EFFECT OF WATER PRICING IN MINOR IRRIGATION ON THE WATER USE BY THE FARMERS

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MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

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In partial fulfillment of the requirement for the
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AUGUST, 2010

CADIDATE' DECLARATION

It is thereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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The thesis titled ñ**Effect of water pricing in minor irrigation on the water use by the farmers"** submitted by Umme Fatima Romana Afroj, Roll: M10072802P, Session October/2007 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of M.Sc in Water Resources Development on 14th August, 2010.

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This thesis is dedicated to my honorable parents,

my husband and my daughter

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ABSTRACT

Water pricing policy, as a strategy for water demand management, aims at water conservation and consequently increases water productivity in agriculture. In this study an attempt was made to understand why a certain pricing system has been adopted by the farmers and pump owners and how this pricing system affected the on-farm water use by the farmers and the water productivity. The study was conducted in 11 villages of two upazilas: Kaliakair upazila and Gazipur Sadar upazila of Gazipur district during the Boro season of 2009. Eight DTWs were selected of which four were under area based pricing system and four were under time based pricing system. Eight STWs were selected of which two were under area based pricing system, two were under time based pricing system and four were under diesel based pricing system. The study has been conducted on the basis of both qualitative and quantitative data as per requirements of the study. Field measurements of water status were taken to know about on-farm water use by the farmers. PRA tools were applied to collect the primary data on use of energy (electricity or diesel), operating hours, costs and benefits, choice of pricing systems of different schemes, etc. Using FAO software CROPWAT (FAO, 1998) reference crop evapotranspiration (ETo) was calculated to find out the crop water requirement and subsequently water use efficiency.

The results of the study show that irrespective of the type of scheme (STW or DTW), water use and water use efficiency depend upon the type of the farm (high land or low land) and pricing system. The water use is higher in high land (average 105%) and area based pricing system (average 37%), compared to low land and quasi volumetric pricing system. It is evident that the water use efficiency is 96% higher in low land and 38% higher in quasi volume based pricing system compared to high land and area based pricing system. Farmers are more judicious in their use of irrigation in quasi volume based pricing system. Water productivity in kg per m^3 of water used in low land is 81% (DTW) and 109% (STW) higher compared to that of high land. The reason is that low lands use less amount of water compared to high land and rice production is almost the same for low land and high land.

The cost of irrigation is different in different pricing systems and is dependent on water use by the farmers, source of energy, pricing system, distribution system, pump capacity, land alignment, distance of land from the tube-well, etc. In diesel based pricing systems of STW, the cost is very high compared to others. Average cost in area based pricing of DTW is Tk.7940/ha and Tk.4940/ha for STW for all types of land. But in a quasi volume based pricing system cost is not uniform for all types of land (low land or high land) and location of farm (near and far from the tube-well). So, in low land and near to the tube-well, average irrigation cost is Tk.9254/ha (DTW) and Tk.10550/ha (STW) in time based pricing, and Tk.13109/ha (STW) in diesel based pricing. In low land and far from the tube-well, average irrigation cost is Tk.16873/ha (DTW) and Tk.15826/ha (STW) in time based pricing, and Tk.21410/ha (STW) in diesel based pricing. In high land and near to the tube-well, average irrigation cost is Tk.17599/ha (DTW) and Tk.21648/ha (STW) in time based pricing, and Tk.23530/ha (STW) in diesel based pricing. In high land and far from the tube-well, average irrigation cost is Tk.33900/ha (DTW) and Tk.32472/ha (STW) in time based pricing, and Tk.39958/ha (STW) in diesel based pricing.

Profit varies due to variation in irrigation pricing, system of pricing, command area, canal maintenance cost, tube-well maintenance cost, etc. In time based pricing system profit per ha is 204% (DTW) and 330% (STW) higher compared to area based pricing system and 75% (STW) higher compared to diesel based pricing system.

Regarding choice of pricing systems, most of the farmers like area based pricing system, because it is simple to understand. Most of the managers like time based pricing system because it is more profitable and management is easier. Some pump owners of STW like diesel based pricing system because the fuel cost is not borne by them. Moreover, in this system the shortage in supply of electricity was not a problem.

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ABBREVIATION

BADC	Bangladesh Agriculture Development Corporation
BBS	Bangladesh Bureau of Statistics
BMDA	Barind Multipurpose Development Authority
BWDB	Bangladesh Water Development Board
DND	Dhaka Narayanganj Demra
DTW	Deep Tube-Well
ETo	Reference Evapotranspiration
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GK	Ganges Kobotak
GWP	Global Water Partnership
kc	Crop coefficient
IIMI	International Irrigation Management Institute
IWFM	Institute of Water and Flood Management
LLP	Low Lift Pump
MOP	Manually Operated Pump
NWP	National Water Plan
NWMP	National Water Management Plan
NWMPP	National Water Management Plan Project
OECD	Organization for Economic Co-operation and Development
O & M	Operation and Maintenance
PRA	Participatory Rural Appraisal
REB	Rural Electrification Board
STW	Shallow Tube-Well
USDA	United States of Department of Agriculture
WMO	World Meteorology Organization
WP	Water productivity
WRI	World Resources Institute
WUE	Water Use Efficiency

CHAPTER ONE

INTRODUCTION

1.1 Background

Agriculture is the mainstream of the economic life of Bangladesh. Although it is a land of mighty rivers with innumerable tributaries, heavy rainfall and recurring floods, yet, irrigation plays a vital role in this country for half of the year when water scarcity seriously handicaps farming operation. Efficient and sustainable irrigation systems are central to boosting agricultural productivity and improving rural livelihoods. National agricultural policy emphasises on efficient irrigation and to promote and develop environmental friendly irrigation (NWMP, 2001). Irrigation through major canals (large-scale irrigation) covers only 1.5% percent of the total irrigated area (BADC,2009), the remainder being classed as minor irrigation consisting of low lift pumps (LLPs), shallow tube-wells (STWs), deep tube-wells (DTWs), manually operated pumps (MOPs) and traditional systems.

Irrigation, specifically minor irrigation development has had a major shift from public sector to private sector investment since 1987. The removal of the import ban on diesel engines of specific makes and models led to a rapid increase in private sector investment on STWs and LLPs. From 1988-1989 further policy reforms to remove duties and standardization restrictions on imports of small diesel engines encouraged further expansion of private sales of STWs and LLPs. By 2008-09 almost 5.13 ha of cultivable land was brought under irrigation coverage by both the public and private sectors (BADC, 2009). It is the policy of government to encourage and promote continued development of minor irrigation and to encourage future ground water development for irrigation by both public and private sector (NWMP, 2001).

Water scarcity and more water demand will certainly emerge as the key constraint to development of irrigation and increased agricultural production. There is a pressing need to achieve a substantially more efficient and productive use of water in irrigation. Water pricing policy, as a strategy for water demand management, aims at water conservation and consequently increases water productivity in agriculture. Water pricing policy is being increasingly recognized as a key instrument for improved water allocation, better conservation and quality preservation (Bazza and Ahmad, 2002). Efficient pricing of irrigation water is usually not possible but even a nominal price for water would offer users some incentive to eliminate at least some of the conspicuous waste and over watering, which occurs when water is treated as a free good (Ray et. al, 1976).

The pricing policy for supplying irrigation water is different in different areas. Water pricing policies of some area are area based, some are quasi-volume based and very few any volume based. Under area-based pricing, farmers pay a fixed price per unit of irrigated area. This is the most common method of pricing. A survey of 12 million hectares of irrigated land, reported in Johansson (2000), indicated that in more than 60% of the cases water is charged for on a per hectare basis. It is easy to administer but has the practical difficulty that the area of land is assumed to be an adequate proxy for the proportion of water received, which may not be so because of logistical, physical and political reasons (Rhodes and Sampath, 1988). Area pricing has little or no effect on water applications by individuals and its effect on water use efficiency is negligible. Irrigation service fee, mostly charged on a per area basis, is primarily used for cost recovery and does not induce efficient water use. On the contrary, it may lead to higher water use since users feel that they are entitled to use as much as they want as they pay for it.

With volumetric water pricing, the charge is based on the amount of water delivered. The advantage of this pricing method is that it encourages farmers to limit their water use. However, it has several disadvantages. First, the implementation costs can be high because meters are required, and they have to be honestly read and reported. When water flow is reasonably constant, implicit quasi-volumetric pricing is possible by charging for time of delivery. This method is easy to monitor and can be found in many small-scale, farmer-managed irrigation systems. Quasi-volumetric water pricing can be used where the objective is cost recovery. It is much simpler to administer than volumetric pricing as there is no requirement for extensive measurement infrastructure and continuous field recording. Volumetric water pricing or tradable water allocations are used where the objective is to reduce water demand in the agricultural sector (Bosworth et al, 2002).

In minor irrigation systems of Bangladesh, the area based pricing is convenient and the common methods of collection of irrigation fee are cash payment and crop sharing. Quasi-volumetric (time based) pricing is also practiced in some areas. A comparative analysis of water pricing showed that area based cash payment is the most favourable system for the farmers and area based output sharing system is the most favourable systems for the pump owners (Amin, 2007). But in the context of Bangladesh, the impact of different water pricing systems on the on-farm water use is not known. In this study an attempt was be made to understand why a certain pricing system has been adopted by the farmers and pump owners and how this pricing system affected the on-farm water use by the farmers and the water productivity.

1.2 Objectives with specific aims and possible outcomes

This research has been carried out with a view to achieve the following objectives:-

1. To assess the on-farm water use by the farmers in different water pricing systems.
2. To assess the water productivity and profitability of different water pricing systems.
3. To determine the choice of the farmers and the pump owners/managers regarding water pricing.

CHAPTER TWO

LITERATURE REVIEW

The growing water scarcity worldwide has increased the call for economic instruments to stimulate rational water use in agriculture. In developing countries where currently agricultural water use is often still heavily subsidised, there exists a tendency of introducing water pricing policies to achieve this goal. The exact impact of water pricing policies on irrigation water use or on the farmers' production system is however mostly unknown.

In order to ascertain a rationale of the study, a number of literatures were reviewed. A brief discussion of reviewed literature is outlined as follows.

2.1 The rationale for water pricing

Irrigation consumes 50–70% of global water resources (Ahmad, 2000; WRI, 2000; Rosegrant and Cline, 2002). Many authors have examined the effectiveness of water pricing as an instrument for improving water allocation and reducing water consumption (Perry, 2001; Bosworth et al., 2002; FAO, 2002; Johansson et al., 2002; Easter and Liu, 2005; World Bank, 2006;). The Fourth Principle of the 1992 Dublin Statements defines water as an economic good in order to achieve efficient and equitable use, and encourages conservation and protection of water resources. The Fourth Dublin Principle denoted a landmark shift in emphasis to the economic dimensions of water use in general, and irrigation development in particular (WMO, 2007). By comparison, the first principle of the 1992 Rio Statements, which supplemented the Fourth Dublin Principle, suggests implicitly that water is a social good (Dinar and Saleth, 2005).

Multiple authors have shown that the effect of an increase in the price of water on the adoption of water conserving irrigation technologies by farmers is positive (Caswell and Zilberman, 1985, Caswell and Zilberman, 1986, Kanazawa, 1992). Contrary to the arguments advanced by the World Bank and others, increases in water charges seem unlikely to results in full cost recovery, greater investment for O and M, increased resource-efficiency, and improvement of income distribution under the current practices of irrigation water supply and the present pricing policy (Chaudhury et al .,1993).

Ahmad (2000) mentioned that the policy of setting a low price for water does not create the proper incentives to use water efficiently. It also sends wrong signals to the producer and consumers about the true scarcity value of resources which often leads to over-production over-consumption of commodities which are resource depleting and environmental polluting. Pricing water consumption 'correctly' is one means of achieving allocation efficiency, the author noted.

Samal and Kolanu (2004) had shown the consequence of under pricing of irrigation water, the most cited problems in this regard are:

- Inadequate cost recovery
- Waste of water
- Improper O & M
- Poor service delivery
- Environmental Degradation
- Increasing inequity

2.1.1 Water charges to encourage efficient use

To achieve an incentive for efficient water use, the price of water must be directly related to the volume delivered. Conceptually, this is identical to an electricity meter where the consumer can decide to switch off or switch on a particular device, and experience a directly proportional response in the electricity bill. The water flow is rather slow in canals, and must be issued well in advance of distant demands. Changes in demand during the period of distribution will result either in shortages—if demand increases unexpectedly— or in surpluses and spills if demand decreases (Bosworth et al., 2002).

As a matter of principle and in accordance with the established rules of economic theory, increase in water prices should normally lead to improved efficiency of water, provided there is a direct relationship between the quantities delivered and the prices charged (Lazaro, 1979).

2.1.2 Major constraints to efficient pricing of irrigation water

Molle and Berkoff (2007) suggested that the main constraints to the efficiency of price mechanisms include 1) when water is wasted at farm level, raising prices generally has no impact on irrigation efficiency and 2) when some water is wasted, the causes often lie largely beyond the control of the end-users (the farmers). The farmers can do little to prevent system losses that may constitute up to half of the total supply and system wastage and shortages are often largely due to unpredictable supply to the scheme, improper internal management and/or poor design rather than farmer behaviour.

As irrigation schemes are rarely demand based, losses largely lie beyond the responsibility of farmers, and management remains a central issue. When system management improves, “wastage” declines, thus again lowering the potential gains from introducing water pricing at the user level. In other words farmers usually merely use whatever water is effectively supplied to them, rather than what they wish to receive (Molle, 2008).

Based on a worldwide review of irrigation pricing policies Cornish et al, (2004) concluded that "when water is scarce, the surest and most common way to make customers use less water is to limit supply". This has indeed been the most favoured solution for restraining demand.

Many water experts recognize water pricing as a policy intervention that can mitigate both quantity and quality dimensions of water scarcity and thus enhance efficient water use. Pricing of water plays two main roles: (1) the financial role, which is a mechanism for recovering the investment and operation and maintenance (O&M) costs, and (2) the economic role of signalling the scarcity value and the opportunity cost of water, to guide allocation decisions both within and across water sub sectors. In economic terms, the full cost of water includes O&M costs, capital costs, opportunity costs, and the costs of economic and environmental externalities (Tsur and Dinar, 1997; Rogers et al., 2002). In most cases, only supply costs are considered in water pricing structures. However, the other cost components can be larger than the supply cost (Rogers et al., 1998; Johansson et al., 2002). Limiting water prices to reflect only supply costs is due partly to the difficulty of measuring other cost components and partly due to political considerations. A study of the Mula Canal in India found that farmers respond to price-induced water scarcity, but water price policy and/or a system of tradable water rights is not the most effective way to increase irrigation efficiencies (Ray, 2002).

Farmers do not play a direct role in determining irrigation water prices. Rather, the wells' owners (private and cooperatives) determine prices that will recover their operational costs and generate a limited profit margin. Operational costs depend largely on the energy (electricity and diesel) prices that fluctuate with changes in the global oil market. The competition among well owners often leads to a close range of water prices. This functions as an incentive to well owners and managers to increase profitability by improving technical performance and reducing the pumping costs (Madi, 2009).

2.2 Types of fees to be charged to individual farmers

According to Burt (2007) there are many ways to charge for irrigation service, including one or more of the following:

a. No charge at all.

b. A per-area fee.

c. A per-crop fee.

d. A per-irrigation fee.

e. A charge per volume of water used.

Burt (2007) explained his article that once the magnitude of the total charges has been established for an irrigation project, there are numerous ways to design individual billing structures. Irrigation project expenses include both fixed expenses (repayment of loans, basic salaries, basic maintenance, long term improvements, etc.) and variable fees that depend upon the volume of water delivered in a year (pumping charges, canal cleaning, water purchases, etc.). Although there are many variations, water user fees can generally be divided into several general categories:

1. Base fees. Base fees are used to provide a stable annual income that is sufficient to pay a certain percentage of the fixed fees that the project will have in all years. These fees are typically based on the irrigated area. This base fee has no aspect of volumetric charging in it.

2. In-kind fees. In some projects, in-kind fees are accepted as part or all of the payment for water delivery service. For example, the only “fee” for water delivery service may be an obligation to clean a section of drain or canal. In other projects, such an obligation may be in addition to cash payments.

3 Charges based on crop type. Area-crop–based pricing systems vary the charge per hectare irrigated by type of crop. The water price variation among crops depends on the policymakers’ objectives. If they want to encourage efficient use of water, the high water-consuming crops such as rice, should have higher prices per hectare. If the price differences are large enough, farmers are likely to switch to alternative crops. Projects with inflexible water deliveries and inexpensive water have often used this as a basis for fees. The implicit assumption is that crop “x” will be irrigated more times than crop “y”, and therefore should have a higher charge. This charging strategy can be relatively simple, but does not promote any sense of good water management by either the farmer or project personnel. Charges based on crop and soil type are not considered to be volumetric charges.

4. Charges based on the number of irrigations per hectare. This basis for fee charges moves one step closer to volumetric charges. Often these projects have a standard turnout size and a standard official turnout flow rate. Furthermore, a certain number of hours would be “typical” for irrigating a certain field area. Therefore, on the average and in theory, project authorities know approximately what volume is delivered to a field, per irrigation.

5. Volumetric water charges. These water fees depend upon the volume of water that is diverted or delivered in a season or year. The economic optimal pricing rule requires that price should be set equal to the marginal cost of providing the water, and it requires

accurate measurement of water through meters. As mentioned earlier, the advantage of this pricing method is that it encourages farmers to limit their water use.

According to Bosworth et al. (2002), there are two types of pricing, 1) Non volumetric pricing and Volumetric pricing. There are several non-volumetric methods commonly used in irrigation: output pricing, input pricing and area pricing. According to Easter and Liu (2005), major methods for pricing water are area-based pricing and volumetric pricing.

Output pricing methods charge a water fee for each unit of output produced by the user. Under input pricing a farmer pays for irrigation water indirectly through higher prices for inputs purchased from the government or water agency. Both input and output pricing are easy to implement since inputs and outputs are readily observable and water use measurement is not necessary (Johansson, 2000).

Area-based water charges are fixed charges, based on the area irrigated or "supposed" to be irrigated. They are often calculated by dividing the total area irrigated into the O&M costs of providing irrigation water, which basically follows the average cost pricing principle. The advantage is that it is simple to calculate, easy for farmers to understand, and the implementation costs are lower than for volumetric pricing because water deliveries do not have to be measured. Also, assuming 100 percent collection rates, charges per hectare, based on average direct cost; result in full recovery of direct costs. Although it gives farmers no incentive to reduce water use per hectare, it is still widely used in many systems throughout the world due to the simplicity of its implementation. The disadvantage of this pricing method is that, once the irrigated area decision is made, the water charge will have no effect on-farmers' water consumption, because the marginal cost of applying additional quantities of water per hectare is zero. Thus, the demand for water is usually higher than it would be under a price or charge that varied by the quantity of water used, and it is likely to lead to overuse of water by farmers near the head of the canal.

2.3 Uniformity of fees among projects

Burt (2007) showed that if fees are truly based upon justifiable expenses, then water charges will be different in each project depending upon the source of the water, pumping expenses, age of system, quality and type of delivery system, labour costs, etc. Fees will often be different in various zones within a single project. For example, some groups of farmers may decide that they want to improve water delivery service in their zone, and they may decide to form an "improvement district" within a project to pay for system upgrades just in their area. Improvement districts are common within irrigation districts in the western U.S.A. In northwest Mexico, the irrigation district "modulos" within a project also have different fees, depending upon their organization and operation. In some countries, there is a uniform national or state wide fee for water. Such a fee is simple to set but it is subject to the whims of politicians and immediately separates the fee from the realities of local conditions (costs) and qualities of service. A uniform fee that does not take individual realities into account is not recommended and almost automatically dooms the program to problems of poor service, low collection rates, and lower-than realistic water charges.

