	236	0.49	0.19	0.092
KP03	2.900	532	0.61	324	0.52	0.20	0.105
KP04	3.250	366	0.57	207	0.47	0.15	0.072
SS01	3.200	343	0.52	178	0.49	0.20	0.098
SS12	4.550	378	0.56	213	0.52	0.19	0.098
SS13	3.600	302	0.63	191	0.47	0.18	0.084
SS07	4.000	366	0.53	195	0.50	0.18	0.089
Average	3.320	424.92	0.56	236.04	0.50	0.18	0.091
Max	4.550	648	0.63	369	0.52	0.23	0.119
Min	2.500	302	0.48	171	0.46	0.15	0.072

Annexure 9: Benefit-Cost analysis of EOS

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	**46820**	**80723**	127543	**117356**	-10187	0.909	115937	106677
2	0	80723	80723	117356	36633	0.826	66677	96936
3	0	80723	80723	117356	36633	0.751	60623	88134
4	0	80723	80723	117356	36633	0.683	55134	80154
5	0	80723	80723	117356	36633	0.621	50129	72878
6	2500	80723	83223	117356	34133	0.564	46938	66189
7	0	80723	80723	117356	36633	0.513	41411	60204
8	0	80723	80723	117356	36633	0.467	37698	54805
9	0	80723	80723	117356	36633	0.424	34227	49759
10	0	80723	80723	125606	44883	0.386	31159	48484
Total							**539931**	**724220**

N.B.: Df indicates discount factor

Annexure 10: Benefit-Cost analysis of DOS

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	**84566**	111961	**94527**	-17434	0.909	101773	85925
2		84566	84566	94527	9961	0.826	69852	78079
3		84566	84566	94527	9961	0.751	63509	70990
4		84566	84566	94527	9961	0.683	57759	64562
5		84566	84566	94527	9961	0.621	52515	58701
6	2500	84566	87066	94527	7461	0.564	49105	53313
7		84566	84566	94527	9961	0.513	43382	48492
8		84566	84566	94527	9961	0.467	39492	44144
9		84566	84566	94527	9961	0.424	35856	40079
10		84566	84566	101127	16561	0.386	32642	39035
Total							**545886**	**583321**

Annexure 11: Sensitivity Analysis of EOS at 10 percent increases of O & M costs

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	46820	88795	135615	117356	-18259	0.909	123274	106677
2	0	88795	88795	117356	28561	0.826	73345	96936
3	0	88795	88795	117356	28561	0.751	66685	88134
4	0	88795	88795	117356	28561	0.683	60647	80154
5	0	88795	88795	117356	28561	0.621	55142	72878
6	2500	88795	91295	117356	26061	0.564	51491	66189
7	0	88795	88795	117356	28561	0.513	45552	60204
8	0	88795	88795	117356	28561	0.467	41467	54805
9	0	88795	88795	117356	28561	0.424	37649	49759
10	0	88795	88795	125606	36811	0.386	34275	48484
Total							**589528**	**724220**

Annexure 12: Sensitivity Analysis of EOS at 10 percent decreases of benefits

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	46820	80723	127543	105620	-21923	0.909	115937	96009
2	0	80723	80723	105620	24897	0.826	66677	87242
3	0	80723	80723	105620	24897	0.751	60623	79321
4	0	80723	80723	105620	24897	0.683	55134	72139
5	0	80723	80723	105620	24897	0.621	50129	65590
6	2500	80723	83223	105620	22397	0.564	46938	59570
7	0	80723	80723	105620	24897	0.513	41411	54183
8	0	80723	80723	105620	24897	0.467	37698	49325
9	0	80723	80723	105620	24897	0.424	34227	44783
10	0	80723	80723	113045	32322	0.386	31159	43636
Total							**539931**	**651798**

Annexure 13: Sensitivity Analysis of DOS at 10 percent increases of O&M costs

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	93023	120418	94527	-25891	0.909	109460	85925
2		93023	93023	94527	1504	0.826	76837	78079
3		93023	93023	94527	1504	0.751	69860	70990
4		93023	93023	94527	1504	0.683	63534	64562
5		93023	93023	94527	1504	0.621	57767	58701
6	2500	93023	95523	94527	-996	0.564	53875	53313
7		93023	93023	94527	1504	0.513	47721	48492
8		93023	93023	94527	1504	0.467	43442	44144
9		93023	93023	94527	1504	0.424	39442	40079
10		93023	93023	101127	8104	0.386	35907	39035
Total							**597843**	**583321**

