ASSESSMENT OF DEEP TUBEWELL DRIVEN IRRIGATION SYSTEM IN THAKURGAON SADAR THANA

A THESIS

BY

MIRAJUM MUNIRA PRIYA

Examination Roll No.: 1605559

Session: 2016-2017

Thesis Semester: July-December, 2017

MASTER OF SCIENCE (MS)
IN
IRRIGATION AND WATER MANAGEMENT

DEPARTMENT OF AGRICULTURAL AND INDUSTRIAL ENGINEERING

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Hajee Mohammed Danesh Science & Technology University, Dinajpur
In partial fulfillment of the requirements for the degree of

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December, 2018

DEDICATED

TO

MY BELOVED PARENTS

&

HONOURABLE TEACHERS

ACKNOWLEDGEMENT

It is the author's great pleasure and privilege to express her indebtedness, deepest gratitude and profound regard to her Supervisor Dr. Mohammad Shiddiqur Rahman, Professor, Department of Agricultural and Industrial Engineering, Hajee Mohammad Danesh Science And Technology University, Dinajpur for his constant encouragement, helpful suggestions and co-operation during the study.

She, likewise extends her gratitude and appreciation to the Co-supervisor Professor Dr. Md. Kamal Uddin Sarker, Chairman Department of Agricultural and Industrial Engineering, Hajee Mohammad Danesh Science And Technology University, Dinajpur, for his guidance and helpful suggestions as well as reviewing the dissertation critically.

The author is indebted to, Md. Jahangir Alam Khan, Superintend Engineer, BMDA, Thakurgaon for his valuable suggestions in the preparation of this manuscript.

The author is also greatful to Md. Shafiqul Islam, Assistant Engineer, BMDA, Thakurgaon for his support and recommendation for the completion of this research work.

The author is sincerely grateful to the authority of BMDA, Thakurgaon, for their help to complete the work.

The author likes to convey her gratitude and sincere appreciation to the teachers of the Department of Agricultural and Industrial Engineering, HSTU, Dinajpur for their encouragement and valuable suggestions during the study period. She also extends her thanks and appreciation to the staff of the Department for their sincere and kind co-operation for different official work.

Sincere gratitude goes to her parents, relatives, brother, sister-in-law for their help and inspiration during this works.

Special thanks and appreciations are extended to her beloved husband, best friend and closest advisor, Md. Nashif Jakariea Nishu for his patience, inspiration, companionship, love and encouragement which were helpful for the successful completion of this study.

Finally, the author is thankful to Almighty Allah to whom she owes all her success.

The Author

ABSTRACT

Studies were conducted in Thakurgaon area during T. Aman season 2016-2017 to Boro season 2017-2018 in order to suggest some important criteria related to improved water management practices for rice based cropping system using deep tubewell. About hundred percent farmers of the study area reported that they received enough water from the respective DTWs for different crops. Most of the farmers of the study area used earthen channel as a distribution system. The actual discharges of three selected DTWs in three locations were 56 lit/s for 20 to30 HP engines. Appropriate pump size should be used to reduce irrigation cost. There were no conveyance loss in buried pipe line. The economic performance of supplemental irrigation by using buried pipe for T. Aman and Boro rice cultivation with irrigated condition is highly profitable. For improved lined water distribution system, saving of irrigation water and distribution time and increase of irrigated area respectively were 13-18%, 25-29% and 46-51% in comparison to that of earthen channel. Similarly for buried pipe distribution system, the above parameters were respectively 98-99%, 56-61% and 80-82% in comparison to that of earthen channel system. To obtain greater conveyance efficiency buried pipe and improved compacted earthen channel should be used to distribute water in the irrigated crop fields. The study shows that continuous standing water is not necessary for optimum yield of rice. Moreover, without sacrificing much yield, about 41 percent and 37 percent of valuable irrigation water can be saved over treatment T1 (continuous standing water) by practicing the treatment T2 (Irrigation depth of 7 cm after 3 days of dissapearance of standing water) respectively. For optimum utilization of irrigation water, water saving technique like irrigating after 3 days of standing water as suggested in this study, should be followed properly.