2.4 Water pricing in various countries

According to Easter and Liu (2005), a higher price is charged during the dry season, when water is scarce, and a lower price is levied in the monsoon or wet season, when water is relatively plentiful. If the price is set high enough in the dry season, it will help limit the number of hectares irrigated in that season. In France, the pricing structure was based on different costs for off-peak and peak water use.

Many different formulations for charging are reported. These include:

- irrigated area: may vary with crop or season;
- water volume delivered: constant rate per cubic metre, and rising block tariff;
- two-part tariffs: fixed per area + volume.

Price per 1 000 m^3

The range in volumetric price is very great. Very high prices are reported for the Netherlands, Tanzania, Israel, Spain etc. The pricing of irrigation water that practice volumetric pricing methods in the following countries are:

Country	**Price per 1,000 m³ (US$)**	**Reference**
Netherlands	1440	Cited in OECD(1999)
Tanzania	420	Mujwahuzi(1997)
Israel	180 - 290	Yaron (1997); Becker and Lavee (2002)
Spain	160	Cited in OECD (1999)
United Kingdom	13-28	Cited in OECD (1999)
United States	16-71	Cited in OECD (1999)
Australia	1.2-10.16	Cited in OECD (1999)
China	27-49.5	Johnson(1999)

Leaving these few very high prices aside, there is still no neat and narrow band in which volumetric prices fall. Canada and Romania report prices below US$1/1,000 m^3 but this represents the lowest extreme. A price of about US$20/1,000 m^3 is probably indicative of the "average" volumetric price charged for irrigation water.

Price per hectare

Where irrigated area is used as the charging basis, there is again a very great range in the prices reported. Here comparisons are more difficult as it is not always clear in the literature whether the figures quoted are seasonal or annual. The highest prices are reported for are:

Country	**Price US$ per ha**	**Reference**
Bangladesh	150/season	NWMP (2000a and 2000b)
China	50-150	Johnson (1999)
Greece	92-210	National average, cited by OECD (1999)
Japan	246	National average, cited by OECD (1999)
Niger	124/season	Abernethy et al. (2000)
Tunisia	124-538	Slim et al.(1997)

Bosworth et al. (2002) showed a comparative feature of water pricing among different countries. In the countries, where irrigated area is used as the charging basis, there is a very great range in the prices. US$ 40-50/ha/year is closer to an 'average' price in more developed countries but in India many states charge not more than US$ 10/ha/year and in Pakistan, the Revenue Department receives approximately US$ 0.33/ha only.

Cornish and Perry (2003) from their case studies on selected schemes in South Asian countries examined that in India, water charges in the major irrigating states are levied on a crop-hectare basis, that is, rates vary across crops, and are charged according to the area irrigated. There is no explicit volumetric charge, but the crop is used as a proxy for volume consumed. For example, the rate for irrigation of rice field in Bihar is Rs 175/ha (equivalent to US$ 3.90/ha).

In Saudi Arabia, Taiwan and Thailand no irrigation charge is taken and the Government subsidise irrigation charges (Ahmad, 2000; Hsiao and Luo, 1997; Molle, 2001).

2.5 Water pricing in Bangladesh

Two types of irrigation project exist in our country; major irrigation project and minor irrigation project. The water pricing rate is different for the different schemes.

NWMP (2000a and 2000b) showed that in Bangladesh, irrigation charging basis varies in two ways; fixed rate per cropping season and per hour of pumping. Fixed rate per cropping season also varies over major surface water schemes and minor irrigation programs. In surface irrigation schemes of Bangladesh, collection rates are no more than 10 percent of the billed revenue, but on deep tube-wells there is almost full collection of revenues due. In six major surface water schemes (GK, Chandpur, Kornaphuli, Manu River, DND and Buri Teesta of Bangladesh Water Development Board - BWDB) irrigation pricing is US$ 0.43-3.01per hectare and in Meghna-Dhonagoda and Pabna irrigation project it varies from US$ 7.65-21.25 per hectare; where as in minor irrigation, average water price is US$148.77-191.29 per hectare. The North Bengal DTW Project of BWDB water pricing rate is US$ 63 per ha. In Barind Multipurpose Development Authority (BMDA), where only electricity runs DTWs are used, water price is US$ 1.59 per pumping hour.

BADC (2005) examined that among South and South-east Asian countries, irrigation cost in Bangladesh is the highest (US$150 per ha). BADC indicates that the cost of production of paddy (per hectare) is much higher in Bangladesh than India, Thailand and Vietnam. Misuse of large quantity of irrigation water, agro-ecological condition, lower irrigation efficiency and uneven distribution of natural water supply throughout the year were indicated as the main reasons for higher production cost of paddy in their report.

Mondal (2000) in his study on performance evaluation of tube-wells mentioned that average irrigation water charge in the study area (Rajbari & Pangsha Thana), is much higher (Tk.10361/ha for DTW and Tk.10471/ha for STW) compared to other irrigation projects like Bakkhali Rubber Dam project (Tk.2139/ha) and DTWs of Comilla district (Tk.4185/ha). He suggested that the charge should be decreased to distribute benefit of irrigation equally between scheme farmers and pump owners.

Saleh & Mondal (2000) showed that in medium scale irrigation projects, for pumped irrigation, irrigation fee (Tk.4330/ha) is more than double of where irrigation is supplied by gravity (Tk.2139/ha).

IIMI (1996) in a survey found that in owners practicing crop share payment (one fourth to one third of the crop at the end of the season) system, the water charges were 62 percent higher than those under a cash payment system. IIMI also found that the STW water charges increased by about 41% and LLP water charges by 47% over the last ten years, irrespective of system of payment for water.

Amin (2007) his case study observed that in Mymensingh district average price of irrigation water in area based pricing system by diesel powered is Tk.7500/ha (STW) and Tk.6500/ha (DTW) and electricity powered is Tk.6000/ha (STW) and Tk.5500/ha (DTW). In case of Output based crop share payment system in Kumarkhali and Sadar Thana of Kustia District by electricity run operation, farmers pay one fourth of the total crop from the land for both the modes -STW and DTW and for diesel powered operation, farmers pay fuel cost and 370kg of dry paddy as establishment cost against per hectare irrigation. In a time basis semi-volumetric pricing method in Poba Thana of Rajshahi District, farmers pay Tk.85/- per hour of irrigation.

CHAPTER THREE

STUDY AREA

3.1 General

From the literature review it has been observed that two types of water pricing systems are dominant in Bangladesh; area based pricing and quasi volumetric pricing. In order to assess the pricing systems in minor irrigation field visits to some schemes in Gazipur district were carried out. The study area is discussed in the following sections.

3.2 Selection of the study area

Gazipur is an extensively irrigated area and about 58.3% of the cultivable land is irrigated by DTWs, STWs and LLPs (BADC, 2009). Because of poor quality of surface water due to industrial pollutions, the farmers generally prefer ground water for irrigation (Rahman, 2009). As Gazipur is easily accessible and is extensively irrigated, it was selected as the study area.

The study was conducted in 11 villages of two upazilas: Polashpur, Jamalpur, Thangerban, Fakirchala, Durgapur, Borochala, of Modhopara union of Kaliakair upazila and Kainjanul, Bahadurpur, Baopara of Kaoltia union and Paschim Duguria, Purbo Duguria of Vawal Mirjapur union of Gazipur Sadar upazila of Gazipur district during the Boro season of 2009. Both shallow tube-wells (STWs) and deep tube-wells (DTWs) were included for field data collection. Representative samples of STWs and DTWs with different pricing systems were selected for analysis. Land elevation, farm location and source of energy were also taken into consideration in selecting the sample. Eight DTWs were selected of which four were under area based pricing system and four were under time based pricing system. Eight STWs were selected of which two were under area based pricing system, two were under time based pricing system and four were under diesel based pricing system.

3.2.1 Location

The study area is located in Gazipur Sadar upazila and Kaliakair upazila of Gazipur district. The area lies between latitude 24°00′N to 24°08′N and longitude 90°12′E to 90°28′E and is bounded by The Shitalakshya river to the east, the Bangshi and the Barinda river to the west, the Banar and the Old Brahmaputra river to the north. The Turag and the Balu rivers flow through the district.

The location maps of the study area are shown in Figures 3.1.a, b & c.

3.2.2 Topography

In Gazipur, there is a combination of flat, undulating, rolling and broken topography. Elevations vary from 9 m to 15 m PWD. Most of the land is high land. The land types are shown in Table 3.1.

Table 3.1: Land type of study area

District	High Land (ha) Fo	Medium High Land (ha) F1	Medium Low Land (ha) F2	Low Land (ha) F3	Very Low Land (ha)	Total Land (ha)
Gazipur	83314	35621	19382	15457	4592	158366

(Source: BBS, 2007)

3.2.3 Land use

In Gazipur district, total land under cultivation is 101475 hectares. Out of total cultivated land, 34.8% single cropped, 50.8% double cropped and 14.4% triple cropped and 16900 ha remain fallow. Total Land under irrigation (by GW and SW) of Gazipur district is 59.4% (BADC 2009). The cropping intensity of Gazipur is almost 166%, which is below the national average of 176 % (BBS, 2007).

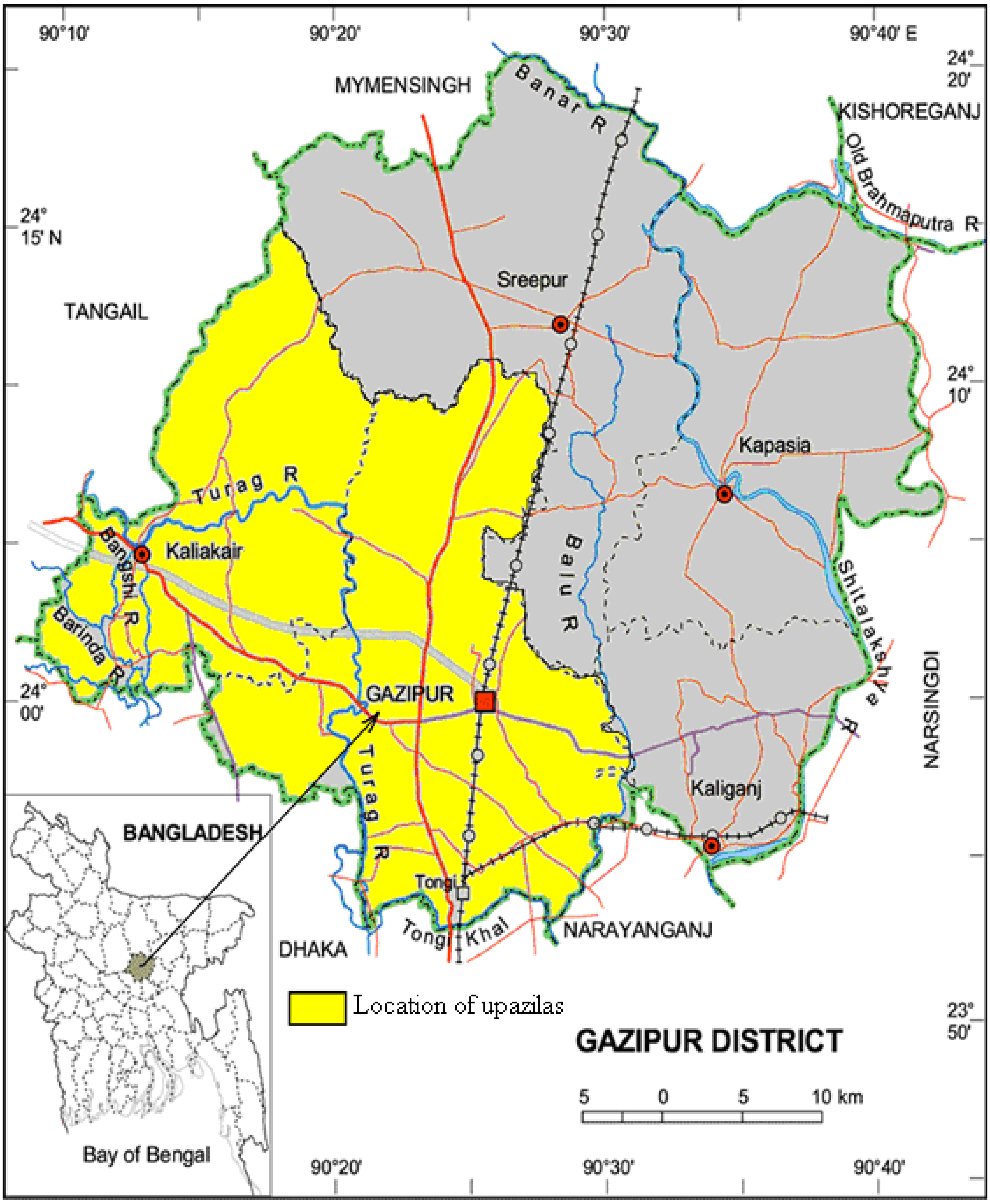

Figure 3.1.a: Location of the upazilas in Gazipur districts. (Source: Banglapedia)

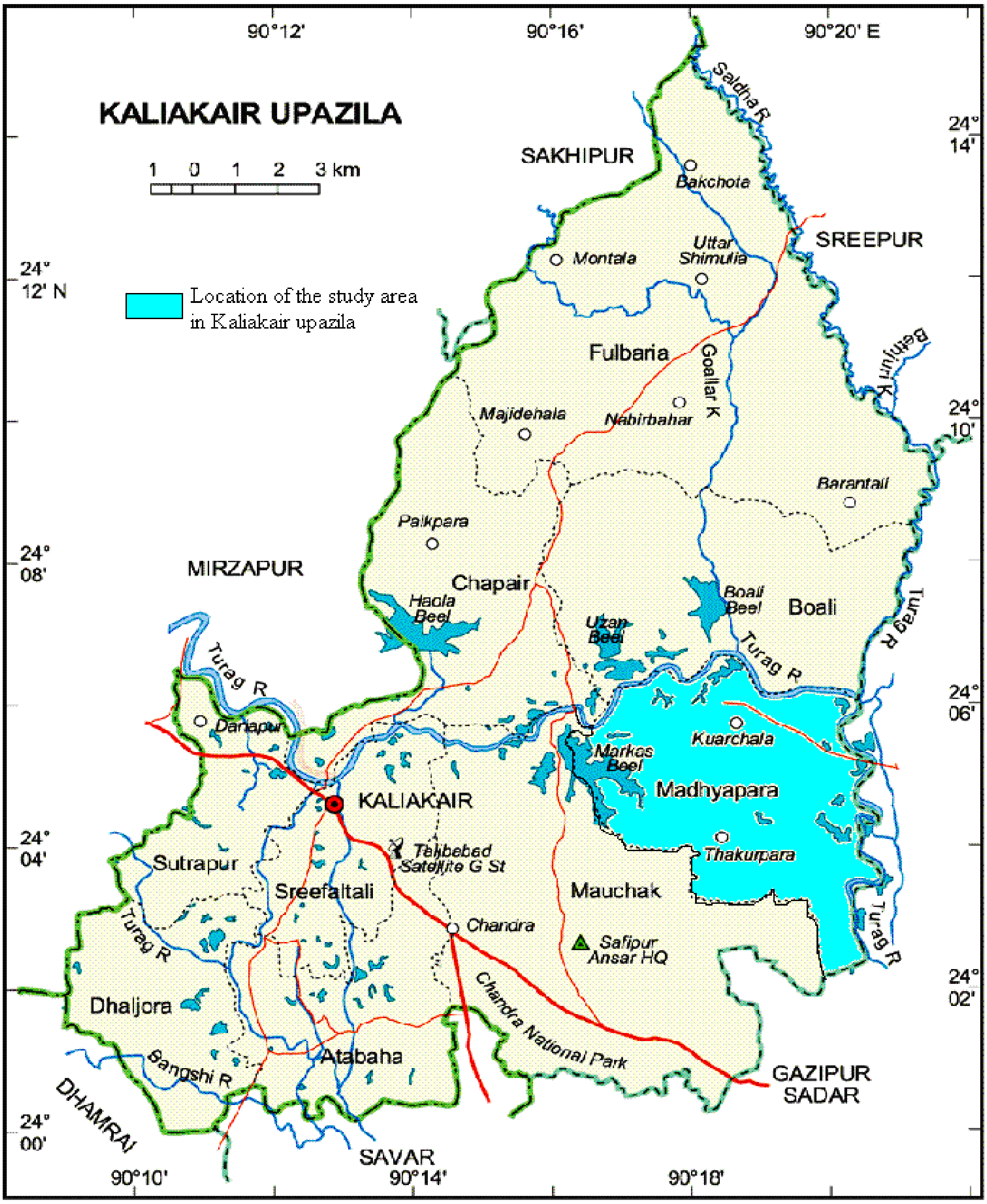

Figure 3.1.b: Location of the study area in Kaliakair upazila. (Source: Banglapedia)

Figure 3.1.c: Location of the study area in Gazipur Sadar upazila. (Source: Banglapedia)

3.2.4 Climate and rainfall

The annual average maximum temperature is 37°C and the minimum is 10.5°C. Maximum temperature occurs during April to May. Average humidity varies from 53% to 83%. The maximum humidity (average 80%) occurs from May to September. The average Annual rainfall in the study area is 2142 mm. The maximum rainfall occurs from June to September. The total rainfall during Boro Season (January to May) varies from 300 mm to 900 mm. The average monthly rainfall data of the study area is shown in Appendix A.

3.2.5 Ground water quality and availability

The ground water quality of the study area is satisfactory for irrigation. The wells are not affected by arsenic contamination. The static water level for DTW of the study area is shown in Table 3.2.

Table 3.2: The static water level of DTW during Boro season

Upazila	Union	Static water level (in metre) of DTW					
		Dec'00	Jan'01	Feb'01	Mar'01	Apr'01	May'01
Kaliakair	Modhypara	8.6	10.6	13.2	13.77	14.09	14.09
Gazipur Sadar	Kawaltia	12.0	13.85	15.45	15.66	16.9	16.63
	Mirjapur	7.1	9.15	9.35	9.97	10.84	10.65

(Source: BADC, 2001)

3.3 Irrigation status

3.3.1 Source of irrigation water, irrigation mode and source of energy as a fuel

In the study area mainly ground water is used for irrigation. In the area nearby the river, surface water is used with help of LLP. But the surface water quality is not suitable for irrigation. A large number of dying industries have been built near by the river and the wastes of these industries pollute the surface water. The ground water is suitable for irrigation and is extensively utilized by both STWs and DTWs.

The district and upazila wise irrigation status are shown in Tables 3.3 and 3.4.