Annexure 14: Sensitivity Analysis of DOS at 10 percent decreases of benefits

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	84566	111961	85074	-26887	0.909	101773	77333
2		84566	84566	85074	508	0.826	69852	70271
3		84566	84566	85074	508	0.751	63509	63891
4		84566	84566	85074	508	0.683	57759	58106
5		84566	84566	85074	508	0.621	52515	52831
6	2500	84566	87066	85074	-1992	0.564	49105	47982
7		84566	84566	85074	508	0.513	43382	43643
8		84566	84566	85074	508	0.467	39492	39730
9		84566	84566	85074	508	0.424	35856	36072
10		84566	84566	91014	6448	0.386	32642	35132
Total							**545886**	**524989**

Annexure 15: Sensitivity analysis of DOS at 10 percent increases of diesel price

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	87491	114886	94527	-20359	0.909	104431	85925
2		87491	87491	94527	7036	0.826	72268	78079
3		87491	87491	94527	7036	0.751	65706	70990
4		87491	87491	94527	7036	0.683	59756	64562
5		87491	87491	94527	7036	0.621	54332	58701
6	2500	87491	89991	94527	4536	0.564	50755	53313
7		87491	87491	94527	7036	0.513	44883	48492
8		87491	87491	94527	7036	0.467	40858	44144
9		87491	87491	94527	7036	0.424	37096	40079
10		87491	87491	101127	13636	0.386	33772	39035
Total							**563857**	**583321**

Annexure 16: Sensitivity analysis of DOS at 10 percent increases of both diesel and benefit price.

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	87491	114886	103980	-10906	0.909	104431	94518
2		87491	87491	103980	16489	0.826	72268	85887
3		87491	87491	103980	16489	0.751	65706	78089
4		87491	87491	103980	16489	0.683	59756	71018
5		87491	87491	103980	16489	0.621	54332	64571
6	2500	87491	89991	103980	13989	0.564	50755	58645
7		87491	87491	103980	16489	0.513	44883	53342
8		87491	87491	103980	16489	0.467	40858	48559
9		87491	87491	103980	16489	0.424	37096	44087
10		87491	87491	111240	23749	0.386	33772	42939
Total							**563857**	**641654**

Annexure 17: Sensitivity analysis of DOS at 20 percent increases of diesel price and 20 percent increases of benefit

Year	Investment cost (Tk.)	O&M cost (Tk.)	Total cost (Tk.)	Benefit (Tk.)	Incremental benefit (Tk.)	DF at 10%	Cost at 10% df	Benefit at 10% df
1	27395	90416	117811	113432	-4379	0.909	107090	103110
2		90416	90416	113432	23016	0.826	74684	93695
3		90416	90416	113432	23016	0.751	67902	85188
4		90416	90416	113432	23016	0.683	61754	77474
5		90416	90416	113432	23016	0.621	56148	70442
6	2500	90416	92916	113432	20516	0.564	52405	63976
7		90416	90416	113432	23016	0.513	46383	58191
8		90416	90416	113432	23016	0.467	42224	52973
9		90416	90416	113432	23016	0.424	38336	48095
10		90416	90416	121352	30936	0.386	34901	46842
Total							**581828**	**699986**

Annexure 18: CASE STUDY

Case-1: A case study of STW Irrigation Business Management System

Mr. Md. Mortuz Ali Munshi and Mr. Md. Abdul Barek are a electricity operated Shallow Tube Well (EOS) irrigation business partner in Kurmushi mauza. Mr. Mortuz is treated as the main actor because of his greater control over the business. He has 12 years of schooling; where as Mr. Barek can write his name only. Moreover, Mr. Mortuz has higher social status compared to Mr. Barek. Mr. Mortuz has also larger portion of command area than his partner. Previously they had two separate diesel engines. Historical backgrounds of these two partners are interesting and important one in management aspects.