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LIST OF ABBREVIATION

BRRI	— Bangladesh Rice Research Institute
MV	— Modern Variety
Mha	— Million hectare
BADC	— Bangladesh Agricultural Development Corporation
BCR	— Benefit Cost Ratio
WARPO	— Water Resources Planning Organization
Mmt	— Million metric ton
DTW	— Deep Tubewell
STW	— Shallow Tubewell
LLP	— Low Lift Pumps
NCA	— Net cultivable area
BWDB	— Bangladesh Water Development Board
IWM	— Institute of Water Modelling
BMDA	— Barind Multipurpose Development Authority
HYV	— High Yielding Variety
S&P	— Seepage and Percolation
ET	— Evapotranspiration
EV	— Evaporation
PET	— Potential Evapotranspiration
G. K. Project	—‘Ganges Kobodak Project
GOB	— Government of Bangladesh
UNDP/FAO	— United Nation Development Programme Food and Agricultural Organization
HP	— Horse Power
BARI	— Bangladesh Agricultural Research Institute
NMIDP	— National Minor Irrigation Development Programme

CHAPTER I

INTRODUCTION

1.1 Statement of the Problem

Irrigation water is a critical factor to make crop production a success in Bangladesh. Although the monsoon climate, with its high humidity and temperature, is favorable for rice cultivation, the rainfall is not evenly distributed throughout the year. About 96 percent of the total rainfall occurs during the month of April to October, leaving the remaining five months of the year essentially dry. Drought conditions prevail over most areas of the country during the months from November to April, when potential evapotranspiration far exceeds rainfall (Manalo, 1976). Due to very limited availability of rain water during dry season (November — April) the Boro rice is fully dependent on irrigation. Among all agricultural inputs, irrigation water is scarce and a costly resource. The cost of irrigation water is increasing day by day with the increase demand of irrigation water. As a result, now a days, each drop of water is being considered as a valuable national resource. Therefore, attempt should be made to utilize this costly resource with minimum waste.

Recently, much concern has been expressed about improving the performance of existing irrigation system. To realize this goal, there is a need to develop and implement practical methodologies to upgrade the performance of the system and enable farmers to achieve higher benefits.

Current rice production methods take large amount of water. Research indications are that a fair amount of the total water used is linked to the prevailing customs and practices in handling water in the production system, which can be significantly reduced without affecting rice yields. Most analyses indicate that a crisis in water availability for agricultural production is likely to get worse in the near future in Bangladesh. Such a crisis would undoubtedly lead to serious rice shortfall. Expansion of irrigated areas using safe sources of water as well as significant improvements in the productivity of water in rice cultivation are needed to avoid the impending crisis. To avoid the problems, new information and innovations in managing water for agriculture are needed.

Proper water distribution system and its efficient management play a very important role in the command area development of any irrigation project. In Bangladesh, use of earthen open channel for water distribution is common especially in minor irrigation secors. These earthen open channel distribution systems suffer from a number of problems, for example, low conveyance and application efficiency, less area covered and high maintenance cost. It is a fact that open channel distribution system confronts some physical obstructions such as natural' drainage channels or khals, embankment or road, high land, irregular or fragmented topography high seepage, and evaporation losses and right of way problem. Another disadvantage of open channel system is that about 2 to 4 percent of the cultivable land is taken up by the open channel distribution system (Michael, 1987). Possible solution to some of these problems, for the areas with plain topography and having heavy to medium textured soil, include construction of improved (compacted) earth channels with necessary water control structures such as checks, diversions, culverts, siphons, aqueducts or short length of highly embanked channels and adequate operation and maintenance of the performance system. However, the loss of agricultural land is unavoidable with open channel system. But for uneven or fragmented topography and light textured soil which has poor cohesion, compaction is ineffective and channels require seasonal reconstruction; and where lined channels which is a costly affairs are easily undermined by erosion of the embankment, buried pipe and flexible hose pipe distribution system may be the best solution to those problems.

There is no problem of right of way as no loss of land is involved in buried pipe water conveyance. There is an economic advantage as well as a practical benefit when a large number of small and fragmented plots belonging to different individuals are not to be crossed to distribute water from a deep tubewell. It is also not necessary to follow plot boundaries, thus it reduces the length of conduit. Since almost all of the system is buried no significant amount of crop land is lost and farming operation can be done above the pipelines. Buried pipe system provides simplified water management with the possibility of more predictable adequate, timely flows of water to maintain prescribed rotational schedules and to prevent water pilferage conflict. Equity of water distribution between head and tail enders is greater in buried pipe system because of reduction in conveyance loss and less opportunities for illegal diversions of water. Despite the clear advantages and benefits by the buried pipe, some problems have been observed in the system, for instance, techniques, high cost initial cost is high but no maintenance cost in curved in the irrigation period.