Table 3.3: Irrigation status of Gazipur district

District	Total area (ha)	Total cultivable area (ha)	Irrigated area by DTW (ha)	Irrigated area by STW (ha)	Irrigated area by LLP (ha)	Irrigated area by traditional method (ha)	Irrigated area by gravity flow (ha)	Total irrigated area by all methods (ha)
Gazipur	180000	101475	16528	30188	12458	108	990	60272

(Source: BADC, 2009)

Table 3.4: Upazila wise irrigation status of study area

Upazila	Area (ha)	Cultivated area (ha)	Irrigation from GW (ha)	Irrigation from SW (ha)	% of irrigation by GW	% of irrigation by GW and SW
Gazipur Sadar	44641	28340	8407	5621	29.66%	49.49%
Kaliakair	31414	17004	6218	1025	36.56%	42.6%

(Source: Ministry of Agriculture, 2004 and BADC, 2009)

Both electricity and diesel are used as a source of energy to operate STWs and DTWs. Electricity is supplied by REB and diesel cost is borne by the farmers. If there is any opportunity to get electricity then pump managers chose electricity as a source of energy. This is because pump operation using electricity is cheaper than diesel. Tube-wells operated by electricity usually run ten to twelve hours per day. Deep tube-wells are installed by the BADC, but at present run by farmers' cooperative societies and shallow tube-wells are privately owned and operated. The total number of DTW and STW and irrigated area are shown in Tables 3.5 and 3.6.

Table 3.5: Source of energy, number of equipment and irrigation area of DTW.

Upazila	Operated by electricity			Operated by diesel		Total	
	Organisation	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Gazipur Sadar	BADC	152	4424	38	651	190	5075
	Others	2	60	0	0	2	60
	Total	154	4484	38	651	192	5135
Kaliakair	BADC	90	1760	18	654	108	2414
	Others	0	0	0	0	0	0
	Total	90	1760	18	654	108	2414

(Source: BADC, 2009)

Table 3.6: Source of energy, number of equipment and irrigation area of STW.

Upazila	Operated by electricity			Operated by diesel		Total	
	Organisation	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Gazipur Sadar	BADC	0	0	0	0	0	0
	Others	223	1420	643	1852	866	3272
	Total	223	1420	643	1852	866	3272
Kaliakair	BADC	0	0	0	0	0	0
	Others	247	1952	700	1852	947	3804
	Total	247	1952	700	1852	947	3804

(Source: BADC, 2009)

3.3.2 Mode of water pricing

In the study area three types of pricing systems are practiced. Area based pricing, time based pricing and diesel based pricing systems. The fees collection system of the study area is summarized below:

- Area based pricing systems (Irrigation fee Tk/decimal)
- Time based pricing systems (Irrigation fee Tk/hour and security fee Tk/decimal)
- Diesel based pricing systems (Irrigation fee Tk/decimal and fuel cost)

CHAPTER FOUR

METHODOLOGY

This study has been conducted on the basis of both qualitative and quantitative data as per requirements of the study and to address the objectives. Field measurements of water status were taken to know about on-farm water use by the farmers. Primary data have also been collected through pump managers of DTWs, pump owners of STWs and farmers to determine the total water use by different schemes, types of pricing and their variations in 11 villages of two Upazilas of Gazipur district.

4.1 Computations of water demand, water use efficiency and water productivity

To fulfil the research objectives, water demand was calculated for determining water use efficiency. Water productivity was also calculated to asses in variations in different pricing systems.

4.1.1 Actual water demand in Boro season during the year 2009

Crop water use, also called evapotranspiration or ET, is an estimate of the amount of water transpired by the plants and the amount of evaporation from the soil surface around the plants. A plant's water use changes with a predictable pattern from germination to maturity. All agronomic crops have a similar water use pattern. However, crop water use depends upon the type of crop and can change from growing season to growing season due to changes in climatic variables (air temperature, amount of sunlight, humidity, wind) and soil differences between fields (root depth, soil water holding capacities, texture, structure, etc.). Using FAO software CROPWAT (FAO, 1998) Reference Crop Evapotranspiration (ETo) was calculated. The ETo was multiplied by the crop coefficient, kc to find out the crop water requirement or ETc.

Normally the farmers transplant their crop from the beginning of January and harvest the same from the beginning of May.

4.1.2 Water use efficiency

Irrigation water use efficiency (WUE) is the ratio between the volume used by plants throughout the evapotranspiration process (Vu) and the volume that reaches the irrigation plots (Vp).

$$WUE = \frac{Vu}{Vp}$$

Water use efficiency can be determined as the ratio of total evapotranspiration of crop (ETc) to the total water used by the farmers.

$$WUE = \frac{\text{Total evapotranspiration of crop (ETc)}}{\text{Total on-farm water use}}$$

Total evapotranspiration of crop (ETc) is dependent on the value kc. For rice, kc value is different for different growing stages of a crop. The kc value of rice crop is shown in Table 4.1. Total ETc value is different for different transplantation date of crop due to variations of climatic data.

Total on-farm water use is the total irrigation applied on-farm and rainfall. Seepage and percolation loss was not considered here in calculating the crop water requirement.

Table 4.1: Crop coefficient kc value for rice

Stages	Vegetative	Reproductive	Ripening
kc	1.1	1.25	1.0

(Source: FAO Irrigation and Drainage Paper 33, Table 18)

4.1.3 Water productivity

Water productivity (WP), like land productivity, is a partial-factor productivity that measures how the systems convert water into goods and services (Molden et al., 2003).

Its generic equation is:

$$\text{Water Productivity (WP)} = \frac{\text{Output derived from water use}}{\text{Water input}}$$

WP was introduced to complement existing measures of the performance of irrigation systems, mainly the effective efficiency (Keller et al., 1996).

WP was calculated for different pricing systems by:

$$\text{WP} = \frac{\text{Rice production in kg per ha}}{\text{Total on-farm water use in m}}$$

Water productivity is expressed as kg per m^3. Total on-farm water use is the total irrigation applied by the farmers and rainfall.

4.2 Data collection

4.2.1 Primary data collection

PRA tools like interview and FGD were applied to collect the primary data. Structured open ended questionnaire interviews were done with the pump managers of DTWs and pump owners of STWs for collecting primary data on use of energy (electricity or diesel), operating hours, costs and benefits of different pricing systems. A structured open ended questionnaire interview was also conducted on the farmers to find out their yields, time of irrigation and profitability of different methods of water pricing. Farmers were selected from both the head and tail ends of each of the projects.

4.2.1.1 Interviews with pump managers (DTW) & pump owners (STW)

Eight interviews with the pump managers of DTW and eight interviews with the pump owners of STW were conducted with different pricing systems. List of interviews with locations of DTWs of pump managers and STWs of pump owners are shown in Table 4.2.

Structured open ended questionnaire interviews were done with the pump managers of DTWs and pump owners of STWs for collecting primary data on use of energy (electricity or diesel), pricing systems, water distribution systems, pump operating hours, time of irrigation water applied, irrigation water availability and quality, various costs and benefits of different pricing systems, choice of pricing systems etc. The interview with the pump manager is shown in photo 1.

Table 4.2: List of interviews with locations of DTWs of pump managers and STWs of pump owners

No.	Type of scheme	Pricing system	Upazila	Village
1	DTW	Area based	Kaliakair	Borochala
2	DTW	Area based	Gazipur Sadar	Purbo Dugri
3	DTW	Area based	Gazipur Sadar	Paschim Dugri
4	DTW	Area based	Gazipur Sadar	Kainjanul
5	DTW	Time based	Kaliakair	Thangerban
6	DTW	Time based	Kaliakair	Jamalpur
7	DTW	Time based	Kaliakair	Palashtali
8	DTW	Time based	Kaliakair	Fakirchala
9	STW	Area based	Kaliakair	Durgapur
10	STW	Area based	Kaliakair	Durgapur
11	STW	Time based	Kaliakair	Thangerban
12	STW	Time based	Kaliakair	Thangerban
13	STW	Diesel based	Gazipur Sadar	Bahadur pur
14	STW	Diesel based	Gazipur Sadar	Baopara
15	STW	Diesel based	Gazipur Sadar	Kainjanul
16	STW	Diesel based	Kaliakair	Thangerban

4.2.1.2 Interview with farmers

In order to study the variations in water use and productivity, farmers were selected from both high land and low land within each of the schemes (STWs and DTWs). In a scheme (both STW and DTW) of quasi volumetric pricing system where time is a factor for conveying the irrigation water, farmers were also selected from both the head and tail ends of the project to determine the cost of irrigation.

A structured open ended questionnaire interviews were conducted on the farmers to find out their yields, time of irrigation, no of irrigation, irrigation water availability, in which time they need irrigation most, mode of irrigation (DTW or STW), and cost of different methods of water pricing. Interviews were conducted with 52 farmers of different pricing system. Land elevation (high or low) and land location (near and far from pump) were considered in selecting farmers. The lists of interviews with farmers are shown in Appendix B. The interview with the farmer is shown in photo 2.

4.2.1.3 FGD with farmers

Sixteen FGDs of sixteen schemes of DTW and STW were conducted with farmers. The numbers of farmers of each FGD were varied from six to twelve depending upon their presence.

FGD is conducted with the farmers about their choice of pricing systems. Qualitative data were collected through FGD. The list of FGD locations is shown in Table 4.2.

4.2.1.4 Field measurement

Field measurements of on-farm water use (time and depth of each irrigation) by the farmers in each of the selected schemes were made. Depth of each irrigation was measured from the difference in the height of the water levels in the field before and after each irrigation.

In each of the schemes, land elevation (high land and low land) and the location of the farm (head and tail end) were also considered for on-farm water use measurements.

Photo1: The interview with pump manager.

Photo 2: The interview with farmer.

4.2.1.5 Soil sampling for soil texture analysis

Soil samples from each of the selected schemes of the project area were collected to know about soil texture. For this 11 soil samples from 11 different schemes comprising of DTW & STW from 11 villages were collected for textural classification. Grain size analysis and hydrometer test were done for textural classification. The textural classification of soil sample according to U.S Department of Agriculture (USDA) is given in Table 4.3.

4.2.2 Secondary data collection

In order to determine the reference crop evapotranspiration, climatic data (wind speed, maximum temperature, minimum temperature, humidity, sunshine hour) during the year 2009 was collected from meteorological department.

Table 4.3: Soil texture of the study area

Type of scheme	Pricing system	Upazila	Village	Specific gravity	Soil type USDA
DTW	Area based	Kaliakair	Borochala	2.349	Sandy Loam
DTW	Area based	Gazipur Sadar	Purbo Dugri	2.28	Sandy Loam
DTW	Area based	Gazipur Sadar	Paschim Dugri	2.35	Loam
DTW	Area based	Gazipur Sadar	Kainjanul	2.36	Sandy loam
DTW	Time based	Kaliakair	Thangerban	2.403	Sandy Loam
DTW	Time based	Kaliakair	Jamalpur	2.604	Sandy Loam
DTW	Time based	Kaliakair	Palashtali	2.393	Loam
DTW	Time based	Kaliakair	Fakirchala	2.352	Silt Loam
STW	Area based	Kaliakair	Durgapur	2.536	Sandy Loam
STW	Time based	Kaliakair	Thangerban	2.403	Sandy Loam
STW	Diesel based	Gazipur Sadar	Bahadurpur	2.24	Silt Loam
STW	Diesel based	Gazipur Sadar	Baopara	2.17	Sandy Loam
STW	Diesel based	Gazipur Sadar	Kainjanul	2.36	Sandy loam
STW	Diesel based	Kaliakair	Thangerban	2.403	Sandy Loam

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 General

The innovations in minor irrigation technologies like Deep Tube-wells (DTW) and Shallow Tube-wells (STW), have led to a rapid expansion of irrigated agriculture in rural Bangladesh. These technologies are either privately owned or rented, except for shallow tube-wells which are all privately owned and operated to irrigate their own land and to sell the water. Water is sold to farmers in different pricing systems. So there exists a variation in water use and irrigation cost to the farmers.

5.2 Water pricing systems in STW and DTW

In the study area two types of pricing system exist; one is area based pricing system and another is quasi volumetric pricing system. In the area based pricing system irrigation fee is collected as per unit of land using irrigation. There is no security fee. In both STW and DTW this type of pricing system exists. The source of energy is electricity for DTWs but STWs use both diesel and electricity although diesel is more common. The cost of electricity is borne by the managers and diesel is borne by the farmers.

In quasi volumetric pricing systems two types of pricing system exist; one is time based and another is diesel based. In time based pricing system source of energy is electricity and irrigation fee is collected on hourly basis. All the farmers under DTW project area have to pay a security fee on area basis. In case of STW no security fee is collected. In case of diesel based pricing system, energy source is diesel and security fee is collected per unit of land using irrigation. The diesel cost is borne by the farmers. In case of DTW there is no diesel based pricing system in the study area.

In quasi volumetric pricing systems, farmers are very much conscious about their water uses and use limited amount of water because they have to consider the time of water delivery. They make high bunds (15 cm to 20 cm) around their land so that their water does not flow to other’s land. Electricity use is also limited. Some projects of time based pricing system practiced area based pricing system earlier; but they have changed from area based pricing system to time based pricing system because of huge electricity bill.

5.3 Water use efficiency in different pricing systems of STW and DTW

Field water use efficiency can be determined as the ratio of total evapotranspiration of crop to the total water use by the farmers. Water use efficiency is a very important parameter in performance evaluation of irrigation projects. Water use within a scheme depends upon the location of the farm. Water uses in low land are less than that of high land in different pricing systems. In a high land, water does not stay for long time; it flows towards low land. So it needs more irrigation and hence more water.

5.3.1 Actual water demand in Boro season during the year 2009

By using FAO software CROPWAT (FAO, 1998) and meteorological data of 2009 of Dhaka district, reference crop evapotranspiration was calculated as shown in Table 5.1.

Because of changes in meteorological data reference crop evapotranspiration (ETo) value is different for different months. So crop water requirement of rice is different for different transplantation period of seedlings. In Tables 5.2, 5.3 and 5.4 crop water requirement of rice was calculated for different transplantation dates (without considering seepage and percolation loss). Total crop water requirement was calculated without considering the land preparation requirement and effective rainfall.

Table 5.1: Meteorological data during the year 2009 and reference crop evapotranspiration (mm/day)

District: Gazipur Upazila: Kaliakair & Gazipur Sadar Latitude: 24◦06′ N Longitude: 90◦22′E Altitude: 8.45m						
Month	Dec 2008	Jan 2009	Feb 2009	March 2009	April 2009	May 2009
Maximum temperature (◦ C)	29	28.1	33.9	36	39.6	37.8
Minimum temperature (◦ C)	10.5	11.1	12.2	15.8	20.4	21.6
Relative Humidity (%)	79	72	55	53	66	72
Rainfall(mm)	0	1	1	43	14	168
Wind Speed in knots	3.3	3.3	4.1	4.0	4.1	3.8
Daily Sunshine (hr)	3.88	5.7	8.7	7.3	8.3	6.75
ETo (mm/day)	2.74	3.03	5.11	5.7	6.47	5.73

(Source: Meteorological Department)

Table 5.2: Total crop water requirement during the year 2009 (without considering the seepage and percolation loss)

Rice transplanted on December 15,2009							
Stages	Month	Day	ETo (mm/day)	kc	ETc (mm/day)	ETc (mm)	Total ETc (mm)
Vegetative	December(15-31)	16	2.74	1.10	3.01	48.22	
	January(1-31)	31	3.03	1.10	3.33	103.32	
	February(1-13)	13	5.11	1.10	5.62	73.07	
Reproductive	February(14-28)	15	5.11	1.25	6.39	95.81	609.09
	March(1-15)	15	5.70	1.25	7.13	106.88	
Ripening	March(16-31)	16	5.70	1.00	5.70	91.20	
	April(1-14)	14	6.47	1.00	6.47	90.58	

Table 5.3: Total crop water requirement during the year 2009 (without considering the seepage and percolation loss)

Rice transplanted on January 1,2009							
Stages	Month	Day	ETo (mm/day)	kc	ETc (mm/day)	ETc (mm)	Total ETc (mm)
Vegetative	January(1-31)	31	3.03	1.10	3.33	103.32	
	February(1-28)	28	5.11	1.10	5.62	157.39	
	March (1)	1	5.70	1.10	6.27	6.27	674.83
Reproductive	March(2-31)	30	5.70	1.25	7.13	213.75	
Ripening	April(1-30)	30	6.47	1.00	6.47	194.10	

Table 5.4: Total crop water requirement during the year 2009 (without considering the seepage and percolation loss)

Rice transplanted on January 15,2009							
Stages	Month	Day	ETo (mm/day)	kc	ETc (mm/day)	ETc (mm)	Total ETc (mm)
Vegetative	January(15-31)	16	3.03	1.10	3.33	53.33	
	February(1-28)	28	5.11	1.10	5.62	157.39	
	March (1-16)	16	5.70	1.10	6.27	100.32	
Reproductive	March(17-31)	15	5.70	1.25	7.13	106.88	722.22
	April(1-15)	15	6.47	1.25	8.09	121.31	
Ripening	April(16-30)	15	6.47	1.00	6.47	97.05	
	May(1-15)	15	5.73	1.00	5.73	85.95	

In Table 5.5 the total crop water requirement is shown for different transplantation dates. The table shows that the crop water requirement is increasing as transplantation date is delayed.

Table 5.5: Total crop water requirement for different transplantation dates

Transplantation date	Total crop water requirement(mm)
December 15	609.09
January 1	674.83
January 15	722.22

5.3.2 On-farm water use in STW and DTW

It was observed from the field study that the on-farm water use in different schemes depend not only upon the water pricing system but also on the elevation of the farm (low land or high land).

5.3.2.1 On-farm water use in low land and high land

On-farm water uses by the farmers depend upon the land elevation (high or low). When water is applied on high land it flows towards low land. For this, the water use in high land is higher than that of low land.

5.3.2.2 On-farm water use (without rainfall) in different pricing systems

The variations of water use in area based and time based pricing systems for DTWs are shown in Figures 5.1 and 5.2. In low land water use varied from 660 mm to 794 mm (average of 730 mm) in area based pricing system compared to 508 mm to 546 mm (average of 522 mm) in time based pricing system. Thus low land farmers in time based pricing system used 28% less water than area based farmers. Water use by the farmers is shown in Appendix C.