Mr. Mortuz started his career as a teacher of a high school at Hamidpur Bazar in 1997. Three years later he resigned his job due to a misunderstanding with managing committee of that school. Thereafter in 1990 he worked as a broker or agent of mustard oil mills in Tangail district (30 km distance from his residence). Mr. Mortuz also got involved with rice mills as a commission agent during 1995. At the same time he was also involved with diesel operated STW business along with his younger brother. He inherited this STW irrigation business from his parents. Since Mr. Mortuz was involved with many other businesses, he left STW irrigation business to his younger brother Mr. Abdus Salam who started to run STW business alone in 2000. After 6 years Mr. Mortuz again returned and started STW business in his previous command area with his younger brother in 2006 and he again left his younger brother from the STW business in 2009. Finally Mr. Mortuz took Mr. Barek as a partner and jointly started EOS irrigation business in 2010. They managed electricity connection for their STW in the same year.

Here one thing is important to mention that, the first initiative for changing diesel engine to EOS came from Mr. Mortuz. Mr. Mortuz and Mr. Barek decided to run STW business jointly for coping with rising diesel price and also to increase command areas from single management to partnership/joint management. The idea first came to Mortuz as "if we connect with electricity we will be able to irrigate both command areas by bearing relatively same operation and maintenance cost". Then they made contact with a middleman (Mr. Abdus Satter) who worked as a contractor for connecting STW with electricity. They have paid Tk. 20000 as connection charge. They purchased electric motor (Tk. 10000) with the help of Mr. Masud Khan, who is an electrical mechanics and has a repairing shop at

Hamidpur Bazar of Ghatail Upazila. Finally they invested Tk 40000 for their electric operated STW to meet all expenses.

Each partner paid Tk. 20000 as investment cost. Mr. Mortuz financed himself from his regular income from vegetables and mustard. He did not sell his diesel engine as safeguard (against irregular electricity supply) and the STW was also used for irrigating vegetables plots during Boro crop seasons. On the other hand, Mr. Barek managed the investment cost by mortgaging out his land (Tk. 5000), selling diesel engine (Tk.9000) and the rest Tk. 6000 from family income. Actually, Mr. Barek has very little land in his command area

Last year (2016), they irrigated about 9.37 acres of land. This command area was formed by accumulating land from Mr. Mortuz (4.87 acres), Mr. Barek (3.6 acres) and Mr. Golap (0.9 acre). Mainly water buyers came from two command areas of the two STW partners (Mr. Mortuz and Mr. Barek). In addition a few irrigators came from another DOS (Mr. Golap) command area. Mr. Mortuz's command area consisted of land from patriarchal and matriarchal relations. He accumulated 2.17 acres of land from patriarchal relations and 2.4 acres from matriarchal relations. Moreover, another 0.3 acre of land accumulated from neighbour Ensun Talukder who lived in Kaijalipur village. Here, one thing is very interesting that most of command areas' land were accumulated from matriarchal side.

Though Mr. Barek have no own land in the command area, he accumulated 3.6 acres of land from his neighbour and relatives as 0.3 acre from cousin Johir uddin, 0.4 acre from his uncle Bisha, 0.5 acre from his uncle Moniruddin, and the rest amount of land from his ex-villagers of Kajalipur.

During the last Boro season (2016), they (Mr. Mortuz and Mr. Barek) operated their STW themselves by rotation without employing any driver (manager/operator). They operated STW in a weekly basis. Mr. Mortuz's son helped him when required and Mr. Barek himself performed the driving task. Their STW motor perfectly operated in last season without any technical difficulties. Again they did not invest any additional money because they paid electric bill after getting returns. They maintained proper rotation in irrigating all plots without any biasness because of crop sharing system as irrigation charge. Moreover, Mr. Mortuz took the opportunity of non-metering system because he suppressed the actual command area to electric office for paying less amount of electric bill (Tk. 20000 as electric bills). However, the total investment cost of their business was Tk. 40000 and operation & maintenance cost was Tk. 21500. The Table 1 below reveals that they received Tk. 28515 as Gross Margin for each from the last Boro season. The partner who worked as manager was also paid the same rate. 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 irrigation business.

Table 1: Cost and return of Mr. Mortuz and Mr. Barek STW irrigation business in 2016.