In buried pipe system, irrigation water is conveyed under low pressure from a header tank adjacent to the tubewell via underground pipelines to an outlet close to the point of final use. Since the pipelines operate under pressure, they can be laid uphill or downhill and thus permits the delivery of irrigation water to areas not accessible by open channels.

All of the above advantages of the buried pipe system are also applicable to the flexible hose pipe distribution system. It is not necessary to install the hose pipe system permanently. A pipeline system is essentially water tight with almost no conveyance and evaporation losses during transmission, so there occurs a considerable amount of water savings requiring less pumping cost. Hose pipe method of water distribution system requires a less investment than that of unlined or lined open channel and buried pipe systems. It may be usable with buried pipe system (Bentum *et al.,* 1995).

Many researchers indicated that rice is the major consumer of irrigation water in Bangladesh. It is grown under two distinct water regimes, continuous flooding and alternate flooding. The conventional method of rice cultivation requires continuous ponded water on the field, which is possible where irrigation water is abundant and cheap. In this method irrigation water that is used for evapotranspiration (ET) and seepage-percolation (S&P) are unavoidable losses. However, rice can be grown under alternate wet and dry conditions without necessarily sacrificing yields and adoption of such a practice may allow saving of costly water in Thakurgaon district (under Old Himalayan Piedmont Plain). Therefore, recommendations are needed on when to irrigate and how much water to apply for increasing the yield of the crop.

The optimum use of irrigation water should be an important strategy for increasing agricultural production in Bangladesh. The overall development of the agricultural sector will require year-round use of the irrigation facilities for productive use of water. The country will realize sustainable benefits if the allocation and distribution of the available water are improved. Field studies are needed to identify the nature and magnitude of water management problems and to develop methods of improving water management, which would help in achieving higher crop yields, irrigation efficiency and greater water distribution equity.

There are very few research studies, which can pin point the location of weaknesses in the performance of irrigation systems. Only fewer can demonstrate how to effectively alleviate them. Field studies are, therefore, needed to identify the causes of low irrigation efficiency of the pumping unit and to develop method of improvement. Such studies are needed to estimate the different losses of water from irrigated rice fields and to determine the actual water requirement for irrigated rice. Thus, potential irrigated area could be achieved by supplying optimum amount of water and reducing excessive losses.

Since groundwater is the main source of irrigation for rice and non rice crops, it is sometime necessary to know the inherent aquifer properties and hydrogeologic characteristics for proper assessment of the available groundwater resources. Therefore, pumping test is needed to evaluate the aquifer characteristics of the Old Himalayan Piedmont Plain Area. Although limited number of studies were carried out by BWDB and other investigators (MPO 1987, Chowdhury *et al.*, 1994 and IWM, BWDB 2005) but the data is not compiled as usable form. So critical analysis of those data is also needed.

In Thakurgaon 1405 DTWs (by BMDA and BADC) are being used to lift groundwater. If appropriate techniques of groundwater extraction based on the resources availability and requirement are not established and unplanned withdrawal is continued, the resulting effects may lead to dangerous imbalance in the local hydrology and environment in near future. So monitoring of groundwater level is very crucial to quantify the amount of recharge in this area for sustainable irrigated agriculture.

All the above mentioned issues need validation to be applicable for a specific area. The irrigation water availability is another important considerations for effective planning of irrigation system which need to be addressed by direct field research. Therefore, the present study was undertaken to develop irrigation strategies for rice cultivation with deep tubewells located at Thakurgaon sadar thana focusing on different important issues related to the success of irrigated agriculture.

1.2 Research Objectives

(i) To assess the present status of irrigation and water management practices for rice based cropping systems;

(ii) To determine the incremental benefit from buried pipe line irrigation system.

(iii) To identify conveyance losses for different water distribution system and savings of conveyance time.