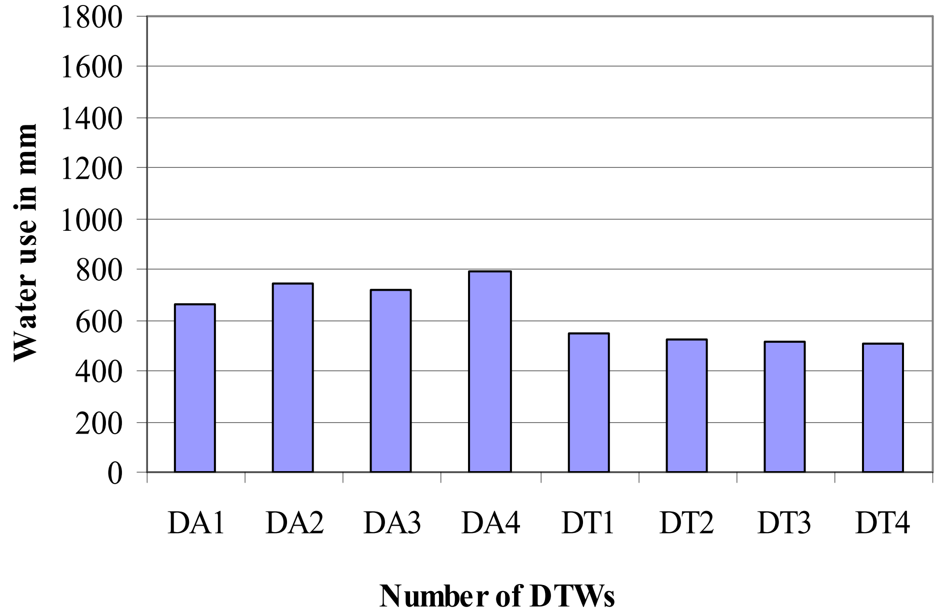

Figure 5.1: Water use in low land (without rainfall) in different pricing systems of DTWs (DA=area based pricing system, DT=time based pricing system)

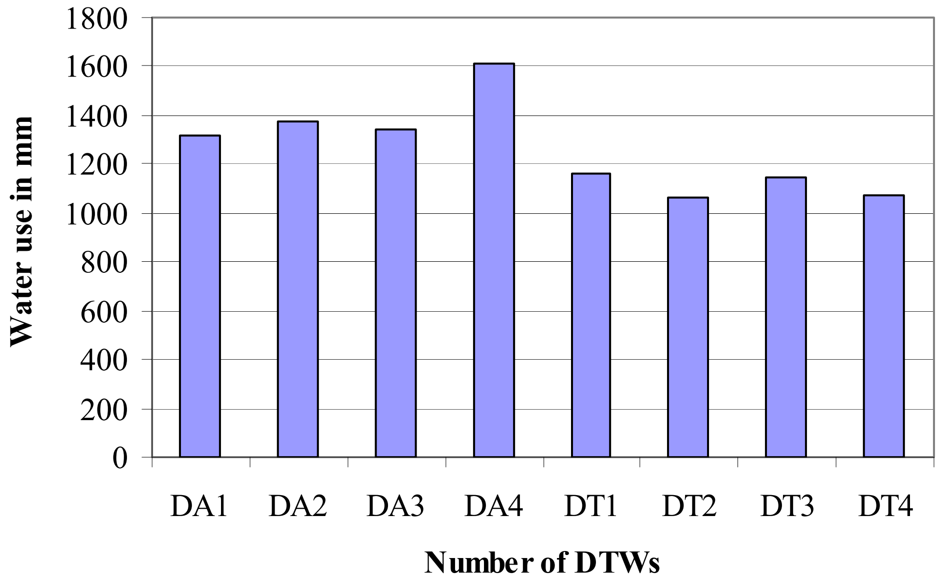

Figure 5.2: Water use in high land (without rainfall) in different pricing systems of DTWs (DA=area based pricing system, DT=time based pricing system)

In high land water use varied from 1321 mm to 1613 mm (average of 1413 mm) in area based pricing system compared to 1067 mm to 1162 mm (average of 1113 mm) in time based pricing system. Thus, high land farmers in time based pricing systems used 21% less water than area based farmers.

The above analysis shows that low land and high land farmers of time based pricing system used 28% and 21% less water than those of area based pricing system.

The variations of water use in area based, time based and diesel based pricing systems for STWs are shown in Figures 5.3 and 5.4. In low land water use varied from 705 mm to 781mm (average 743 mm) in area based pricing system, 540 mm to 546 mm (average 543 mm) in time based pricing system and 489 mm to 591 mm (average 556 mm) in diesel based pricing system. Thus low land farmers in time based pricing system used 27% less and in diesel based pricing system 25% less water than area based farmers.

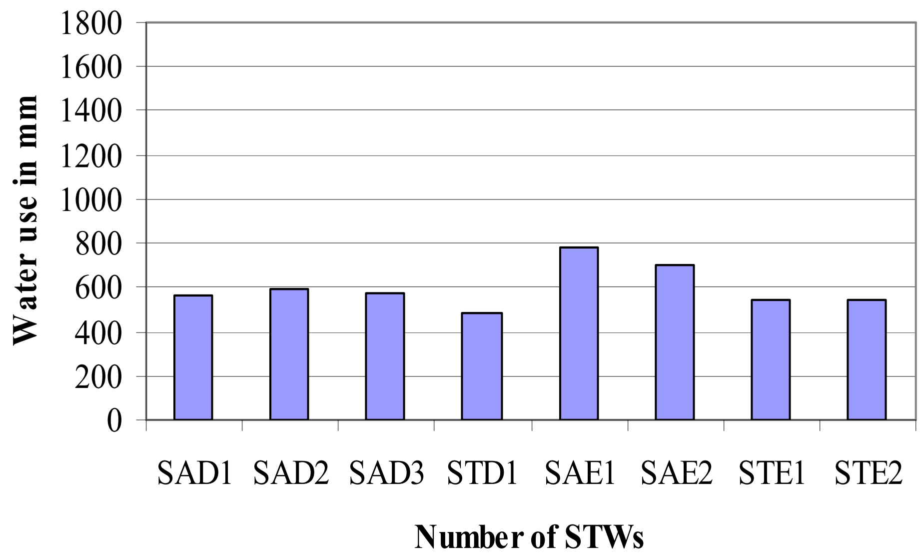

Figure 5.3: Water use in low land (without rainfall) in different pricing systems of STWs (SAD = diesel based pricing & security fee on area basis, STD= diesel based pricing & security fee on time basis, SAE =area based pricing system & energy source electricity, STE=time based pricing system & energy source electricity.)

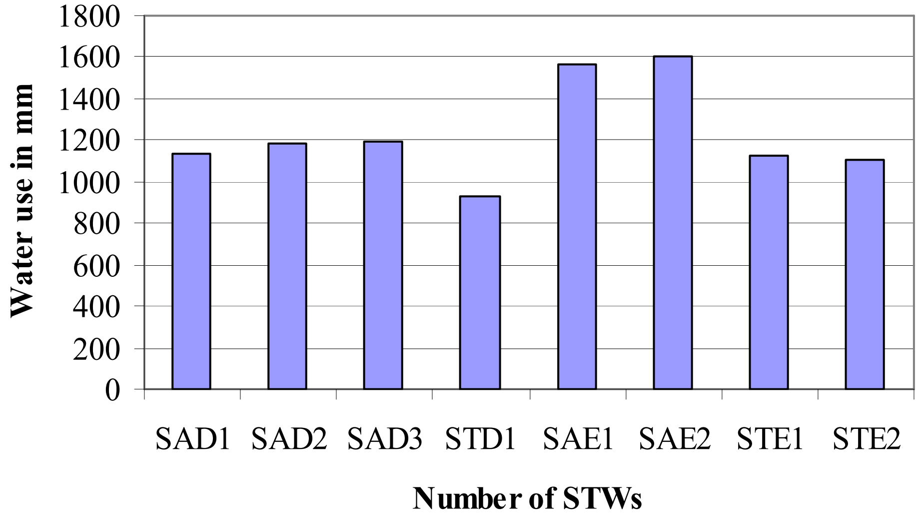

Figure 5.4: Water use in high land (without rainfall) in different pricing systems of STWs (SAD = diesel based pricing & security fee on area basis, STD= diesel based pricing & security fee on time basis, SAE =area based pricing system & energy source electricity, STE=time based pricing system & energy source electricity)

In high land water use varied from 1562 mm to 1607 mm (average 1584 mm) of area based pricing system, 1105 mm to 1124 mm (average 1115 mm) of time based pricing system and 933 mm to 1194 mm (average 1110 mm) in diesel based pricing system. Thus high land farmers in time based pricing system and in diesel based pricing system used 30% less water than area based farmers.

From the Table 5.6 it can be seen that the average water uses in low land in area based pricing system is slightly high in STW (average 743 mm) than DTW (average 730 mm). In time based pricing system it is slightly high in STW (average 543 mm) than DTW (average 522 mm). In diesel based pricing system it is (average 556 mm) also nearer to time based pricing system. So the maximum water use is in area based pricing system compared to diesel based and time based pricing system in both STW and DTW.

Table 5.6: Average on-farm water use in STWs and DTWs (without rainfall)

Types of schemes	Pricing system	Average on-farm water use in low land in mm	Average on-farm water use in high land in mm
DTW	Area based	730	1413
	Time based	522	1113
STW	Area based	743	1584
	Time based	543	1115
	Diesel based	556	1110

Similarity it can be been seen in Table 5.6 that water uses in high land in area based pricing system are slightly higher in STW (average 1584 mm) than DTW (average 1413 mm). In time based pricing system it is almost same in STW (average 1115 mm) and DTW (average 1113 mm). In diesel based pricing system it is (average 1110 mm) nearer to time based pricing system. So the maximum water use is in area based pricing system than time based and diesel based pricing system in both STW and DTW. Moreover, the water use is similar in area based and time based pricing system of both STW and DTW.

In the Table 5.7 average percentage of water savings in time based and diesel based pricing system compared to area based pricing system are shown. In the table it is seen that water savings in time based and diesel based pricing system is almost same in both high land and low land.

Table 5.7: Average percentage of water savings in quasi volume based pricing system compared to area based pricing system

Types of schemes	Pricing system	Average percentage of on-farm water use in low land compared to area based pricing system	Average percentage of on-farm water use in high land compared to area based pricing system
DTW	Time based	28 % less	21% less
STW	Time based	27% less	30% less
	Diesel based	25% less	30% less

From the above analysis it can be inferred that irrespective of the type of scheme (STW or DTW), water use depends upon the land elevation of the farm (high land or low land) and pricing system. Thus, water use is higher in high land (average 105%) and area based pricing system (average 37%) compared to low land and quasi volumetric pricing system.

5.3.3 Water use efficiency in low land and high land of DTWs & STWs in different pricing systems

From Table 5.8 it can be observed that for DTWs the water use is more efficient in time based pricing system than that of area based pricing system in low land. Efficiency varies from 0.79 to 0.86 (average of 0.835) in area based pricing system and 1.12 to 1.19 (average of 1.165) in time based pricing system in low land. In time based pricing system the efficiency value is above 1. But, actual water use on low land by the farmers is not below actual ET. The additional unaccounted water came from high land and seepage from the irrigation canal. This phenomenon also happened in area based system but even then they applied irrigation.

Table 5.8: Water use efficiency in low land of different DTWs

Sample	Date of transplantation	Irrigation water applied on-farm (without land preparation) in mm	Total rainfall in mm	Total on-farm water use in mm	Total ETc in mm	Efficiency
DA1	December 15,2008	660	57	717	609	0.85
DA2	January 1,2009	743	57	800	675	0.84
DA3	January 1,2009	724	57	781	675	0.86
DA4	January 1,2009	794	57	851	675	0.79
DT1	January 1,2009	546	57	603	675	1.12
DT2	January 1,2009	521	57	578	675	1.17
DT3	January 1,2009	514	57	571	675	1.18
DT4	January 1,2009	508	57	565	675	1.19

(DA=area based pricing system, DT=time based pricing system)

From Table 5.9 it can be observed that in case of DTWs water was not efficiently used in high land of different pricing systems. Efficiency varied from 0.39 to 0.49 (average of 0.45) in area based pricing systems and 0.52 to 0.60 (average of 0.56) in time based pricing systems in high land. In time based pricing systems efficiency is higher than that of area based pricing systems.

Table 5.9: Water use efficiency in high land of different DTWs

Sample	Date of transplantation	Irrigation water applied on-farm (without land preparation) in mm	Total rainfall in mm	Total on-farm water use in mm	Total ETc in mm	Efficiency
DA1	January 1,2009	1321	57	1378	675	0.49
DA2	January 1,2009	1378	57	1435	675	0.47
DA3	January 15,2009	1340	225	1565	722	0.46
DA4	January 15,2009	1613	225	1838	722	0.39
DT1	January 15,2009	1162	225	1387	722	0.52
DT2	January 1,2009	1067	57	1124	675	0.6
DT3	January 1,2009	1149	57	1206	675	0.56
DT4	January 15,2009	1073	225	1298	722	0.56

(DA=area based pricing system, DT=time based pricing system)

From Table 5.10 it can be observed that in case of STWs water use is more efficient in quasi volume based pricing system than that of area based pricing system in low land. Efficiency varied from 0.73 to 0.80 (average of 0.765) in area based pricing system, 1.12 to 1.13 (average of 1.125) in time based pricing system, 0.98 to 1.12 (average of 1.05) in diesel based pricing system. In a quasi volume based pricing system efficiency values are above 1; actually water use on low land by the farmers is not below actual ET. Additional unaccounted water came from high land and seepage from the irrigation canal.

Table 5.10: Water use efficiency in low land of different STWs

Sample	Date of transplantation	Irrigation water applied on-farm (without land preparation) in mm	Total rainfall in mm	Total on-farm water use in mm	Total ETc in mm	Efficiency
SAD1	December 15,2008	565	57	622	609	0.98
SAD2	January 1,2009	591	57	648	675	1.04
SAD3	January 1,2009	578	57	635	675	1.06
STD1	Decembe15,2008	489	57	546	609	1.12
SAE1	Decembe15,2008	781	57	838	609	0.73
SAE2	Decembe15,2008	705	57	762	609	0.8
STE1	January 1,2009	546	57	603	675	1.12
STE2	January 1,2009	540	57	597	675	1.13

(SAD = diesel based pricing & security fee on area basis, STD= diesel based pricing & security fee on time basis, SAE =area based pricing system & energy source electricity, STE=time based pricing system & energy source electricity)

In case of STWs, from Table 5.11 it can be observed that water is not efficiently used in high land of different pricing systems. Efficiency varied from 0.39 to 0.40 (average of 0.395) in area based pricing systems, 0.51 to 0.62 in diesel based pricing system (average of 0.565), 0.54 in time based pricing systems in high land of STWs. In quasi volume based pricing systems efficiency is higher than that of area based pricing systems.

From Table 5.12 it can be seen that water use efficiency in low land in area based pricing system of DTWs are slightly higher than that of STWs. In time based pricing system efficiency is almost same in both STWs and DTWs. In diesel based pricing system the efficiency is close to time based pricing system. Similar results were also observed in high land as shown in Table 5.12. It is evident that the water use efficiency is 96% higher in low land and 38% higher in quasi volume based pricing system compared to high land and area based pricing system in both DTW and STW. Farmers are more judicious in their use of irrigation in quasi volume based pricing.

Table 5.11: Water use efficiency in high land of different STWs

Sample	Date of transplantation	Irrigation water applied on-farm (without land preparation) in mm	Total rainfall in mm	Total on-farm water use in mm	Total ETc in mm	Efficiency
SAD1	December 15,2008	1130	57	1187	609	0.51
SAD2	January 15,2009	1181	225	1406	722	0.51
SAD3	January 15,2009	1194	225	1419	722	0.51
STD1	December 15,2008	933	57	990	609	0.62
SAE1	January 15,2009	1562	225	1787	722	0.40
SAE2	January 15,2009	1607	225	1832	722	0.39
STE1	January 15,2009	1124	225	1349	722	0.54
STE2	January 15,2009	1105	225	1330	722	0.54

(SAD = diesel based pricing & security fee on area basis, STD= diesel based pricing & security fee on time basis, SAE =area based pricing system & energy source electricity, STE=time based pricing system & energy source electricity)

Table 5.12: Average water use efficiency in DTWs and STWs in different pricing systems

Types of schemes	Pricing system	Average water use efficiency in low land	Average water use efficiency in high land
DTW	Area based	0.835	0.45
	Time based	1.165	0.56
STW	Area based	0.765	0.395
	Time based	1.125	0.54
	Diesel based	1.05	0.565

From the above analysis it can be inferred that irrespective of the type of scheme (STW or DTW), water use efficiency depends upon the elevation of the farm and pricing system.

5.3.4 Water savings

Water used for irrigated rice is very high compared to other crops. In ground water irrigated systems, where the cost of water resource development and water lifting is very high, the need for water-efficient rice production system is most pressing.

5.3.4.1 Water savings in low land compared to high land in different pricing systems

In the previous article it can be seen that water used in low land is less than that of high land. Now water savings in low land can be analyzed both in STW and DTW.

From Table: 5.13 it can be observed that water use in low land is almost half than that of high land. Water savings in low land vary from 44% to 56% (average of 51%) in different pricing systems of DTWs. More water is used in high land than that of low land.

Table 5.13: Total on-farm water use (including rainfall) and percentages of water savings in low land in different pricing systems of DTWs

Sample	Water use in low land (in mm)	Water use in high land (in mm)	Percentages of water savings in low land
DA1	717	1378	47.97%
DA2	800	1435	44.25%
DA3	781	1565	50.10%
DA4	851	1838	53.70%
DT1	603	1387	56.52%
DT2	578	1124	48.58%
DT3	571	1206	52.65%
DT4	565	1298	56.47%

(DA= area based pricing system, DT=time based pricing system)

A similar analysis for STWs is shown in Table 5.14. From the table it can be observed that like DTWs water use in low land is almost half of that of high land. Water savings in low land vary from 45% to 58% (average of 53%) in different pricing systems of STWs.

Table 5.14: Total on-farm water use (including rainfall) and percentages of water savings in low land in different pricing systems of STWs

Sample	Water use in low land in mm	Water use in high land in mm	Percentages of water savings in low land
SAD1	622	1187	47.60%
SAD2	648	1406	53.91%
SAD3	635	1419	55.25%
STD1	546	990	44.85%
SAE1	838	1787	53.11%
SAE2	762	1832	58.41%
STE1	603	1349	55.30%
STE2	597	1330	55.11%

(SAD = diesel based pricing & security fee on area basis, STD= diesel based pricing & security fee on time basis SAE =area based pricing system & energy source electricity, STE=time based pricing system & energy source electricity)

From the above table it can be inferred that irrespective of pricing system, the water savings in low land are almost the same in both DTWs (average of 51%) and STWs (average of 53%) compared to high land.

5.4 Time of irrigation in different pricing systems

As the on-farm water use varied in different pricing systems, the farmers were asked about the time (field water status) when they irrigate.

5.4.1 Time of irrigation in area based pricing systems

In DTWs of area based pricing system, the farmers applied irrigation water in three phases. At vegetative stages they applied water at their land when soil is slightly dry or is just wet. At reproductive stages, they applied irrigation water when soil is wet or had some water (1 cm to 2.5 cm). At that time they have to irrigate frequently as the weather is very hot and dry. At ripening stages, they applied irrigation water when the soils dry up.

In STWs of area based pricing system, applications of irrigation water is similar to that of DTWs. At the vegetative stage irrigation is applied when the standing water in the field is at 1 cm to 2.5 cm. At the reproductive stage water is applied when the soil is wet or had about 1 cm of standing water. From ripening stages up to harvest they applied water when soil is dry. After ripening normally irrigation is not essential.

5.4.2 Time of irrigation in time based pricing systems

In DTWs of time based pricing system, there are no rules of water application. When farmers are able to pay they buy water. At initial stages, once water is applied on land, it stays for long time. At that time they apply water when soil is slightly dry. But at reproductive stages more water is needed. Moreover at that time weather is also very hot and dry. So water does not stay for a long time. They have to irrigate continuously. But farmers are not always able to pay. Electricity problem also arises. So they apply water when soil is dry up. At ripening stages water application is not necessary, they applied water when soil is dry.

In STW of time-based pricing system, they applied irrigation water in the first two month when soil is slightly wetted. In reproductive stages, irrigation water has to be applied frequently. Then they applied water when soil is dry. At ripening stages water is not essential and they apply irrigation when soil is dry.

5.4.3 Time of irrigation in diesel based pricing systems

In diesel-based pricing system, in a first two-month they applied irrigation water when soil is wetted. In reproductive stages, irrigation water has to be applied frequently. Then they applied water when soil is dry. At ripening stages water is not essential, it applied when soil is completely dry up.