Item	**Tk.**	**US$**
Maintenance cost [Electric bill Tk. 20000, Channel repairing Tk. 1500]	21500	276
Interest on Operating capital @ 10 %	1075	14
Total	**22575**	289
Paddy (1/4 share), [37 quintals@Tk. 1892]	70004	897
By products (Straw)	9600	123
Total return	**79604**	1021
Gross margin/STW	**57029**	731
Gross margin/partner	**28515**	366

*Taka 78= US$ 1.0

Some observations were made from the field investigation:

1) In kurmushi mauza (Madha para), Hazi gusthi (lineage) were dominated class and Mortuz' father from Munshi gusthi got marriage with Hazi gusthi. Hazi gusthi possesses most of the land in those areas. Munshi gusthi were also influential gusthi particularly due to religious practitioner. After building new marital relationship both gusthis (Hazi and Munshi) acquired higher power and status in the social system. Still they have been continuing their marital relationship among the two gusthi. Mortuz and his elder brother Malek both got marriage with Hazi gusthi (Mr. Mortuz married with daughter of Mr. Mokbul Master and Mr. Malek married with daughter of Mr. Ahmed Ali). Through this endogamous marital relationship, Mortuz accumulated larger command area from his matriarchal relations.

2) Ensun Talukder having 0.3 acre of land tried to change command area by capturing land from Mortuz STW to Nazimuddin STW due to some misunderstanding. Moreover,

Nazimuddin came from same village of Ensun Talukder. But Nazimuddin did not agree to irrigate the land of Ensun Talukder due to established social norms and also higher social position of Mortuz. Finally, Ensun Talukder was bound to continue his Boro cultivation by irrigating his plots from Mortuz's STW, although he belonged to powerful gusthi (Talukder) in his own village of Kaijalipur.

Case 2: A case study of Electric Mechanic (Motor Mechanic) of STW

Mr. Masud Khan is an electric mechanic/electrician working at Hamidpur bazar of Ghatail Upazila. Though he did not receive any formal or technical education, he is providing better service through learning by doing. Mr. Khan worked as a wage labourer to the workshop of Tangail district at the beginning of his professional life. Before getting involved with the workshop he earned for his family by rickshaw pulling. Now he has an electric repairing shop at Hamidpur bazar of Ghatail Upazila and he started this shop in 1988. He has appointed two assistants for providing fast repairing services to his clients. Mr. Khan provides all kinds of electrical services particularly in STW motor repairing, starter making, switch board making, changing phase, and he also helps farmers for purchasing new or old STW motors. Moreover, he purchases old motors from different parts of Bangladesh, particularly ship motors and rice mill motors. After purchasing old motors he repairs it according to farmer's demand of HP and then sells to the farmers. He spends Tk 900 for making a starter of STW and sells it for Tk 1200. Generally, he charges Tk. 1000 as service charge for repairing 7 HP motor and keeps the old coils. He charged extra Tk 600 for those clients who wanted to take their old coils of burnt motor. Most of the time farmers pay about Tk. 1500 as repairing cost for 7 HP STW motors (including service charge and coil costs) in case of coil burn. There are two different shapes of Chinese electric motor available in markets such as motor having blank space and no blank space in the coil shape. Mr. Khan informs that motors having blank space in the coil shape require more electricity and these also more vulnerable to burning. However, Mr. Khan sold 73 electric STW motors and repaired (minor and major difficulties) 113 motors in the last Boro season (2017) in the surrounding areas of Tangail district. Though there are another 4 electric repairing shops in Hamidpur bazar of Ghatail Upazila, he is dominating due to his long business experience. Moreover, he trains other electric mechanics to come to this profession. He earns about Tk 50000 as a profit by providing STW motor related services after bearing all expenses (purchasing old motors, coils, assistant salary, rent of the shop etc.). The electric operated STW owners (such as Mr. Khursed from Kaijalipur and Mr. Mortuz from Kurmushi) opined that they were happy and satisfied with Mr. Khan for his services. Besides seasonal STW electric motor repairing services, he also provides servicing to household electrical goods (fan, refrigerators, radios, etc.) and also rice mill motors.

Figure: Mr. Masud Khan, an Electric Mechanic working at Hamidpur bazar of Ghatail Upazila in his shop.

Case 3: A case study of coping with changing diesel prices as well as role of samaj (community leader).