(iv) To identify the major constraints to irrigated rice crop;

CHAPTER II

REVIEW OF LITERATURE

Bangladesh is the 4th largest country in Asia with respect to rice area and production (IRRI, 2018). The net cultivable area at present is about 8.42 Mha (Million hectare) while the net area sown is 7.99 Mha (Ministry of Agriculture, 2001). Rice is the staple food for her people. It grows in all the three crop growing seasons of the year and occupies about 77 %(10.71 Mha) of the total cropped area of about 13.96 million hectares (Mha). At present, rice alone constitutes about 92% of the total food grains produced annually in the country. It provides about 75% of the calorie and 55% of the protein in the average daily diet of the people (Bhuiyan *et al.,* 2002). It also ensures political stability for the country and provides a sense of food security to the people.

Rice is grown under both irrigated and rainfed conditions in three distinct seasons — Aus, Aman and Boro. Aus is planted in March — April and harvested in July-August. Transplanted Aman (T. Arnan) is grown from July-August to November-December. Boro rice is grown entirely under irrigated conditions and is planted in December-January and harvested in April-May (BRRI, 1984).

Modern varieties (HYV) of rice cover about 94% of Boro rice, 56% of T. Aman and 32.5% of Aus. At present, total area under MV rice is 62% (6.63 Mba) of rice cultivated area (10.71 Mha) and the contribution of MV rice to the annual rice production is 77%. The total rice production is 23.06 million metric tons (Mmt) of which 17.71 Mmt is from MVs and the rest 5.35 Mmt is from local varieties during the same period (Bhuiyan *et al.,* 2002). The national average yield of HYV rice in Aus, T. Aman and Boro seasons are 2.75, 3.43 and 4.72 t/ha respectively and those for local varieties are 1.55, 1.68 and 2.23 t/ha for the above mentioned seasons. The average rice yield, irrespective of seasons and varieties is 2.15 t/ha.

In Bangladesh, rice is by far the largest irrigation user, with over 82% of the total irrigated area. All modern variety (MV) boro is irrigated, whereas only a small proportion of the aus and other crops (7% and 5% respectively) receive either full or supplemental irrigation. MV boro cropping has been the driving force behind minor irrigation expansion. Wheat, potatoes and vegetables are the other main irrigation users, with over 40%, 80% and 40% respectively of their total areas under irrigation. Wheat is the largest user of irrigation after rice, with about 6% of the total irrigated area. The boro crop area in 2004 reached to about 4.8 Mha which is 88.22% of the area irrigated during Rabi season (BADC, 2005). The irrigated single-crop boro could reach about 4 Mha (WARPO, 2000).

The demand for rice will be increasing in future in the country because of increasing population size. The projected population is about 169 millions by the year 2025 (Bhuiyan *et al.,* 2002). This needs to produce about 27.8 million metric tons (Mmt) of clean rice (41 Mint paddy) to feed the population by the year 2025, which is about 21% higher than the production level of 2000. This increasing demand has to be met from our limited and shrinking land resources. Targeting high yield by providing irrigation facility with a higher cropping intensity is the most logical way of raising the total production at the national level. But the scope for increasing cropping intensity in future seems low since it has already reached at about 175%. So the most important way is to bring more rainfed land under irrigation facility for growing modern varieties. Therefore, strategies have to be developed for sustaining the production to match the demand with the limited land and water resources of Bangladesh.

In agricultural development work, people from different disciplines with different backgrounds and interest work together for a defined objective that is increased production. Very often water (mostly groundwater) plays a decisive role in crop production; therefore, improved management of irrigation water is essential for effective implementation of agricultural development programmes.

Hillel (1972) reported that there has been a tendency in water management to save water per unit of land area and “green up” more land. However, basic aim of water management is not to save water but to increase production per unit of water supply by avoiding water stress and preventing water from becoming a limiting factor in crop growth.

Sattar *et al.* (1988) evaluated the performance of the North Bangladesh Tubewell project the Deep tubewell Irrigation System in Thakurgaon. The discharge capacities of the tubewells, conveyance efficiency in the distribution system, on farm water losses, command area efficiency were calculated. According to Hassan *et al.,* (1992) water loss in the main lined channels of the three selected tubewells were 91.0 and 52.0 lit/hr/m^2 before repairing of the channels while the corresponding figures were 43.0 and 7.0

lit/hr/m^2 after repairing of the canals. Similarly, water losses in earthen canals were 105.0 and 208.0 lit/hr/m^2 which were 8% and 9% of the outlet discharges. Total distribution losses for each tubewells were about 42% and 30%. Field data indicated that the deep tubewell command area could be increased significantly through reduction of conveyance losses.