The applications of irrigation in different stages of different pricing systems are shown in Table 5.15.

Table 5.15: Irrigation water application in different stages of field status

Stages		Area based		Time based		Diesel based
		DTW	STW	DTW	STW	STW
Vegetative	Field status	Slightly dry/ is just wet	Standing water (1-2.5 cm)	Slightly dry	Slightly wet	Wet
	Number of irrigation	7(L) 16(H)	8(L) 16(H)	5(L) 14(H)	6(L) 16(H)	7(L) 15(H)
Reproductive	Field status	Wet/had some water(1-2.5 cm)	Wet/ had some standing water(1 cm)	Dry	Dry	Dry
	Number of irrigation	6(L) 10(H)	7(L) 18(H)	4(L) 8(H)	5(L) 8(H)	5(L) 8(H)
Ripening	Field status	Dry	Dry	Dry	Dry	Dry
	Number of irrigation	2(L) 4(H)	2(L) 4(H)	2(L) 4(H)	2(L) 4(H)	2(L) 4(H)
	Total number of irrigation	15(L) 30(H)	17(L) 38(H)	11(L) 26(H)	13(L) 28(H)	14(L) 27(H)

(L= Low land, H= High land)

From the table it can be seen that application of irrigation water is different in vegetative stages and reproductive stages in DTW and STW of different pricing systems. But at ripening stages water application is same for all pricing systems. In area based pricing systems more water is used than quasi volumetric pricing systems. Because in area based pricing systems farmers pay a fixed amount and use unlimited water. On the other hand farmers have to pay on hourly basis in a time-based system or bear diesel cost in a diesel based pricing system.

5.5 Rice production in different pricing systems

Rice production was less in this season (2009) compared to that of an average year. Most of the lands were affected by pest and insect attack. Rainfall in the year was also less (from January to May the total rainfall was 227 mm) compared to other years (average of 455 mm) as shown in Appendix A. Electricity problem also prevailed. In reproductive stages crop productions were hampered due to lack of water. Pump managers could not operate their pump timely because of irregular supply of electricity.

5.5.1 Rice production in area based pricing systems

In most of the farm of area based pricing systems, rice production is comparatively less than other years. The productions are shown in Table 5.16.

5.5.2 Rice production in time based pricing systems

In time based pricing system, rice production was also not satisfactory in this year. Rice production was also below area based pricing system because in the reproductive stages, sufficient water was not applied on-farm. Because of less rainfall and hot weather farmers had to apply irrigation frequently but because of frequent power failure they could not apply water at right time. The productions are shown in Table 5.17.

5.5.3 Rice production in diesel based pricing systems

In diesel based pricing systems rice production was also less in this year and it was also below area based pricing system. At the reproductive stages, sufficient water was not applied on-farm. Farmers had to buy diesel frequently in that stage and to apply water they had to maintain a serial. So they could not apply water at right time. The productions are shown in Table 5.18.

Table 5.16: Rice production in area based pricing systems

Sample	Variety	Rice production in sample farm (2009) (t/ha)	Rice production in average year (t/ha)
DA1	BR-29	6.48(low land) 6.45(high land)	7.25(both low and high land)
DA2	BR-29	5.18(low land) 6.04(high land)	6.99 (both low and high land)
DA3	BR-28	5.01(low land)	6.99 (both low and high land)
	BR-29	5.18 (high land)	
DA4	BR-29	5(low land) 5.7(high land)	5.96(low land) 6.99 (high land)
SAE1	BR-28	5.57(high land)	6.48(high land)
	BR-29	6.1(low land)	6.86(low land)
SAE2	BR-28	5.44(high land)	6.09(high land)
	BR-29	5.83(low land)	6.99(low land)

Table 5.17: Rice production in time based pricing systems

Sample	Variety	Rice production in sample farm (2009) (t/ha)	Rice production in average year (t/ha)
DT1	BR-29	3.56 (low land)	6.09 (low land)
	Hybrid	5.44 (high land)	6.48 (high land)
DT2	BR-29	3.79 (low land) 4.14(high land)	6.22 (low land) 6.22(high land)
DT3	BR-29	4.53 (low land) 5.18 (high land)	6.22(low land) 5.7 (high land)
DT4	BR-28	4.92(low land)	6.48(low land)
	BR-29	5.14(high land)	6.74(high land)
STE1	BR-29	4.4(low land) 4.99(high land)	6.09 (low land) 6.74 (high land)
STE2	BR-28	5.08(low land)	5.7(low land)
	BR-29	5.44(high land)	6.99(high land)

Table 5.18: Rice production in diesel based pricing systems.

Sample	Variety	Rice production in sample farm (2009) (t/ha)	Rice production in average year (t/ha)
SAD1	BR-28	4.14(lowland) 4.53(high land)	5.18(lowland) 5.7(highland)
SAD2	BR-28	4.18(lowland) 5.54(high land)	5.96(lowland) 6.48 (high land)
SAD3	BR-28	3.88(low land)	6.74 (low land)
	BR-29	3.93(high land)	6.99 (high land)
STD1	BR-29	4.14 (lowland) 4.27 (high land)	6.22(low land) 6.48(high land)

From the above table it can be observed that rice production in both area based pricing system and quasi volume based pricing system are almost same in all DTWs and STWs in average year; but in this year (2009) quasi volume based pricing system production is 25% less than that of an average year.

5.6 Water productivity in low land and high land in different pricing systems

Water used by the farmers is different in different pricing systems. In low land less water is used by the farmers; because, water comes from high land and also from seepage of water from irrigation canal.

In case of DTW of an area based pricing system water productivity in kg/ m^3 in this year (2009) varied from 0.64 to 0.92 (average of 0.718) and in time based pricing system it varied from 0.60 to 0.89 (average of 0.743) for low land. It is almost the same for both pricing systems. The variations of water productivity are shown in Figure 5.5. The details calculations are shown in Appendix C.

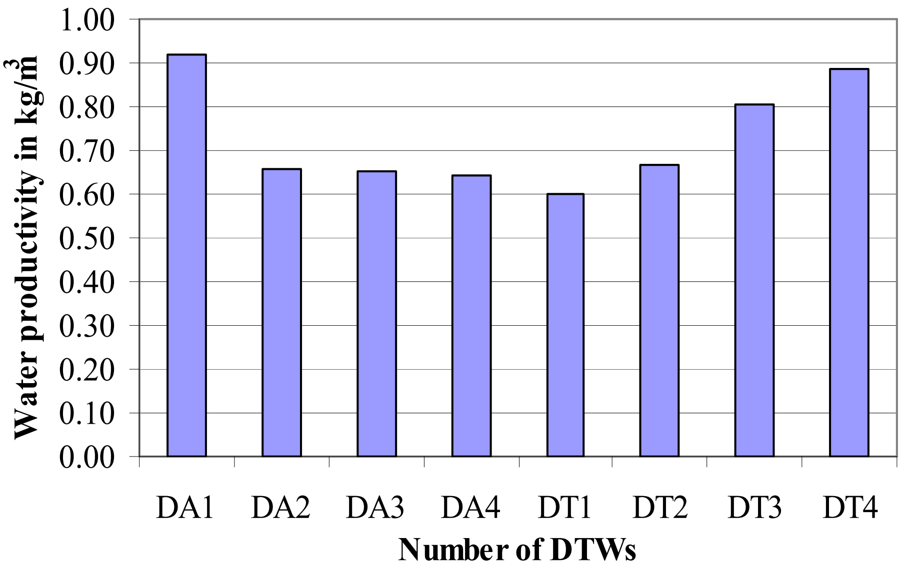

Figure 5.5: Water productivity in kg/m^3 in low land of DTWs

In high land water productivity in kg per m^3 varied from 0.34 to 0.48 (average of 0.403) for area based pricing system and 0.38 to 0.44 (average of 0.405) for time based pricing system. It is also the same for both pricing systems. The variations of water productivity are shown in Figure 5.6.

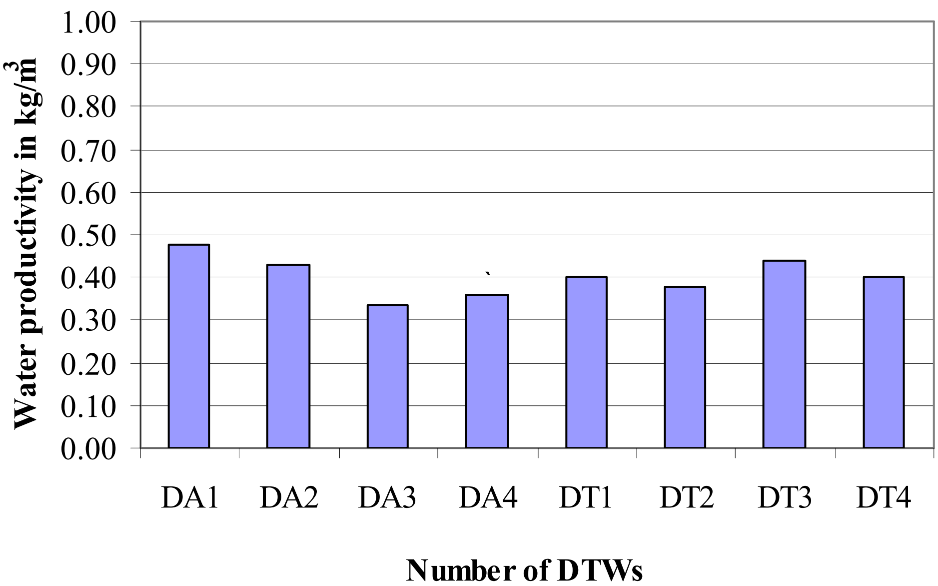

Figure 5.6: Water productivity in kg/m^3 in high land of DTWs

From the Figures 5.5 and 5.6, it can be seen that water productivity in kg per m^3 of water used in low land is average 81% higher compared to that of high land. The reason is that low land use less amount of water compared to high land. And rice production is almost same for low land and high land. So the water productivity in low land is higher than high land.

In case of STW of an area based pricing system water productivity of this year (2009) in low land in kg per m^3 of water varied from 0.74 to 0.77 (average of 0.755), in diesel based pricing system it varied from 0.62 to 0.77 (average of 0.683), in time based pricing system 0.87 to 0.74 (average of 0.81). It is slightly high for time based pricing system compared to area based and diesel based pricing system. The water productivity for STW of low land is shown in Figure 5.7.

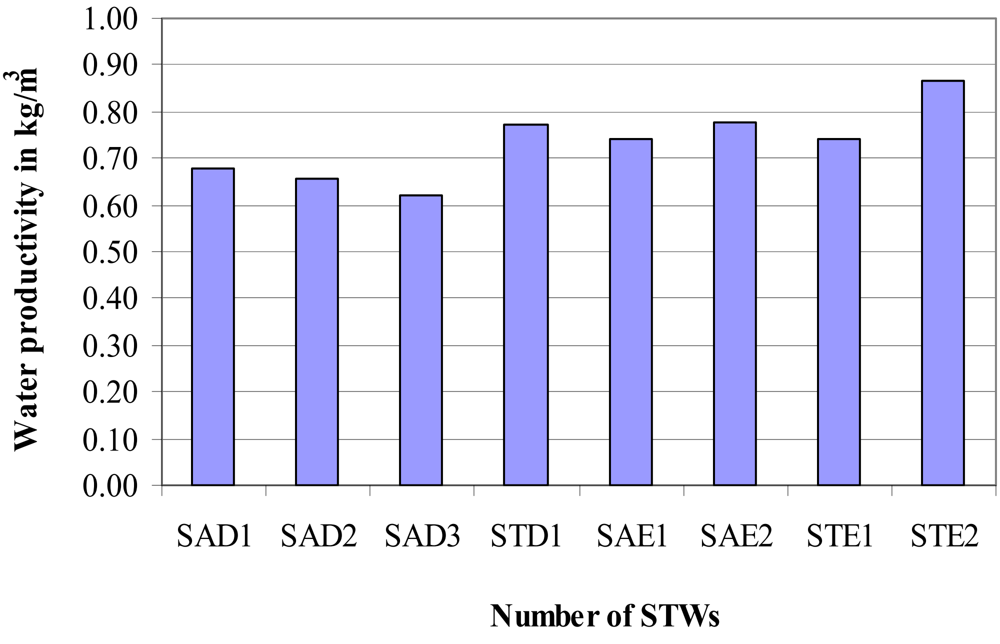

Figure 5.7: Water productivity in kg/m^3 in low land of STWs

In case of high land the water productivity this year (2009) in kg per m^3 of water used varied from 0.30 to 0.32 (average of 0.31) for area based pricing system, 0.38 to 0.42 (average of 0.4) for time based pricing system, 0.28 to 0.44 (average of 0.376) for diesel based pricing system. Like low land, the water productivity is also slightly higher for time based pricing system. The water productivity for STW of high land is shown in Figure 5.8.

From the Figures 5.7 and 5.8, it is seen that water productivity in kg per m^3 of water used in low land is 109% higher compared to that of high land. Reason is that low land use less amount of water compared to high land. And rice production is almost same for low land and high land. So the water productivity in low land is higher than high land.

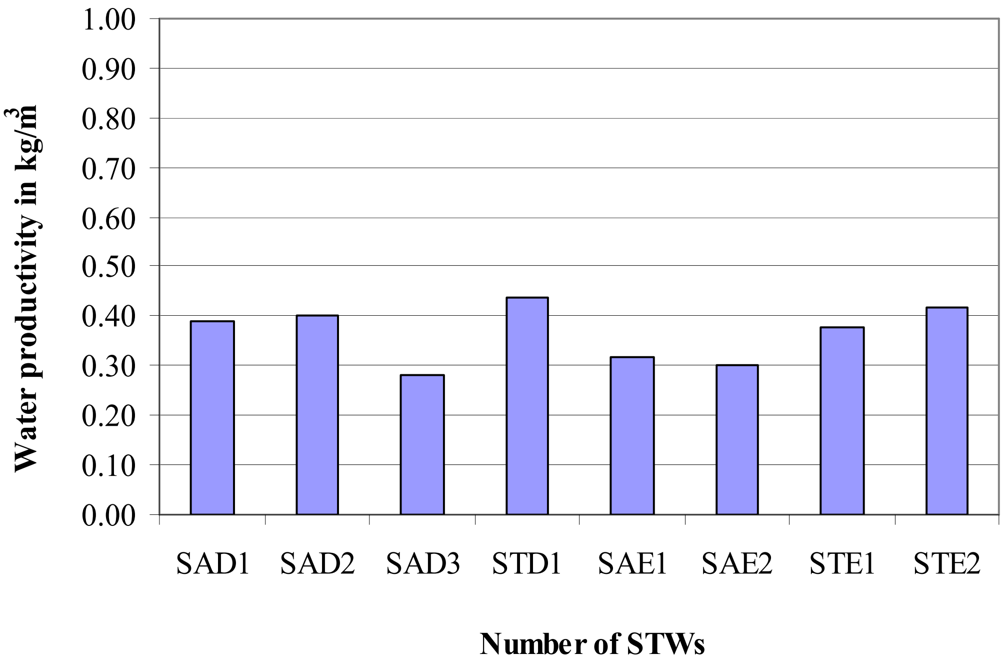

Figure 5.8: Water productivity in kg/m^3 in high land of STWs

From above observation it can be seen that water productivity in kg per m^3 of water used in different pricing system are almost same for all DTWs. It is slightly high (7% for low land and 29% for high land) of STW in of time based pricing system compared area based pricing system. But in a diesel based pricing system it is 9% less in low land and 21% more in high land compared to area based pricing system. This is shown in Table 5.19.

Table 5.19: Average water productivity in kg per m^3 of water used in different pricing systems

Types of schemes	Pricing systems	Average water productivity in kg per m^3 of water used in low land	Average water productivity in kg per m^3 of water used in high land
DTW	Area based	0.718	0.403
	Time based	0.743	0.405
STW	Area based	0.755	0.31
	Time based	0.81	0.4
	Diesel based	0.683	0.376

Normally rice production is almost same in all pricing systems of DTW and STW in an average year. In the previous discussion it has been seen that in time based and diesel based pricing systems less water is used compared to area based pricing system. So water productivity in kg per m^3 of water used should be high for time based pricing system and diesel based pricing system. But this year production is 16% less in area based pricing, 21% less in time based pricing and 31% less in diesel based pricing systems than that of an average year due to insect and pest attacks and for this reason water productivity in kg per m^3 of water used is almost same in all pricing systems of DTW and it is slightly high for STW in time based pricing system.

5.7 Irrigation pricing and profitability

The cost of irrigation is different in different pricing systems. Cost is dependent on water use by the farmers, source of energy, system of pricing, distribution system, pump capacity, land alignment, distance of land from the tube-well etc. Here four conditions of farmers' lands are identified.

- Low land and near to the tube-well.
- Low land and far from the tube-well.
- High land and near to the tube-well.
- High land and far from tube-well.

In an area based pricing system cost is same for all the above conditions of farmers' land. But in a quasi volume based pricing system it is different because irrigation water is delivered to the farmer's land either on time basis or on diesel basis. More time leads to more cost as well as more diesel.

5.7.1 Irrigation pricing in DTW and STW

In an area based pricing system, irrigation fee is collected per unit of land using irrigation. All farmers have to pay under project area. Irrigation fee is fixed for all conditions of land (high or low).Whether the farmers take water or not, they have to pay for it. For the sample DA1 irrigation fee is Tk.5646/ha, Tk.10586/ha for the sample DA2 & DA3 and Tk.4940/ha for the sample no DA4. For the sample no SAE1 and SAE2 irrigation fee is Tk.4940 /ha.

In a time based pricing system irrigation fee is collected on an hourly basis. All farmers have to pay a fixed security charge under project area of DTW and in STW no security fee is collected. Then when the farmers need irrigation water they buy it on an hourly basis. For the sample DT1 security fee is Tk.1729/ha and irrigation fee is Tk.60/hr, for the sample DT2 security fee is Tk.1729/ha and irrigation fee is Tk.50/hr, for the sample DT3 security fee is Tk.2118/ha and irrigation fee is Tk.60/hr and for the sample DT4 security fee is Tk.1977/ha and irrigation fee is Tk.75/hr. For the sample STE1 it is Tk.30/hr, for the sample no STE2 it is Tk.40/hr. No security fee is collected in STE1 and STE2.

In a diesel based pricing system all farmers have to pay a fixed security charge on an area basis under project area. Then when they need irrigation water they buy the fuel. For the sample SAD1 security fee is Tk.3528/ha, for sample SAD2 security fee Tk.4234/ha and for the sample SAD3 it is Tk.2117/ha and for the sample STD1 it is Tk.50/hr.

The pricing systems and rate of DTW and STW are shown in Table 5.20.