Mr. Md. Abdul Kader has a diesel operated STW in Sheksimul Mauza. He purchased this STW in 2010 from Mr. Md. Abdul Hanif. Mr. Hanif sold his diesel engine to meet financial needs for continuing business and also to bear the expenses of his daughter's marriage. Mr. Kader operated his DOS with irrigating 4.8 acres of land till 2015. Last year (2016), he was unable to operate the diesel engine due to higher fuel prices and financial crisis. Again he neither could arrange new partners (sharing business) nor manage capital required for changing DOS to EOS. Moreover, he tried his best to be a partner of Mr. Latif's electric operated shallow Tube Well (EOS), but Mr. Latif and his existing partners denied him of any partnership in their business. After long discussion and with the help of samaj (community leader) they settled new type of arrangement, where Mr. Kader had paid Tk. 6000 to Mr. Latif and his partners for irrigating 4.8 acres land under his (Mr. Kader) STW command area. In addition he paid Tk. 2000 as driving/management cost and also Tk. 2000 for channel making and repairing cost. Mr. Kader as usual had taken 1/4 share of crop for his STW command areas like as before without operating his diesel engine. From this arrangement Mr. Kader benefited greatly (Tk. 9000 as Gross margin), though he doubted about the sustainability of this arrangement. Mr. Latif and his partners (Mr. Akter and Mr. Ezaz) were also happy with the new arrangement due to non metering electric billing system. So, this case study illustrates the coping strategy of running diesel operated Shallow Tube Well (DOS) with increasing diesel prices.


Figure: A view of STW shed and discussion between investigator and STW operator.

Case 4: A case study of cooperation helps to earn more income in STW irrigation business.

This is a case of electric operated Shallow Tube Well (EOS) owned by four partners in the Kurmushi Muaza. They formed partnership in 2015 by 1/4 sharing arrangement. Before partnership formation every body was involved in diesel operated Shallow Tube Well (DOS) irrigation business in that area. Mr. Salam and Mr. Maziber had single owned DOS, while Mr. Rashid and Mr. Shahidul had partnership DOS. They were not from the same village. Mr. Salam came from Kurmushi village and another three from Mujahati village. Mr. Salam has little literacy and can only sign, whereas others have higher educational qualification. Though they are not close relatives, they formed partnership STW because they knew the benefits of cooperation. They have taken Mr. Salam as a partner because of his larger command areas. They accumulated 23.2 acres of land, which comprised of earlier DOS command areas of Mr. Salam 9.5 acres, Mr. Maziber 4.5 acres and Mr. Rashid and Mr. Shahidul jointly 9.2 acres of land. They got connected with electricity easily because of one partner (Mr. Rashid) having good linkage with PDB officials (Mr. Rashid is also a retired service holder having M.A. degree). The total cost of purchasing motor, pump, pipes, boring, housing and connection fees was Tk. 55000 shared equally by them. They irrigated this larger command area by operating 10 Horse power (HP) electric motor and they appointed two drivers for operating the pump and managing the command area. The Table 2 reveals that after meeting all cost (operation and maintenance) each partner earned gross margin of Tk. 39947 in the first year of operation. So, this case study illustrates that the cooperation helps to earn more income in STW irrigation business.

Table 2: Cost and return of a partnership STW irrigation business in 2016.

Item	Tk.	US$
Maintenance cost [Electric bill Tk. 36000, driver salary Tk. 42000, Motor repairing Tk.3000 and channel repairing Tk. 2500]	81500	1045
Interest on Operating capital	4075	52
Total cost	**85575**	1097
Paddy (1/4 share), (11.70 tons@ Tk. 18920)	221364	2838
By products (Straw)	24000	308
Total return	**245364**	3146
Gross margin/STW	**159789**	2049
Gross margin/partner	**39947**	512

Case 5: A case study for non-cooperation in STW irrigation business

This is a case study for non-cooperation in STW irrigation business. Mr. Nasiruddin, Mr. Sader Fakir and Mr. Jabber are STW owners and their STW location is very close to each other. But they did not make any cooperation with each other. One EOS was owned by Mr. Sader Fakir and other two partners. Last year (2016), Mr. Sader and Mr. Nasiruddin took an initiative to form partnership with each other. But they did not success because they did not settle how the share of STW would be distributed among the partners. Mr. Nasiruddin demanded 1/3 share and it was also settled by samaj, but Mr. Sader's partners disagreed to provide 1/3 share. They agreed to give 1/4 share as they already had three partners. Finally they did not success to form partnership management and failed to earn higher gross return. If they succeed to form partnership management, then their operation and maintenance cost (such as electric bill, driver salary, repairing motor and channel repairing etc.) cost would be reduced at the remarkable rate and they would get higher gross return. The Table 3 reveals the cost and return of both Mr. Sader and Mr. Nasiruddin STW irrigation business in 2016.