Rashid *et al.* (1996) conducted another study under different pump types in Rangpur, Jessore and Manikgonj area to determine the water use efficiency at farm level and identifies the profitable cropping pattern in irrigated environment. Three Deep Tubewells (DTWs), three shallow tubewells (STWs) and three low lift pumps (LLPs) were selected for the study in each of 3 selected districts. Information was collected by both experimentation and interviewing the farmers and tubewell managers. The average irrigation coverage were 20.9 ha, 4.2 ha and 11.9 ha under DTW, STW and LLP respectively. The water use efficiency for rice was 88%, 88% and 87% under DTW, STW and LLP, respectively and that for potato, wheat, and onion was 80%, 100% and 80%, respectively.

Rahman and Desai (1997) carried out a study on On-farm water management in summer rice and reported that application of 5 cm of irrigation water to rice field one day after standing water disappeared was compared with farmer's water management practices. in the experimental treatment, averaged over 3 years 29% of the irrigation water normally used by farmers saved with about 55% higher yield per unit of water applied. An irrigated rice crop required on average 1200 mm water during its growing period (Yoshida, 1981).

A lysimeter study in the BRRI Farm revealed that total amount of water required for saturation (0-5 mm) treatinent was 1630 mm. It was observed that there was no significant yield difference between 5 cm standing water and saturation condition in the growing period. BRRI (1982) observed that for an irrigation treatment of 5 cm standing water, total amount of water required by Boro rice in 88 days was 169 cm. Average ETc was 6.2 mm and average evaporation was 5.5 mm per day. BRRI (1982) also reported that for a treatment of 5 cm standing water, total amount of water required by Boro rice in 90 days life cycle was 102.4 cm. Average S & P was 5.2 mm per day and ETc was.6.2 mm. per day and average evaporation loss was 4.2 mm/day.

A research was undertaken by BRRI (1983) that the total amount of water required by Boro rice in 114 days in winter season was 174.4 cm maintaining 5.0 cm of standing water in the crop field during the growing period of Boro rice; seepage & percolation and ET were found to be 95.7 cm and 78.7 cm, respectively.

BRRI (1986) reported that irrigation requirement of Boro rice was 1070 mm in treatment of 5-7 cm continuous standing water. A study was conducted by BRR1 (1988) at Amla Farm, G K. Kustia showed that irrigation requirement for Boro rice was 1600 mm for maintaining 5 to 7 cm continuous standing water in the field. Khan (1994) observed that total amount of irrigation water required for high yielding variety (HYV) Boro rice was 987 mm in Mymensingh.

A field experiment by Karim *et al.* (1996) was carried out in a clay terrace soil to assess grain yield, water requirement, and weed control for Boro rice cultivation in Bangladesh to avoid wastage of water without hampering crop yield. Bore was grown in the dry to pre-monsoon seasons of 1992 and 1993 under different irrigation and weeding treatments with recommended applications of fertilizers. Limited irrigation, maintaining a moisture regime between field capacity and saturation, significantly reduced grain yield. However, irrigation leading to standing water showed no significant difference in grain yield, irrespective of the depth of water, and gave grain yields of 4.5-5.0 t/ha. The water requirement for Boro rice was 620-700 mm from transplanting to harvest. Water use efficiency was highest for irrigation with minimum standing water between saturation and 1 cm, or for moisture regime between field capacity and saturation, depending on the intensity of rainfall during the growing season.

Dastane (1974) suggested determination of effective rainfall by an empirical method which is also known as water use — rainfall ratio method. In this method effective rainfall is computed as ratio of potential evapotranspiration plus seepage and percolation to the total rainfall for a certain group of days during the growing period and is expressed in percentage. The number of days in a group is based on soil types, soil moisture properties, and weather conditions. Dastane 1977 used this approach and computed effective rainfall in some projects in India.