Table 5.20: Pricing rate of DTW and STW

Types of wells	Sample	Pricing system	Source of energy	Fuel cost carried by	Security fee	Irrigation fee
DTW	DA1	Area based	electricity	manager	-----	Tk.5646/ha
	DA2	Area based	electricity	manager	-----	Tk.10586/ha
	DA3	Area based	electricity	manager	-----	Tk.10586/ha
	DA4	Area based	electricity	manager	-----	Tk.4940/ha
	DT1	Time based	electricity	manager	Tk.1729/ha	Tk.60/hr
	DT2	Time based	electricity	manager	Tk.1729/ha	Tk.50/hr
	DT3	Time based	electricity	manager	Tk.2118/ha	Tk.75/hr
	DT4	Time based	electricity	manager	Tk.1977/ha	Tk.60/hr
STW	SAD1	Diesel based	Diesel	farmers	Tk.3528/ha	-----
	SAD2	Diesel based	Diesel	farmers	Tk.4234/ha	-----
	SAD3	Diesel based	Diesel	farmers	Tk.2117/ha	-----
	STD1	Diesel based	Diesel	farmers	-----	Tk.50/hr
	SAE1	Area based	electricity	manager	-----	Tk.4940/ha
	SAE2	Area based	electricity	manager	-----	Tk.4940/ha
	STE1	Time based	electricity	manager	-----	Tk.30/hr
	STE2	Time based	electricity	manager	-----	Tk.40/hr

5.7.2 Variation in pricing in different systems

In area based pricing system, pricing should be same for all projects. In fact, it is not uniform. Reason is that pump managers of DTWs are the influential persons of the village. Whatever they want, they do it. Farmers have no choice about their pricing. But some managers are co-operative to the farmers and they make small profit. In the Figure 5.9 for the sample DA4 and DA1, price is less compared to other samples. The sample DA1 price is close to DA4. The manager of DA1 changes their irrigation pricing every year depending upon the profit they make. The pricing of sample DA2 is very high. The

Manager of this DTW said that transformer of their project had been stolen two times; he had to buy transformer and had to pay bank loan. The pricing of sample DA3 is also high. The manager of this DTW informed that his project area is small. So he cannot recover his pump operating cost without increasing irrigation cost. Shallow tube-well SAE1 and SAE2 are under area based pricing system and irrigation cost is same for both project (Tk.4940 /ha). The average cost is Tk.7940/ha of DTW for all conditions of land.

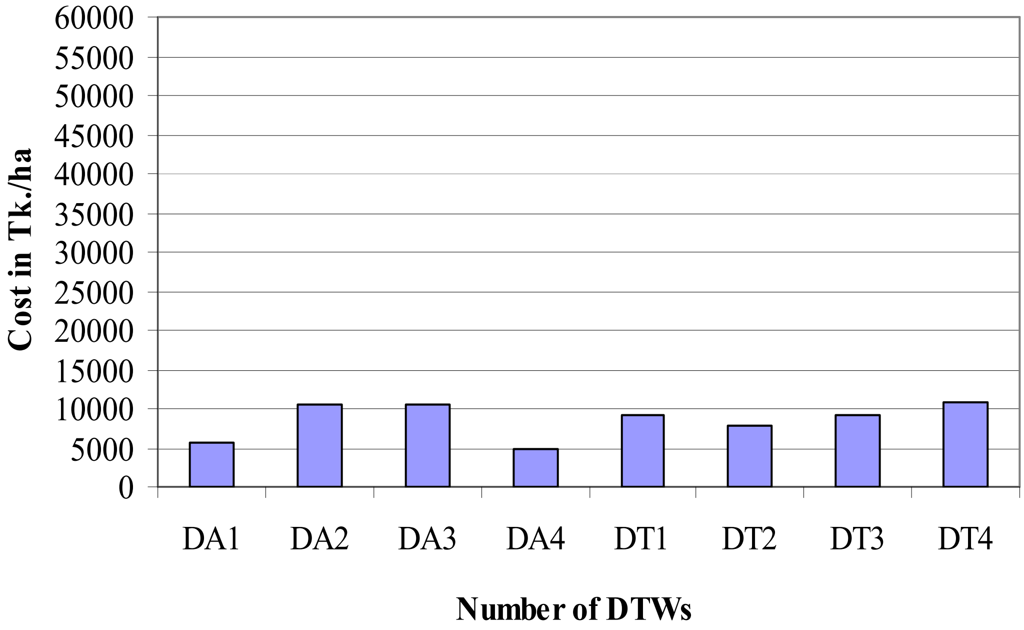

Figure 5.9: Cost in Tk. per hectare in low land and near to the tube-well of DTWs

In case of quasi volume based pricing system, cost is not uniform for high land and low land and also depends upon whether the farm is near or far from the tube-well. When land is low and near to the tube-well, cost is low; when the same land is far from tube-well cost is increased because more time is needed to convey the irrigation water to the field. When land is high and far from the tube-well, the cost is the highest of all conditions. When the same land is near to the tube-well cost is decreased. Time based pricing system or diesel based pricing system in a high land and far from tube-well is not favourable for farmers.

In case of time based pricing system of DTW, for low land and near to the tube-well cost varied from Tk.7733 to Tk.10762 per hectare (average of Tk.9254/ha). This is shown in Figure 5.9. This value is nearer to maximum value of area based pricing systems and 16.55% higher than the average value as shown in Table 5.21. The details calculations of cost are shown in Appendix C.

For low land and far from tube-well cost are varied from Tk.12579 to Tk.19936 per hectare (average of Tk.16873 per ha). The minimum value of time based pricing system is much higher than the maximum value of area based pricing system. The variations of pricing are shown in Figure 5.10.

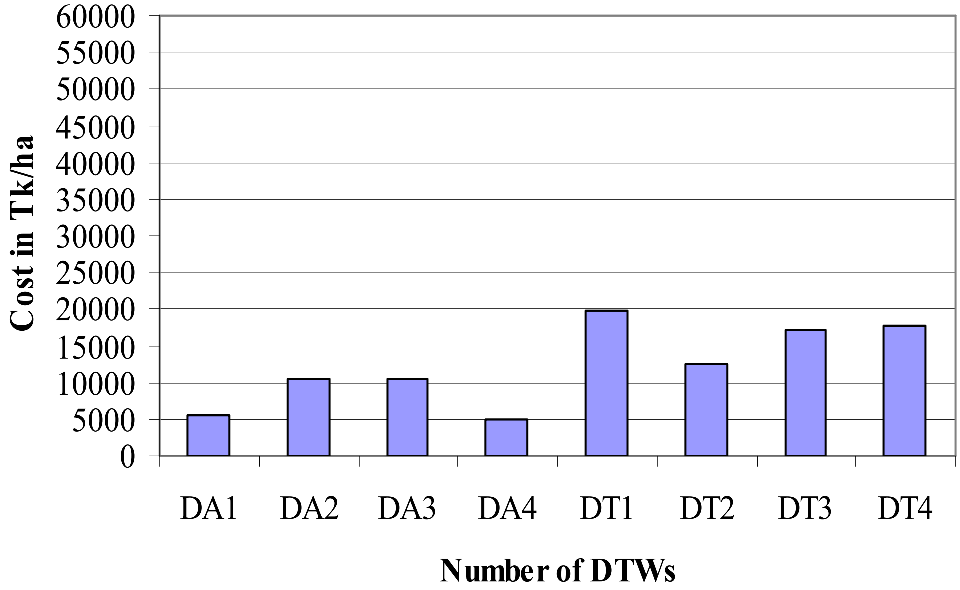

Figure 5.10: Cost in Tk. per hectare in low land and far from the tube-well of DTWs

In a high land and near to the tube-well the cost varied from Tk.14030 to Tk.20537 per hectare (average of Tk.17599 per ha); which is much higher than that of the area based pricing system. In a high land and far from tube-well cost is very high and ranges from Tk.23959 to Tk.40473 per hectare (average of Tk.33900 per ha). The variations are shown in Figures 5.11 and 5.12.

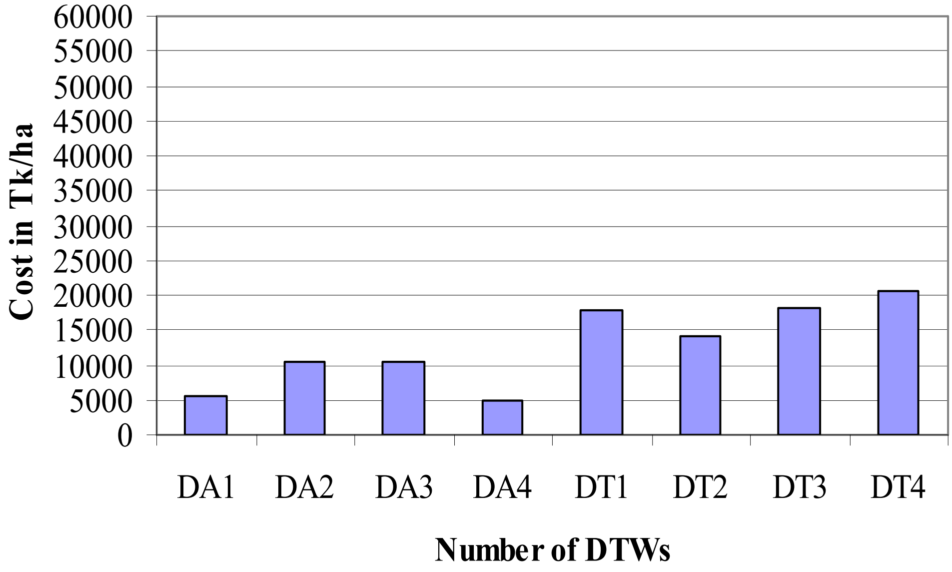

Figure 5.11: Cost in Tk. per hectare in high land and near to the tube-well of DTWs

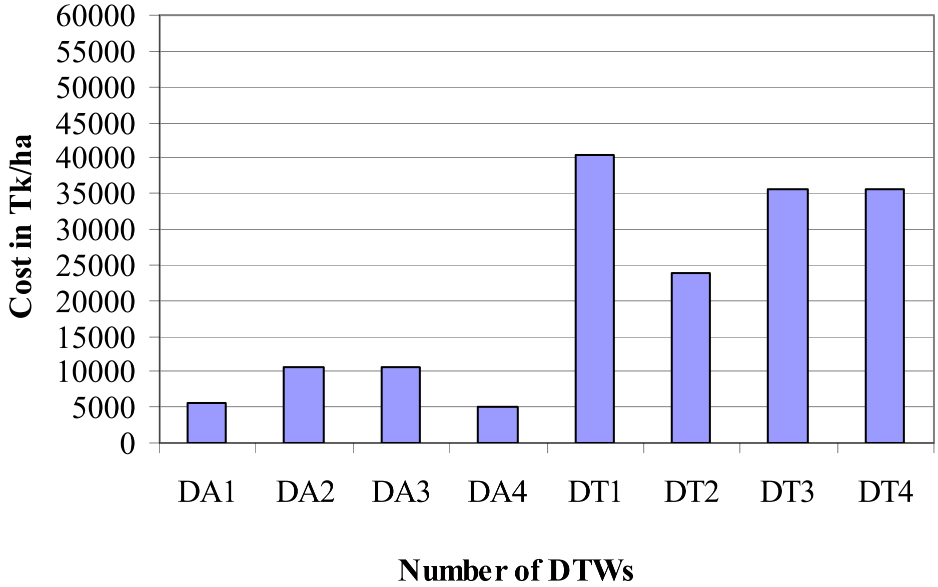

Figure 5.12: Cost in Tk. per hectare in high land and far from the tube-well of DTWs

In diesel based pricing systems of STWs SAD1,SAD2,SAD3 and STD1, irrigation cost for low land and near to the tube-well varied from Tk.10010 to Tk.15962 per ha (average of Tk.13109 per ha), Tk.17229 to Tk.28732 per ha(average of Tk.21410 per ha) in a low land and far from tube-well, Tk.15785 to Tk.30474 per ha (average of Tk.23530 per ha) in a high land and near to the tube-well and Tk.30224 to Tk.54853 /ha (average of Tk.39958 per ha)in a high land and far from the tube-well. This is shown in Figures 5.13, 5.14, 5.15 and 5.16.

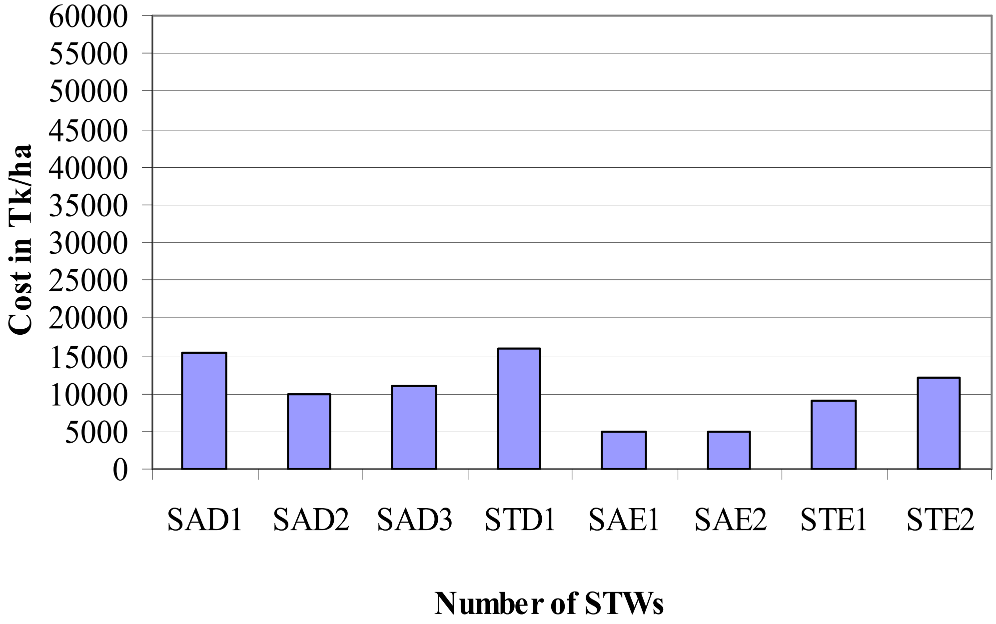

Figure 5.13: Cost in Tk. per hectare in low land and near to the tube-well of STWs

For time based pricing system of Shallow tube-well STE1 and STE2, irrigation cost varied from Tk.9104 to Tk.11997 per ha (average of Tk.10550 per ha) in low land and near to the tube-well, as shown in Figure 5.13. In low land and far from the tube-well the cost varied from Tk.13656 to Tk.17996 per ha (average of Tk.15826 per ha), shown in Figure 5.14. In high land and near to the tube-well it is Tk.18737 to Tk.24559 /ha (average of Tk.21648 per ha) and Tk.28105 to Tk.36838 per ha (average of Tk.32472 per ha) in high land and far from the tube-well. This is shown in Figures 5.15 and 5.16. Variation in pricing is due to differences in irrigation prices in different project.

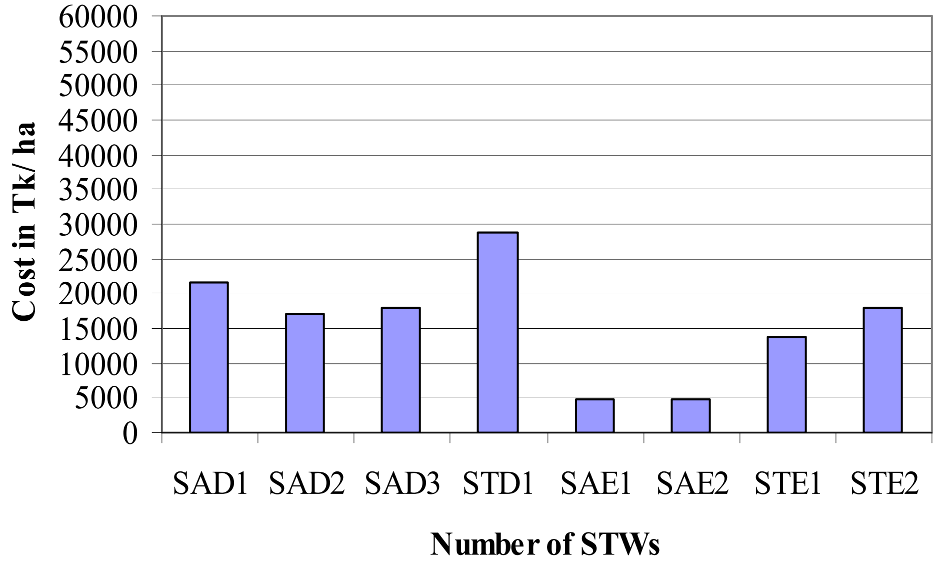

Figure 5.14: Cost in Tk. per hectare in low land and far from the tube-well of STWs

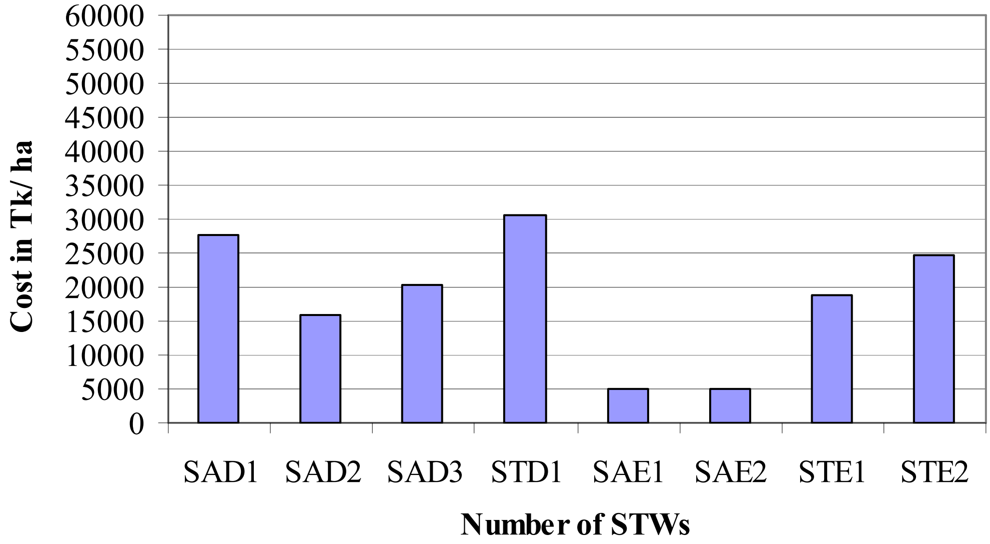

Figure 5.15: Cost in Tk. per hectare in high land and near to the tube-well of STWs

In time based pricing system of DTW irrigation fee is higher than that of STW. Moreover in DTW security fee is also collected. But average cost variation in STW is higher than that of DTW. This is because water distribution system is different. In STW water is conveyed through 5 cm diameter pipe and need more time to convey water to the field.

In case of diesel based pricing system of STW (sample SAD1, SAD2 and SAD3), security money is collected on area basis. For SAD1, irrigation cost is high compared to SAD2 and SAD3, because pump capacities are different. Pump capacities are 12 H.P of SAD1 and SAD2, and 16 H.P of SAD3. SAD1 and SAD3 run for 40 minutes with 1 litre of diesel and SAD2 runs for 1 hour 15 minutes with 1 litre of diesel.