Table 3: Cost and return of Mr. Sader and Mr. Nasiruddin STW irrigation business in 2016.

Item	Mr. Sader Fakir		Mr. Nasiruddin	
	Tk.	US$	Tk.	US$
Maintenance cost (Electric bill, driver salary, repairing motor and Channel repairing)	38000	487	35500	455
Interest on Operating capital	1900	24	1775	23
Total cost	**39900**	512	**37275**	478
Paddy (1/4 share), [Mr. Sader 40 quintals and Mr. Nasiruddin 28 quintals @ Tk. 1500]	62436	800	45408	582
By products (Straw)	6000	77	4000	51
Total return	**68436**	877	**49408**	633
Gross margin/STW	**28536**	366	**12133**	156
Gross margin/partner	**9512**	122	**8725**	112

Case 6: Social Power influence on STW irrigation business

Mr. Khoka and Mrs. Halima were the partners (sharing ratio is 75:25) of a STW of Shekh Shimul mauza under Dighalkandi Union of Ghatail Upazilla of Tangail district. Mr. Khoka had 5 years education and other woman partner Mrs. Halima had no formal education but can sign only. She (including her 18 years old son) was separated from her husband 15 years ago. She was also a cousin of her partner Mr. Khoka. Their technical knowledge about STW machineries was very poor. Mr. Khoka went abroad (Dubai) to do job in 2013 and then his wife Mrs. Hanufa had taken the responsibility of the STW. Mrs. Hanufa also had no formal education and was poor in technical knowledge about STW machineries.

The command area of 2.30 hectares under their STW was fully used for Boro cultivation. Mrs. Halima had only 10 decimal cultivable lands but other partner had no land at all under this command area. Nineteen irrigators irrigated their plots from their STW last Boro season (2016). From the plots under command area of their STW, they got 1285 kg of Boro rice as one fourth share of total production which was equivalent to Tk. 24330. In this year (2017), they are facing problems with a neighbour. The neighbour proposed to engage as a partner of their STW as he is the owner 360 decimal of land under the command area. But they disagreed and denied the neighbour's proposal. They replied that they already established full set of STW business and the proposal is not acceptable. Lastly, the neighbour installed a new STW in his own land which is very close to their STW. They made discussions with villagers to solve the problem. The villagers gave opinion against the installation of new STW but the neighbour refused to accept their suggestion. Mrs. Hanufa and Mrs. Halima also wanted the help from government authority, but they failed to communicate. The neighbour has strong social power as he was a former Union Parishad (UP) Member and owner of much land in their locality. Other irrigators, however, still agree to continue Boro rice cultivation from the old STW. That's why they (Mrs. Halima and Mrs. Hanufa) set up mind to keep their old STW in the same place but finally they moved their STW to another location of the same command area due to trouble for making irrigation channel along the neighbour's plots. So, this case study illustrates that the social power influence on STW irrigation business.

Annexure 19: FOCUSED GROUP DISCUSSION (FGD)

A focused group discussion was made with different stakeholder such as pump owners and irrigators, STW installer, STW operators/drivers/managers, STW mechanics and Electric motor mechanics, irrigation equipment traders, complementary import dealers and support service providers in order to obtain different types of information regarding STW irrigation technology and profitability of Boro rice production. Data/information's collected through discussion with different stakeholder are described in the following.

1. FGD with STW Installer

STW installers work as a group which consists of 5-7 members in the study area. There were about six (6) groups of installers involved in installing services in the study areas. Generally, they bore 65 to 80 ft for STW installation in this areas. Most of them did not have any technical education from formal institution, but they trained-up by doing the work in practical. Basically, they install STW at the start of the season and rest of the time of year they are involved in other occupations also, particularly in agriculture. Installers opined that they purchase their required equipments jointly or in some cases one group member finances the whole amount of expenditure. Each group installs about 15-20 STWs in a season and it depends on new STW entrance in the field and re-installation. There are mainly three types of pipe and strainer used for STW installing in the study area such as PVC, Iron, and Bamboo. The bamboo filter was made by installer by using bamboo, iron ring, net (filter), string. Farmers use bamboo filter because of its cost effectiveness. The farmers and installers feel that the bamboo filter helps to discharge more water. The installation charge varies Tk. 1500-4000 on the basis of boring depth and pipe diameter. In addition the STW owner provides one/two meals to the installers group. Again, installer bore 20-30 feet depth for hand tube well which is used to supply water at the time of the main installing activities. They linked two PVC pipes by heating and also using taps and glue. Most of the time STW owner collects related equipment from nearer market of Hamidpur bazar. There are about 5 shops in that area and they mostly provide hand tube well, pipes, filters, tapes, glue and other materials. The shopkeepers also provide warranty services for some specific brand of PVC pipes. Generally, farmers withdraw and re-install their STW after 5-10 years. One thing is interesting that in case of single investment in installer group, the investor plays as an owner (proprietor) and he pays other group members on daily wage basis. After paying wage to the group members, he takes rest of the money as his investment benefits.