Bhuiyan (1981) used effective rainfall as a component in determining irrigation requirement in measuring irrigation system performance. He mentioned that the effective rainfall depended not only on duration, intensity and distribution of rainfall but also on water management practices of the farmers. Therefore, for a given rainfall its effectiveness may vary among the fields in the system. So the best method of determining the effective rainfall is to calculate the value based on field water status and rainfall. To obtain a good representative value of effective rainfall a large number of fields should be monitored but that requires substantial time and resources. The author concluded that among various methods, the water use-rainfall ratio method is less expensive and easy to use but gives reasonable results for some rainfall patterns. The limitations of this method are: (i) it does not consider the fanner's field management practice as a variable in estimating effective rainfall and (ii) it does not consider relative magnitude of rainfall for the group periods in computing the weekly, monthly or seasonal average effective rainfall values. He suggested that the average will be a better value over simple average in computing the weekly, monthly and seasonal effective rainfall.

The use of evaporation data for estimating consumptive use has been regarded as the most convenient and practical method. The effects of solar radiation, temperature, wind, and humidity on the rate of evaporation are integrated when standard evaporation pans are used. In this manner PET is estimated and actual evapotranspiration is determined by multiplying PET by a coefficient specific to a particular type and growth stage of the crop (Doorenbos and Pruitt, 1975)

Giron and Wickham (1976) estimated Evapotranspiration for rice by using the relationship ET = B + A (EV) where, ET is the daily rate of evapotranspiration (mm/day); EV is the daily rate of evaporation (mm/day) measured by class A pan; "a" is the pan factor. From empirical data, they assumed "a" to be 0.8 for the first six weeks of crop growth and 0.9 for the remaining period. In the above equation, "b" is an empirical constant and its values were 0.25 mm/day for the dry season. However, Wickhamn (1974) has concluded that potential ET can be roughly equated with evaporation measured by Class A pan, which assumes that the water used through flooded lowland rice crop is approximately the same as that of flooded bust unplanted rice paddies.

Wickham and Sen (1978) reported a crop factor of nearly unity for flooded rice for estimating ET from class A pan evaporation. Tomar and 0' Toole (1979) suggested that changes in rice plant physiology contribute to the increasing rate of ET as the reproductive growth stage is approached. Sevendsen stated that the real question is not whether ET increases, but whether the ratio of ET to evaporation increases with plant growth. Tomar and O' Toole reviewed about 30 experiments on ET for rice conducted throughout Asia over the last 50-year period and indicated that ET/EV begins at about 1.0 and increases to about 1.3 at the time of flowering. They recommended a pan factor of 1.3 for calculating ET in rice for tropical regions of Asia. Variation in the ET rates for different rice growth stages is controversial. However, these variations are of minor practical, importance for the management of existing irrigation systems as other water losses are much larger than these variations normally account for (Bhuiyan, 1982)

Seepage and percolation (S&P), in addition to ET, generally constitute the unavoidable losses in water application and distribution. These two constitute the most elusive components of the water balance (Wickham, 1971). In most cases there is no easy means of measuring S&P separately, hence they are treated collectively.

The important environmental factors affecting the rate of S&P are depth of water table, density of drainage net work, and topography and size of the rice growing area (Wickham, 1971; Kampen, 1970; Ghani, 1978). Management factors that influence S&P include puddling, soil compaction, and insufficient water supply leading to dried and cracked soil (Kawasaki, 1975; De Datta and Kerim, 1974; Tabbal, 1975). Heavy clay soils greatly retard vertical movement of water, and well puddled soils impede it further. In Bangladesh, it was found that percolation loss on Madhupur clay soil varied from 1,5 to 2.0 mm/day, and in silt loam soil daily seepage and percolation losses varied from 13 to 24 mm/day and 3 to 14 mm/day, respectively (Khan, 1978)

Bhuiyan (1982) reported that seepage — percolation (S&P) are site specific and depend on soil texture, water table depth, proximity to drainage outlet and fanner's field water management status Gham (1978) reported that in addition to the above factors seepage percolation at the field level are also affected by puddling and standing water depth status 'of the rice fields and the crop growth stages.