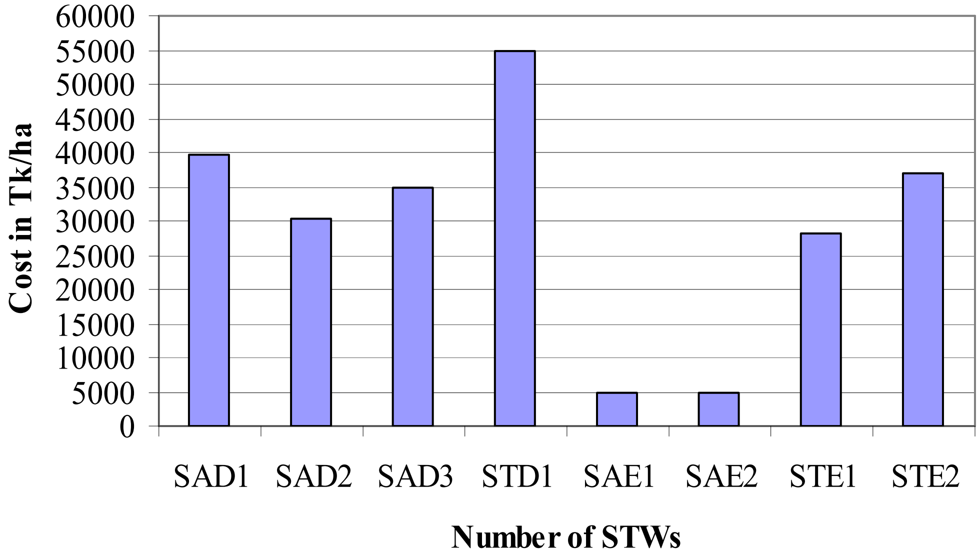

Figure: 5.16 Cost in Tk. per hectare in high land and far from the tube-well of STWs

From the above discussion it can be observed that although in time based and diesel based pricing system less water is used than area based pricing systems but cost is very high compared to area based pricing system. Moreover there is a large variation in cost between these systems. In diesel based pricing systems of STW, the cost is very high compared to others as shown in Tables 5.21 and 5.22 followed by time based pricing systems of STW and DTW.

Table 5.21: Percentage increase in cost in different pricing systems of DTW

Location of land	Average cost in area based pricing of DTW Tk./ha	Average cost in time based pricing of DTW Tk./ha	% increase in cost in time based pricing of DTW compared to area based pricing
Low land and near to the tube-well	7940	9254	16.55%
Low land and far from the tube-well	7940	16873	112.51%
High land and near to the tube-well	7940	17599	121.65%
High land and far from the tube-well	7940	33900	326.95%

Table 5.22 Percentage increase in cost in different pricing systems of STW

Location of land	Average cost in area based pricing of STW Tk./ha	Average cost in time based pricing of STW Tk./ha	% increase in cost in time based pricing of STW compared to area based pricing	Average cost in diesel based pricing of STW Tk./ha	% increase in cost in diesel based pricing of STW compared to area based pricing
Low land and near to the tube-well	4940	10550	113.56%	13109	165.36%
Low land and far from the tube-well	4940	15826	220.36%	21410	333.4%
High land and near to the tube-well	4940	21648	338.2%	23530	376%
High land and far from the tube-well	4940	32472	557.32.%	39958	708.86%

5.7.3 Profitability of pump managers & pump owners in different systems of pricing

Profit of DTW and STW depends on what amount of irrigation fee is collected and amount of total expenditure of pump manager and pumps owners. If project area increases fee collection also increase.

5.7.3.1 Various cost of pump managers and pump owners

There are two types of costs of the operation and maintenance of pump. One is fixed cost and another is variable cost. Salary of driver, manager and Chawkidar are fixed costs. Electricity bill, canal maintenance cost, tube-well maintenance costs are variable costs. Electricity bill depends on its use. In the study area most of the canal is unlined earthen canal. Very few canals of area based pricing system are lined canal. To reduce water losses, sometime canals are covered by plastic polythene. Canal condition of the study area is shown in photo 3. For unlined canal, it has to be repaired every year. When energy source is diesel they have no fuel cost because farmers bear fuel (diesel) cost. The various costs of DTWs are shown in Table 5.23.

Photo 3: Unlined canal using polythene in time based pricing system of the study area

Table 5.23: Various variable costs of DTWs in different pricing systems

Sample	Command area (ha)	Electricity bill (Tk.)	Lined canal (m)	Canal maintenance cost (Tk.)	Tube-well maintenance cost (Tk.)
DA1	36.8	79755	549	15000	30000
DA2	14.2	52909	91	1000	0
DA3	8.5	46000	30.5	0	20000
DA4	17.3	51557	18	15000	28200
DT1	17.7	45485	0	0	33000
DT2	19.8	48480	61	3000	20000
DT3	14.2	44659	24	0	18000
DT4	13.5	36800	0	1000	18000

(DA=area based pricing system, DT=time based pricing system)

From Table 5.23, it can be observed that some of the canals are lined. The cost of lining was borne either by Union Parishad or BADC. But in a time based pricing system some canal are unlined. They are not interested about lining of canal because water loss is not a concern for them.

From Table 5.23 it has been also observed that in an area based pricing system canal maintenance cost of area based pricing systems are higher (Tk.15000) in some project than time based pricing systems. This is because in area based pricing systems manager is responsible about water distribution and water loss is a key factor for him. But in a time based pricing systems manager do not think about maintenance of canal. Water distribution depends upon the proper management of systems. If manager is co-operative, honest and friendly to farmers then there exist good management.

The tube-well maintenance cost includes 1) buying and repairing of various parts 2) the mechanic charge, 3) electricity line repair etc. Tube-well maintenance cost of DA1 and DT1 are high because motors of the tube-well burned out and had to be repaired. The pipe under the motor was also damaged and had to be repaired.

From Table 5.24 it can be observed that all canals are unlined earthen canal and canal maintenance cost is nil in all schemes except for SAE1 and SAE2.Water loss is not a factor for the pump owners in a quasi volume based pricing system. In time based pricing system of STW, hose pipes are also used instead of canal. As in a time based pricing system farmers have to pay on time basis and in a diesel based pricing system farmers bear the fuel cost, The pump managers are not concern about water loss in conveyance. But in an area based pricing system farmers pay a fixed cost and use unlimited water. So pump owners have responsibility to maintain the canal.

Tube-well maintenance cost of STW included 1) servicing before starting, 2) buying and repairing various parts like well pump, piston ring, plunger, well filter, bearing etc 3) mechanic charge. Tube-well maintenance cost of SAD2, STE1 and STE2 are high because motor of the tube-well burned out three times and had to be repaired. In STW of diesel operating systems there is exist another extra cost (mobil cost). When electricity is used as a fuel mobil cost is not needed.

Table 5.24: Various variable cost of STWs in different pricing systems

Sample	Pricing system	Command area (ha)	Canal system	Driver salary (Tk.)	Canal maintenance cost (Tk.)	Tube-well maintenance cost (Tk.)	Mobil cost (Tk.)
SAD1	Diesel based	1.70	Unlined	**	0	2500	1200
SAD2	Diesel based	3.54	Unlined	5000	0	10000	2400
SAD3	Diesel based	2.83	Unlined	3000	0	1500	2040
STD1	Diesel based	1.56	Unlined	**	0	3000	1440
SAE1	Area based	3.12	Unlined	**	2000	3000	0
SAE2	Area based	2.41	Unlined	**	1800	2700	0
STE1	Time based	1.84	Pipe and Unlined	**	0	5000	0
STE2	Time based	1.84	Pipe and Unlined	**	0	6000	0

(Note: ** pump operated by manager)

5.7.3.2 Profit or loss of pump managers & pump owner's in different systems of pricing

There exist variations in profit due to variation in irrigation pricing, system of pricing, command area, canal maintenance cost, tube-well maintenance cost etc. The managers of time based pricing systems are very much careless about their maintenance; although they earn large profit. As they deliver water on time basis, they are not concerned about the maintenance of the canal. The maintenance of the canal is left to the farmers and they have to maintain the irrigation canal by their own cost. The profit or loss of managers of DTW during the Boro season is shown in Table 5.25 and for STW it is shown in Table 5.26.

From the Table 5.25, it has been observed that in a time based pricing system managers gain more profit than area based pricing system. The details of calculations are shown in Appendix D. In an area based pricing system of sample DA4, it has been seen that manager of that DTW made no profit during Boro season. His tube-well maintenance cost was high this year because the machine was changed from two phase line to three phase line by the help of converter. From Table 5.25 it has been also observed that the profit per ha is the maximum in time based pricing system and it is on average 204% higher compared to area based pricing system. In an area based pricing system maximum profit per ha occurred in DA2 because irrigation fee was higher compared to others area based pricing system.

For the STW, the pump owners also irrigate their own farm with the water from STWs. The profit and losses of STW owners (Table 5.26) were calculated considering the total irrigated area (including own land). From the Table 5.26 it has been observed that for the sample STE2 and STD1 total irrigable land are equal (1.84 ha), but profit are different. This is because of different pricing system. For the sample STE2 irrigation fee is collected on time basis and pump owner has to bear fuel cost and tube-well maintenance cost. And irrigation water is distributed through the unlined canal and 5 cm dia pipe; so it takes more time to deliver water on the farm. And for the sample STD1 security fee is collected on time basis, but pump owner does not bear fuel cost; only bear tube-well maintenance cost. So this manager gains large profit. The details calculations are shown in Appendix D.

From Table 5.26, it can be observed that all STWs were not profitable in this year. Some could not make profit. Two events SAD2 and SAD3 did not make profit in this year. This is because only these two samples have a fixed driver salary cost. Tube-well maintenance cost of SAD2 was also high this year. For SAD3, irrigation fee is comparatively less than other diesel operating pricing system. Total fee collection (Tk.6000) of this sample is very low compared to others. It has been observed that highest profit per ha occurred in STE1 although their irrigable land is smallest of all other samples. Then sample STE2 and STD1 made large profits. Sample SAE1, SAE2 and SAD1 made small profits. In STW of time based pricing system this profit per ha is 330% higher compared to area based pricing system and 75% higher compared to diesel based pricing system.

From the above discussion it can be observed that in a time based pricing system profit is maximum compared to others systems in both DTW and STW.

Table 5.25: Profit or loss of pump managers of DTWs in different pricing systems

Sample	Total land (ha)	Total expenditure (Tk.)	Total fee collection (Tk.)	Subsidy (20% on current bill) (Tk.)	Profit/loss (Tk.)	Profit/loss Tk./ ha
DA1	36.8	172755	208000	15951	51196	1391
DA2	14.2	78909	150000	10582	81673	5764
DA3	8.5	81000	90000	9200	18200	2141
DA4	17.3	112257	85400	10311	-16546	-958
DT1	17.7	93485	170168	9097	85781	4844
DT2	19.8	86480	303381	9696	226597	11427
DT3	14.2	62659	185392	89312	131665	9292
DT4	13.5	82800	237706	7360	162266	12055

(DA=area based pricing system, DT=time based pricing system)

Table 5.26: Profit or loss of pump owners of STWs in different pricing systems

Sample	Pricing system	Total land (ha)		Total expenditure	Total Fee collection considering fee from own land	Profit/loss	Profit/loss
		Without own land	With own land	(Tk.)	(Tk.)	(Tk.)	(Tk./ ha)
SAD1	Diesel based	1.28	1.70	3700	6000	2300	1353
SAD2	Diesel based	2.27	3.54	17400	15000	-2400	-678
SAD3	Diesel based	1.84	2.83	6540	6000	-540	-191
STD1	Diesel based	1.56	1.84	4440	21545	17105	9296
SAE1	Area based	1.56	3.12	7426	15400	7974	2556
SAE2	Area based	1.70	2.41	7662	11900	4238	1758
STE1	Time based	1.28	1.56	13087	30990	17903	11476
STE2	Time based	1.28	1.84	14409	27451	13042	7088

5.8 Choice of pricing systems by farmers and managers

In the previous sections water used by the farmers on-farm, water productivity and irrigation cost of farmers and finally profits made by the managers have been presented. In the following section the choice of a manager of DTW, Pump Owners of STW and the farmers regarding irrigation pricing is presented. These were done by the interviews with the managers and FGDs with the farmers.

5.8.1 Choice of managers of DTW

The managers in general preferred time based pricing systems. They presented the following reason:

- It is more profitable than others system.
- When the manager could not properly manage their project then he prefers time based pricing system. Because how long the tube-well is operating is not concern for him. In this system farmers are very conscious about their water uses and give irrigation fee on hourly basis. There is both efficient electricity use and water use.
- In a time based pricing systems pump manager only give attention on tube-well maintenance and no attention on canal maintenance. Because water loss is not concern for him.

5.8.2 Choice of pump owners of STW

Some STWs run by electricity and some by diesel. If there is no opportunity to connect electricity line then they operate by diesel. As the STW project area is small compared to DTW project area, they like diesel based pricing systems. They showed the reason as follows:

- It is simple to operate and no initial investment is required.
- There is problem with supply of electricity, so diesel based system overcomes this problem.

- Pump Owner likes diesel based pricing system as he does not bear the fuel cost. Moreover he also collects security fee from all farmers on area basis.
- Management is easier. When farmers bring diesel he operates his pump.
- In a diesel based pricing systems pump owner only give attention on tube-well maintenance and no attention on canal maintenance. Because water loss is not concern for him.

5.8.3 Choice of the farmers

Most of the farmers liked the area based pricing systems. They presented the following reasons as follows:

- High land farmers very much appreciated the area based pricing system because in time based pricing system their irrigation cost becomes very high. They get large amount of water with a fixed cost in area based pricing. Some low land farmers have objection about this system because they do not need much water but give the same price as high land farmers. But, in general most farmers like the area based pricing system.
- Area based pricing system is easy to understand.
- Farmers have no tension regarding buying of diesel or watching the time of irrigation supply. Canal maintenance is also not concern for them. They give price on area basis and use unlimited water.

Some projects of time based pricing used to practice area based pricing system earlier. But they changed their pricing system because in an area based pricing systems electricity bill was high .There were huge water losses.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Irrigation water pricing affects the water use by the farmers and varies widely over different modes and methods of minor irrigation in our country. In this study an attempt has been made to identify the on-farm water uses by the farmers, water productivity and profitability, and choice of farmers and managers regarding irrigation pricing in different pricing methods (area based, diesel based and time based pricing) over different modes (STW & DTW) and energy sources (electricity & diesel) of minor irrigation.

From the analysis it can be inferred that irrespective of the type of scheme (STW or DTW), the water use depends upon the type of the farm (high land or low land) and pricing systems. The water use is higher in high land (average 105%) and area based pricing system (average 37%) compared to low land and quasi volumetric pricing system.

Like water use, water use efficiency also depends upon the elevation of the farm and pricing system. The water use efficiency is 96% higher in low land and 38% higher in quasi volume based pricing system compared to high land and area based pricing system in both DTW and STW. Farmers are more judicious in their use of irrigation in quasi volume based pricing system.

From analysis it can be seen that water productivity in kg per m^3 of water used in low land is 81% (DTW) & 109% (STW) higher compared to that of high land. The reason is that low land use less amount of water compared to high land. Rice production is almost same for low land and high land. So the water productivity in low land is higher than that of high land.

Normally rice production is almost the same in all pricing systems of DTWs and STWs in an average year. But this year, the production is 16 % less in area based pricing, 21% less in time based pricing and 31% less in diesel based pricing systems than that of an average year due to insect and pest attacks and for this reason water productivity in kg per m^3 of water used is almost same in all pricing systems. It is slightly high in time based pricing system of STW.

From the analysis it can also be observed that although in quasi volume based pricing system less water is used than area based pricing systems but cost is very high compared to area based pricing system. Moreover there is a large variation in cost between these systems. Average cost in area based pricing of DTW is Tk.7940 per hectare and Tk.4940 per hectare for STW for all types of land. But in a quasi volume based pricing system cost is not uniform for all types of land (low land or high land) and location of land (near and far from the tube-well). When land is high, number of irrigation increases, and then irrigation cost also increases. Again when the farm is far from the tube-well then cost also increases.

In low land and near to the tube-well average irrigation cost is Tk.9254/ha (DTW) and Tk.10550/ha (STW) in time based pricing, and Tk.13109/ha (STW) in diesel based pricing. In low land and far from the tube-well average irrigation cost is Tk.16873/ha (DTW) and Tk.15826/ha (STW) in time based pricing, and Tk.21410/ha (STW) in diesel based pricing. In high land and near to the tube-well average irrigation cost is Tk.17599/ha (DTW) and Tk.21648/ha (STW) in time based pricing, and Tk.23530/ha (STW) in diesel based pricing. In high land and far from the tube-well average irrigation cost is Tk.33900/ha (DTW) and Tk.32472/ha (STW) in time based pricing, and Tk.39958/ha (STW) in diesel based pricing. It has been seen that in a diesel based pricing system of STW, cost is maximum compared to others systems.

There exists variation in profit due to variation in irrigation pricing, system of pricing, command area, canal maintenance cost, tube-well maintenance cost etc. From the analysis it has been observed that the profit per ha in time based pricing system of DTW is 204% higher compared to area based pricing system. In STW of time based pricing system profit per ha is 330% higher compared to area based pricing system and 75% higher compared to diesel based pricing system. It has been seen that in a time based pricing system profit is maximum compared to others systems in both DTW and STW.

Regarding choice of pricing systems, most of the farmers like area based pricing system, because it is simple to understand. They give price on area basis and use unlimited water.

Canal maintenance and water loss is also not concern for them. Most of the pump managers like time based pricing system because it is more profitable and management is easier. Some pump owners of STW like diesel based pricing system because the fuel cost is not borne by him. Moreover, this system overcomes the problem of shortage in supply of electricity.

6.2 Recommendations

Based on the findings of the study, the following recommendations have been made:

- The study has been conducted in 11 villages of 2 upazilas. It should be carried out in more villages of different upazilas in order to establish the findings.
- Although time based pricing is very efficient in terms of water use by the farmers, the irrigation fee is very high compared to area based pricing. So irrigation fee should be reduced in time based pricing system to encourage the farmers to adopt the system. The irrigation fee can be fixed by a national committee depending on different parameters (depth of water level, farm location, pump capacity, conveyance system, use of energy, etc.)
- In this study water use by surface water mode has not analyzed. So, in future surface water pricing system should be taken into consideration.

References:

Abernethy, C. L., Sally, H., Lonsway, K. & Maman, C. (2000) Farmer-based financing of operations in the Niger Valley irrigation schemes, Research Report 37. Colombo, IWMI. 38 pp.

Ahmad, M. (2000) Water pricing and markets in the Near East: policy issues and options. Published Elsevier, Water Policy 2 (3), pp 229–242. July 2000.

Amin, M.R. (2007) Water pricing in different minor irrigation systems, Unpublished M.Sc Thesis, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET).

BADC (2009) "Minor Irrigation Survey Report 2008-09", Government of the People's Republic of Bangladesh, Ministry of Agriculture, June 2009.

BADC (2005) "Minor Irrigation Survey Report 2004-05", Government of the People's Republic of Bangladesh, Ministry of Agriculture, 2005.

BADC (2001) "Ground Water Monitoring Data Book", Survey and Monitoring project for Development of Minor Irrigation, BADC, March 2000- December 2001.

BBS (Bangladesh Bureau of Statistics) (2007) "Statistical Yearbook of Bangladesh", 27th edition, Government of the People's Republic of Bangladesh, Planning Division, Ministry of Planning, July 2008.

Bazza, M. and Ahmad, M.(2002) A Comparative Assessment of Links between Irrigation Water Pricing and Irrigation Performance in the Near East, Conference on Irrigation Water Policies: Micro and Macro Considerations Organized by the World Bank, Agadir, Morocco, 15-17 June 2002.

Becker, N. & Lavee, D. (2002) The effect and reform of water pricing: the Israeli experience, Published in International Journal of Water Resource Development, volume 18(2), pp 353-366.

Bosworth, B., Cornish, G., Perry, C., Van, S. F. (2002) Water charging in irrigated agriculture, Report OD 145, HR Wallingford, 90 pp. December 2002.