2. FGD with STW operator/driver/manager

STW operator is also known as lineman / driver (who maintain supply of irrigation water to the line/channel) in the study area. The main task of STW operator was to operate and maintain STW, but they also maintained supply of irrigation water in irrigation channel in time as per required. They followed some kind of distribution route to irrigate their plots to avoid any conflicts among the irrigators. He was also responsible to care about collection of paddy from the irrigator’s field as irrigation charge. There was no significant difference between operator’s salary with respect to diesel or electricity run STWs.

The manager/driver/operator of the STW was appointed by the owners and their salaries were paid only for Boro season (about 4 months). Payment for operator was paid in kind as 32 maunds (1200 Kg) Boro paddy for a four month period of irrigation season or some where monthly salary is paid for operator and that is near about Tk. 8000 and operator is appointed for 4 or 5 months. Actually, the payment varied from operators to operators due to differences in experiences. Some partners performed as STW manager alternatively in a seasonal or weekly or monthly or yearly basis. The partner who worked as manager was also paid the same rate. 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 the control over the STW irrigation business.

3. FGD with STW Mechanics and Electric Motor Mechanics

The diesel operated Shallow Tube Well (DOS) owners mainly go to 3 markets near the study areas for repairing their STWs. There are 10 workshops in these 3 market places. The mechanics only repair DOS and 6 mechanics work in the selected 5 mauzas. Every mechanic is involved with 20-70 DOS, depending on their experiences and quality of works. The DOS owners appointed mechanics each season for their STWs on consideration of rapport, locality and quality of works. The rate of each machine is 3 maunds (about 120 kg) of Boro rice fixed by their association. They feel that the rate is reasonable in a competitive market. The better mechanics have involvement with more numbers of STWs but the rate of payment is the same. They have opportunity to work with STWs owner for 5 months, while 1.5 month is pick season of their work. Repairing of cylinder, piston, nozzle, plunzer, wheel bearing etc were the main works of STWs. According to the mechanics opinion, about 70 percent diesel machineries/engine or motor come from China, 10 percent from India, 10 percent from Japan and the rest 10 percent come from Germany and England. Delivery pipe is fitted with lower diameter than main pipe due to adjustment with lower electricity supply in peak period of Boro season (when much irrigation is required for Boro plots). They reported that bamboo made strainer supply more water than plastic strainer. The price of bamboo strainer is also lower. About 40 percent owners use bamboo strainer, while 50 percent owners use plastic strainer in the study areas. The mechanics are also involved with second-hand machine business. They make profit per STW as Tk. 2000. When they sell the second-hand machine to the owners they do not provide any warranty for any kind of trouble. They also help the owners for purchasing new STW machines with payment of Tk. 200 to Tk. 400 per STW.

There are 5 electric repairing shops (working as electric mechanic/electrician/rural mechanic) in Hamidpur bazar of Ghatail Upazila for the study area. They provide all kinds of electrical services particularly in STW motor repairing, starter making, switch board making, changing phase, and they also helps farmers for purchasing new or old STW motors. Besides seasonal STW electric motor repairing services, they also provide servicing to household electrical goods (fan, refrigerators, radios, etc.) and also rice mill motors.

4. FGD with STW spare parts sellers

There were engaged 12-15 shops in the study area for STWs spare parts selling. The shop owners did not only sell the STWs spare parts but also sold various type of spare parts of DTWs, motor cycle, bicycle, power tiller, van, rickshaw etc. They opined that STWs spare parts selling business is for 4 months during Boro season. They have liaison with STWs mechanics also. When some STW owners give the responsibility to mechanics for purchasing the spare parts, he buys spare parts from the specific shop sometimes. They also mentioned that a higher demand of China spare parts was found because of lower price and availability even in small shops in the study area.