Walker and Rushton (1986) mentioned that field efficiencies for irrigated rice crops are often low. Field studies on seven sites in Indonesia showed that the rice crop used only about one-third of all water delivered to the fields. Under continuous flow field, water use efficiency was found to be 25-30%. Ghani *et al.* (1990) reported that field water use efficiency varied from 36% to 69% in Aus season in large scale irrigation project. These low efficiencies are due to excessive losses of water from rice fields as seepage and percolation. Ritu and Mondal (2002) conducted studies on the of various standing water depths on seepage and percolation (S & P) rate from the rice fields and observed that S & P increases with the increase of water depth in rice field. The depth of irrigation water varied from 2.5 cm to 12.0 cm with an increment of 0.5 cm and the S & P rate varied from 5 mm/day to 17.5 mm/day.

Bangladesh Rice Research Institute (BRRI, 1986) conducted experiments with four different irrigation interval- continuous standing water, 10 days interval, 15 days interval and 20 days interval to determine the most suitable one for rice irrigation in late Boro season and found that the 10 days irrigation interval is the best with respect of yield and water requirement. But the yield did not significantly differ from continuous standing water condition. The yields against the four different treatments were 7.37 t/ha, 7.50 t/ha, 5.98 t/ha and 5.78 t/ha respectively and the irrigation water requirement were 530 mm, 442 mm, 338 mm and 201 mm respectively in addition to 496 mm of rainfall.

The methodology followed by BRRI (1986) to determine the suitable irrigation interval was conceptually correct and practically acceptable for the farmer’s fields but the interval 5 days among the treatments seems too long. It was reported that 10 days irrigation interval was the best over 5 days or 15 days interval but what would have been the results for 7 days or 12 days interval are not known. So, it would have been better if the gap of interval were maximum 3 days. The yield of 5.78 t/ha for 20 days interval with only 697 mm of water in Boro season seems to be very high in respect of water requirements. Actually the crop was in late Boro season which may be called early Aus season and received enough rainfall. It may happen that as the rainfall was 496 mm, which is quite high in Boro season, may help to maintain available water during the whole growing period and that is why there is no significant difference in yield among the treatments.

Another study (BRRI 1990) on minimum water application for optimum yield of rice conducted in Gazipur area concluded that continuous standing water in rice field is not necessary for optimum yield. Moreover, without sacrificing yield, about 28, 12 and 23 percent of valuable irrigation water can be saved over continuous standing water by practicing saturation level, 7 days irrigation interval and 10 days irrigation interval, respectively.

This study reported that 23% of valuable water was saved in the treatment of 10 days irrigation interval without sacrificing yield. From this study it is not clear whether it is not possible to get the same yield with higher interval than 10 days. So, it would have been “better if the results for longer interval were known. It is also important to know the number of days without standing water (Number of dry days) in the plot in between each irrigation for each treatment, as these dry days are mainly responsible for yield reduction in the longer irrigation interval. But this information is lacking in the above study.

Some reviews showed that (Khair and Hussain; 1978 and Khair *et al.,* 1980) about one-fourth to one —third of all water diverted for irrigation purpose at various places in Bangladesh is lost in conveyance through the unlined earthen channel where seepage accounts to high rates due to various socio-technical reasons. Similarly, Miah (1984) found that losses in the earthen channels of Bangladesh minor irrigation projects are mostly due to seepage through porous banks and some leakage through poorly sealed outlets. Nevertheless, these studies (Khair and Hussain, 1978; Khair *et al.,* 1980) could not decipher the effect of soil types nor the information could relate the degree of compaction in terms of different levels of bulk density or porosity and even with the depth of flow in the channels that been emphasized by numerous investigators (Sattar 1983).

Biswas (1987) conducted an experiment to determine the water loss in 100 m canal made of different soil types and reported that the conveyance losses were 5 to 12 % with an average value of 9% for loamy. Soil, 3 to 8% with an average value of 6% for silty soil and 2 to 6% with an average value of 4% of clay soil.

A study (Rashid *et al.,* 1987) carried out in five places of Bangladesh indicates wider variations of the conveyance loss even within the same soil texture. The reasons behind these variations were not specified and no correlation of losses with the variables were made. Even the channel condition remains vague and undefined while determining such conveyance loss. However, a collaborative research (Rashid *et al.,* 1991) has some indication about the compaction of the earthen channel that could reduce the conveyance losses by about 34- percent, but the author failed to mention the range of compaction or the level of moisture content at which the channel subgrades were compacted.