Burt, C. M. (2007) Volumetric irrigation water pricing considerations, Published online: 30 May 2007, Irrigation Drainage System, Irrigation Training and Research Centre (ITRC), California Polytechnic State University (Cal Poly). San Luis Obispo, CA 93407, USA.

Caswell, M. and Zilberman, D. (1986) The effects of well depth and land quality on the choice of irrigation technology, American Journal of Agricultural Economics 68, no. 4(1986): 798-811.

Caswell, M. and Zilberman, D. (1985) The choices of irrigation technologies in California, American Journal of Agricultural Economics 67, no. 2(1985): 224-234.

Chaudhury, M.G., Majid, S. A. and Chaudhury, M. G. (1993) The policy of Irrigation Water Pricing in Pakistan, Aims, Assessment and Needed Redirections, The Pakistan Development Review, 32:4 Part II (Winter 1993) pp 809-821.

Cornish, G., Bosworth, B., Perry, C., Burke, J. (2004) Water Charging in Irrigated Agriculture: An Analysis of International Experience, Food and Agriculture Organization of the United Nations, Rome.

Cornish, G. A. and Perry, C. J. (2003) Water Charging in Irrigated Agriculture: Lessons from the Field. Report OD 150, HR Wallingford Ltd, Wallingford, UK.

Dinar, A. and Saleth, R.M. (2005) Issues in water pricing reforms: from getting correct prices to setting appropriate institutions. In: Folmer, H., Titenberg, T. (Eds.), The International Yearbook of Environmental and Resource Economics 2005/2006, Edward Elgar, Cheltenham, UK.

Doorenbos, J. and Kassam, A. H. (1979) Yield response to water, FAO Irrigation and Drainage Paper No. 33, FAO, Rome, Italy.

Easter, K.W. and Liu, Y. (2005) Cost recovery and water pricing for irrigation and drainage projects. Agriculture and Rural Development Discussion Paper No 26, World Bank, Washington, DC.

FAO, IIDS and NWRC (1998) Crop Wat 4 Windows Version 4.3 Food and Agricultural Organization of the United State, Institute of Irrigation and Development Studies and National Water Research Centre, Cairo.

FAO (Food and Agriculture Organization) (2002) How Design, Policy and Management Affect Performance of Irrigation, Prepared by Herve Plusquellec. FAO, Bangkok, Thailand.

Hsiao, C. & Luo, C. (1997) In A. Dinar & A. Subramanian, eds. Water pricing experiences: an international perspective, World Bank Technical Paper No. 386. pp. 115-119, Washington, DC, World Bank.

IIMI (International Irrigation Management Institute) (1996) Study on Privatization of Minor Irrigation in Bangladesh, International Irrigation Management Institute and Bangladesh Agricultural University.

Johansson, R.C., Tsur, Y., Roe, T.L., Doukkali, R., Dinar, A., (2002) Pricing irrigation water: A review of theory and practice. Water Policy 4 (2), 173–199.

Johansson, R C. (2000) Pricing Irrigation Water: A Literature Survey, World Bank, Washington, D C, 80pp.

Johnson, III, S.H. (1999) Management transfer in the Guanzhong Plain, Shaanxi Province, China. 7 pp. (available at http://www.chileriego.cl/mexico/M10001.pdf).

Kanazawa, M. T. (1992) Econometric Estimation of Groundwater Pumping Costs: A Simultaneous Equations Approach, Water Resources Research 28, no. 6(1992): 1507-1516.

Keller, A., Keller, J. and Seckler, D. (1996) Integrated Water Resource Systems: Theory and Policy Implications, Research Report 3, International Water Management Institute, Colombo, Sri Lanka.

Madi, M. O. A. (2009) Farm-level perspectives regarding irrigation water prices in the Tulkarm district, Palestine. Institute of Environmental and Water Studies, Birzeit University, P.O. Box 14, Birzeit, The West Bank, Palestine. 9 April 2009.

Ministry of Agriculture (2004) Data Bank-Ground Water and Surface Water Resources Bangladesh, BMDA, March 2004.

Molden, D., Murray, R.H., Sakthivadivel, R., Makin, I., (2003) A water productivity framework for understanding and action. In: Kijne, J.W., Barker, R., Molden, D. (Eds.) Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford, UK, pp. 1–18.

Molle F., (2008) Can water pricing policies regulate irrigation use? Paper presented to the 13th World Water Congress, 1-4 September 2008, Montpellier, France.

Molle, F. and Berkoff, J. (2007) Water pricing in irrigation: mapping the debate in the light of experience, Irrigation Water Pricing: The Gap between Theory and Practice, Chapter 2, Comprehensive Assessment of Water Management in Agriculture, CABI, Wallingford, pp. 21-93.

Molle, F. (2002) To price or not to price? Thailand and the Stigmata of ‘‘Free Water’’, Conference on Irrigation Water Policies: Micro and Macro Considerations Organized by the World Bank, Agadir, Morocco, 15-17 June 2002.

Molle, F. (2001) Water pricing in Thailand: theory and practice, Research Report No. 7, Kasetsart University, Thailand, DORAS Centre, 78 pp.

Mondal, M.S. (2000) Performance Evaluation of Some Selected Deep and Shallow Tube-wells in Irrigation Development, Unpublished M.Sc thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka.

Mujwahuzi, M.R. (1997) Tanzania. In A. Dinar & A. Subramanian, eds. Water pricing experiences: an international perspective, World Bank Technical Paper No. 386. pp. 120-124, Washington, DC, World Bank.

NWMP (2000a) “Draft Development Strategy”, Volume-7, Annex-1, Regulatory and Economic Instruments, Water Resources Planning Organization, Ministry of Water Resources, Government of the Peoples Republic of Bangladesh with Halcrow and Mott MacDonald (consultants).

NWMP (2000b) “Draft Development Strategy”, Volume-5, Annex-D, Legacies and Lessons, Water Resources Planning Organization, Ministry of Water Resources, Government of the Peoples Republic of Bangladesh with Halcrow and Mott MacDonald (consultants).

NWMP, (2001) National Water Management Plan, Ministry of Water Resources, December.

Lazaro, R.C. (1979) Irrigation Policy and Management Issues: An Interpretive Seminar Summary. In Donald C. Taylor and Thomas H. Wickam (eds) Irrigation Policy and the Management of Irrigation Systems in Southeast Asia, Bangkok, The Agricultural Development Council, Inc.

OECD (Organisation for Economic Co-operation and Development) (1999) Working party on economic and environmental policy integration - agricultural water pricing in OECD countries, ENV/EPOC/GEEI (98)11/FINAL Unclassified, 59 pp.

Perry, C. (2001) Water at any price? Issues and options in charging for irrigation water, Irrigation and Drainage 50(1), 1–7, International Water Management Institute, Colombo, Srilanka.

Rahman, M. (2009) Impact of the Bangsi River water quality on rice yield, Unpublished M.Sc (WRD) Thesis, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), March 2009.

Ray, I., (2002) Farm-level incentives for irrigation efficiency: some lessons from an Indian canal. Forthcoming in: Water Resource Update, Issue on Incentives and Trading in Water Resource Management, Issue No.121, January 2002.

Ray, A., Bruce, C. and Hotes, F.L. (1976) Cost recovery policies for irrigation projects: informal guidelines, Paper presented for informal guidance of persons involved in cost recovery policies for irrigation projects, World Bank, Washington, DC.

Rhodes, G. F and Sampath, R. K. (1988) Efficiency, equity and cost recovery, Implication of water pricing and allocation schemes in developing countries, Canadian Journal of Agricultural Economics 36:103-117.

Rosegrant, M.W. and Cline, S. (2002) The politics and economics of water pricing in developing countries, Water Resources Impact 4 (1), 6–8.

Rogers, P., De Silva, R., Bhatia, R. (2002) Water is an economic good: how to use prices to promote equity, efficiency, and sustainability, Water Policy 4, 1–17.

Rogers, P., Bhatia, R., Huber, A. (1998) Water as a social and economic good: how to put the principle into practice, Global Water Partnership, Swedish International Development Cooperation Agency, Stockholm, Sweden.

Saleh, A.F.M. and Mondal, M.S. (2000) Performance Evaluation of Rubber Dam Project in Irrigation Development, Final Report R02/2000, Institute of Flood Control and Drainage Research, BUET, Dhaka, April 2000.

Samal,C. K. and Kolanu, T. R. (2004) Water Pricing and Decentralized Irrigation Management in Andra Pradesh-Schism between objectives and realities, Deutcher Tropentag, Berlin, 2004.

Slim, Z., Lazhar, E.E.M. & Mongi, S. (1997) Tunisia. In A. Dinar & A. Subramanian, eds. Water pricing experiences: an international perspective, World Bank Technical Paper No. 386, pp. 125-133, Washington, DC, World Bank.

Tsur, Y. and Dinar, A. (1997) The relative efficiency and implementation costs of alternative methods for pricing irrigation water, The World Bank Economic Review 11 (2), 243–262.

WMO (World Meteorology Organization) (2007) The Dublin Statement on Water and Sustainable Development. Available on: http://www.wmo.ch/

World Bank, (2006) Reengaging in Agricultural Water Management: Challenges, Opportunities, and Trade-offs, Water for Food Team, Agriculture and Rural Development Department (ARD), World Bank, Washington, DC.

WRI (World Resources Institute) (2000) A guide to world resources 2000-2001: people and ecosystems: the fraying web of life, United Nations Environment Program (UNEP), the United Nations Development Program (UNDP), the World Bank, and the World Resources Institute (WRI), Washington, DC.

Yaron, D. (1997) Israel. In A. Dinar & A. Subramanian, eds. Water pricing experiences: an international perspective, World Bank Technical Paper No. 386, pp. 61-63, Washington, DC, World Bank.

Appendix A

Monthly rainfall (in mm) of Dhaka station

	Jan	Feb	Mar	Apr	May	Sum (Jan-May)	June	July	Aug	Sep	Oct	Nov	Dec	Annual
1995	7.6	26.7	0.2	116.9	214	365.4	279.5	340.1	363.4	208.8	93.2	127.9	1.5	1779.8
1996	0	21.7	55.4	270.3	279	626.4	311	287	293.9	202.8	323.5	0	0	2044.6
1997	6.1	4.8	57	161.6	141.1	370.6	247.1	458.1	365.3	553.1	12.5	2.4	23.5	2032.6
1998	0	4	49.3	155.7	420.2	629.2	100.6	578	527.3	293	127.5	73	0	2328.6
1999	0	0	0	14	431	445	380.00	538	359	369	327.7	7.9	0	2426.6
2000	17.1	48.3	143.3	186.9	524.9	920.5	162.5	225.40	352.9	204.6	170.6	0	0	2036.5
2001	0	0.20	0	44.9	384.7	429.8	439.7	201.00	249.2	189.4	196	13.60	0	1718.7
2002	18	1.00	63.6	135.3	262.3	480.2	393.5	424	286.70	105.4	48.9	157.20	0	1895.9
2003	0	14.30	93.3	91.3	174.2	373.1	469.1	220.2	262.10	399	127.5	0.00	45.2	1896.2
2004	0	0.00		142.4		142.4	533.5	317.8	187.10	946	208.5	0.00	0	2335.3
2005	4.2	2.10	128.1	67.4	270	471.8	190.1	508.8	273.2	512.50	407.1	2.00	0	2365.5
2006	0	0.00	0	188.8	205.4	394.2	368.4	290.8	210.20	649.40	93.6	7.40	0	2014
2007	0	32.90	7.8	137.8	124.1	302.6	652.4	720.2	430.4	221.80	297	108.70	0	2733.1
2008	23	56.00	45	91	205	420	577	563	319	279.00	227	0.00	0	2385
2009	1	1.00	43	14	168	227								
													Average	2142

(Source: Hydrology Department, BWDB (1995-2007) & Meteorological Department, 2008-2009)

Appendix B

List of interviews with farmers

Types of scheme	Pricing system	Upazila	Village	Number of farmers	Location
DTW	Area based	Kaliakair	Borochala	1	High land
				1	Low land
DTW	Area based	Gazipur Sadar	Purbo Dugri	1	High land
				1	Low land
DTW	Area based	Gazipur Sadar	Paschim Dugri	1	High land
				1	Low land
DTW	Area based	Gazipur Sadar	Kainjanul	1	High land
				1	Low land
DTW	Time based	Kaliakair	Thangerban	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
DTW	Time based	Kaliakair	Jamalpur	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
DTW	Time based	Kaliakair	Palashtali	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
DTW	Time based	Kaliakair	Fakirchala	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Area based	Kaliakair	Durgapur	1	High land
				1	Low land
STW	Area based	Kaliakair	Durgapur	1	High land
				1	Low land
STW	Time based	Kaliakair	Thangerban	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Time based	Kaliakair	Thangerban	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Diesel based	Gazipur Sadar	Bahadur pur	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Diesel based	Gazipur Sadar	Baopara	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Diesel based	Gazipur Sadar	Kainjanul	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well
STW	Diesel based	Kaliakair	Thangerban	2	Low land, near and far from the tube-well
				2	High land, near and far from the tube-well

Appendix C

Irrigation water use by the farmers, water productivity and irrigation cost of different pricing systems

1) Pricing System: Area based

Sample DA3

Source of energy: Electricity, Pump capacity 25 H.P, pipe diameter 6 inch

1 bigha=	35	decimal
Land:	52.5	decimal
Production	29	maund
type:	low	
Location:	near the machine	

On-farm water use in inch	No of use
2.75	1
2.5	1
2.25	1
2	7
1.75	4

Total no of irrigation	14	
Total water use	28.5	inch
	724	mm
Rainfall	57	mm
Total on-farm water use	781	mm

Rice production	19.33	maund/bigha
	136.44	maund/ha
	5092.42	kg/ha
Water productivity	0.65	kg per m^3

Irrigation Cost

Irrigation fee	Tk.1500	per bigha
Total cost	Tk.10586	per ha

2) Pricing System: Time based

Sample: DT2

Source of energy: Electricity, Pump capacity 25 H.P, pipe diameter 6 inch

1 bigha=	35	decimal
Total Land:	70	decimal
Production	32	maund
Land type:	high	
Location:	far the from the pump (350m)	

On-farm water use in inch	No of use
2.25	5
2	10
1.75	4
1.5	1
1.25	1
1	1

Total no of irrigation	22	
Total water use	42	inch
	1067	mm
Rainfall	57	mm
Total on-farm water use	1124	mm

Rice production	16.00	maund/bigha
	112.91	maund/ha
	4214.41	kg/ha
Water productivity	0.375	kg/m^3

Irrigation cost

Irrigation fee	Tk.50/hr
Security cost	Tk.245/bigha
For 1 inch water deliver in far land time needed	1.5 hr per bigha
Total operating hour	1.5*42=63 hr/bigha
Total Operating cost	63* 50=3150Tk/bigha

Total cost	245+3150=3395Tk/bigha
	Tk.23959/ha

3) Pricing System: Diesel based

Sample: SAD3

Source of energy: Diesel, Pump capacity 16 H.P, pipe diameter 5 inch

1 bigha=	35	decimal
Land:	28	decimal
Production	12	maund
Land type:	low	
Location:	near to the tube-well	

On-farm water use in inch	No of use
2.5	2
2.25	1
2	1
1.75	2
1.5	1
1.25	2
1	6

Total no of irrigation	15	
Total water use	22.75	inch
	578	mm
Rainfall	57	mm
Total on-farm water use	635	mm

Rice production	15.00	maund/bigha
	105.86	maund/ha
	3951.01	kg/ha
Water productivity	0.62	kg/m^3

Irrigation cost

Irrigation fee	Tk.300/bigha	
1 litre diesel run for	40 min	
For 1" water deliver in near land time needed	0.83 hr per bigha	
Diesel used	(0.83*22.75*60)/40=28.32	litre / bigha
Diesel cost	(28.32*44)=1246.245	Tk per bigha
	(diesel cost Tk.44/litre)	
Total cost (1246.245+300)=1546.245	Tk per bigha	
Tk.10912/ha		

Appendix D

Profitability of managers of DTWs and pump Owners of STWs in different pricing systems

1) Pricing System: Area based

Sample DA1
Source of energy: Electricity, Pump capacity 25 H.P, pipe diameter 6 inch

A)Total Expenditure			
1.Current Bill			
December'08	Tk.	13740	
January'09	Tk.	16720	
February'09	Tk.	17785	
March'09	Tk.	19600	
April'09	Tk.	11910	
Total Bill	Tk.	79755	
2.Driver salary(12 month)	Tk.	18000	
3.Manager salary	Tk.	0	
4.Tube-well maintenance	Tk.	30000	
5.Drain Maintenance	Tk.	15000	
6.Chakider salary(2 person, for 5 month)	Tk.	30000	
Total expenditure	Tk.	172755	
B) Total Fee Collection			
Irrigation fee	Tk.	800	per bigha
Total land		260	bigha
Total fee collection	Tk.	208000	
Subsidy(20% on current bill)	Tk.	15951	
Total earning	Tk.	223951	
Profit	Tk.	51196	

2) Pricing system: Time based

Sample: DT2
Source of energy: Electricity, Pump capacity 25 H.P, pipe diameter 6 inch

A) Total Expenditure			
1.Current Bill			
January'09	Tk.	9163	
February'09	Tk.	12056	
March'09	Tk.	13146	
April'09	Tk.	10527	
May'09	Tk	3588	
Total Bill	Tk.	48480	
2.Driver salary	Tk.	10000	
3.Manager salary	Tk.	5000	
4.Tube-well maintenance cost	Tk.	20000	
5.Drain Maintenance cost	Tk.	3000	
Total expenditure	Tk.	86480	
B) Total Fee Collection			
Security fee		Tk.245/bigha	
Total land		140 bigha	
Total Security fee collection		Tk.34300	
Irrigation fee		Tk.50/hr	
A)Low land(near to the tube-well)		45 bigha	
Total operating hour		17.015 hr/bigha	
Total operating cost		Tk.850.75/bigha	
Total cost in low land(near to the tube-well)		Tk.38283.75	
B)Low land(Far from the tube-well)		25 bigha	
Total operating hour		30.75 hr/bigha	
Total operating cost		Tk.1537.5/bigha	
Total cost in low land(Far from the tube-well)		Tk.38437.5	
C)High land (near to the tube-well)		20 bigha	
Total operating hour		34.86 hr/bigha	
Total operating cost		Tk.1743/bigha	
Total cost in high land(near to the tube-well)		Tk.34860	
D)High land(Far from the tube-well)		50 bigha	
Total operating hour		63 hr/bigha	
Total operating cost		Tk.3150/bigha	
Total cost in high land(far to the tube-well)		Tk.157500	
Total fee collection		Tk.303381	
Subsidy(20% on current bill)		Tk.9696	
Profit		Tk.226597	

3) Pricing system: Diesel based

Sample: SAD3
Source of energy: Diesel, Pump capacity 16 H.P, pipe diameter 5 inch

Total land	20	bigha
A) Total Expenditure		
1.Fuel cost	Tk.	0
2.Canal Maintenance	Tk.	0
3.Tube-well Maintenance cost	Tk.	1500
4.Mobile cost(17litre, Tk.120/litre)	Tk.	2040
5.Driver salary(5 month)	Tk.	3000
Total expenditure	Tk.	6540
B) Total Fee Collection		
Irrigation fee		Tk.300/bigha
Total fee collection(consider own land)		Tk.6000
loss(consider own land)		Tk.-540