Babel *et al.* (1990) conducted a laboratory experiment to study the relationship for hydraulic parameters viz, pressure head, discharge and physical characteristics, i.e. diameter and length of microtubings, which are used as emitters, connectors and pressure regulators in drip irrigation system. It was observed that the discharge through microtubings increased with the increase in diameter but decreased with increase in length. There effects were more prominent at higher pressure heads. The flow through microtubings was classified as laminar, transition zone and turbulent, based on the Reynolds number. They concluded that the general flow equations developed in pipe hydraulics are also applicable to microtubings. Hagen-Poiseuille and Blasius and empirical equations for friction coefficient, given for large size pipes were also verified for their application to mcrotubings. These equations can be used with reasonable accuracy in the Darcy-Weisbach equation for calculation of frictional head-loss in microtubings in laminar and turbulent flow conditions respectively

Mitsuno (1991) discussed that with pumped pipe irrigation supply, water can be used at low energy levels but is not possible in open channel system. The system enables water to be used at high efficiency and makes rational water control and management possible. They also discussed how friction and system losses can be reduced and considers the most effective use of energy.

Bentum *et al.* (1995) described the use of buried pipe systems and flexible surface hose pipe in Hebei Province, China and their contributions to improve water use and increased management flexibility. The average area served by a buried pipe system is 4 to 5 ha. A substantial increase in irrigation command areas has resulted from the adaptation of existing buried pipe systems use to distribute irrigation supplies from the outlet. New developments use a buried pipedirectly connected to a tubewell pump or to larger buried pipe systems, in many cases facilitating the conjunctive use of water from several sources. The distinctive features of system design, construction and operation are described, along with capital cost estimates and an outline of benefits, which include flexibility to grow small areas of high-value crops. They also mentioned that on small buried pipe systems on the ground surface to replace lined channels. These extend the benefits of buried pipe irrigation system beyond the outlet and offer an alternative to the higher capital investment required for more extensive permanent buried pipe installations.

BRRI (1998) reported that about 100% conveyance loss reduced by using buried pipe. They also reported that irrigation timing was reduced by about 50% in comparison with lined channel irrigation systems at Rajshahi and Chuadanga. BRRI (1999) also reported that irrigation coverage increase about 42 percent after introducing the PVC and plastic pipe distribution system in a DTW.

A study has been undertaken by Muniruzzaman (1999) to evaluate the performance of the newly introduced buried pipe method of water distribution systems in Bangladesh. But a very few references have been found at home and abroad in relation to pipe irrigation systems. Muniruzzaman (1999) evaluated the technical and economic performance of buried pipe method of water distribution system at Sherpur district. There were significant variations in the water losses from scheme to scheme. These varied from 5.70 l/s/l00m to 6.72 1/s/100m, averaging 6.08 l/s/100m of channel length, whereas, the water losses from buried pipe varied from 0.14 l/s/100m to 0.42 1/s/100m with an average of 0.29 l/s/100m. Land occupied by lined channel before buried used was 0.8 to 2 percent (260 to 600m^2) and after buried pipe used was 0.04 to 0.13 percent (20 to 60 m^2) of the total command area. The land saved by buried pipe was 0.76 to 1.87 percent (240 to 540m^2) of the command area. It was found that about 47 to 55 percent time was saved by using buried pipe compared to lined channel and consequently saved the labour and increased the command area of about 40 to 50 percent. Irrigation water is uniformly distributed by using buried pipe and in case of shortage of irrigation water light irrigation supply is possible. The economic performance of supplemental irrigation by using buried pipe for T. Aman cultivation with irrigated condition is highly profitable. The BCR ranged from 1.33 to 5.18 for Boro 1.75 to 2.36 for T. Aman crops.

CHAPTER III

MATERIAL AND METHODS

3.1 Description of the Study Area

The study area lies in the vicinity of Thakurgaon sadar thana and is situated approximately at latitude and longitude 26.0803° N, 88.4404° E. (Fig 3.1).

3.2 Site Selection

The study was conducted during the period 2016-2017 Boro seasons, 2017-2018 T. Aman. Two deep tubewells (DTWs) were selected from Salendhar and one deep tubewell were selected from Jaganathpur unions of Thakurgaon Sadar thana to analyse the soil properties. Besides, three deep tubewells from the above mentioned sites were selected to evaluate the present status of technical performance of on-farm water management and to assess the impact of irrigation by using DTWs with lined channel and buried pipe method of water distribution systems.

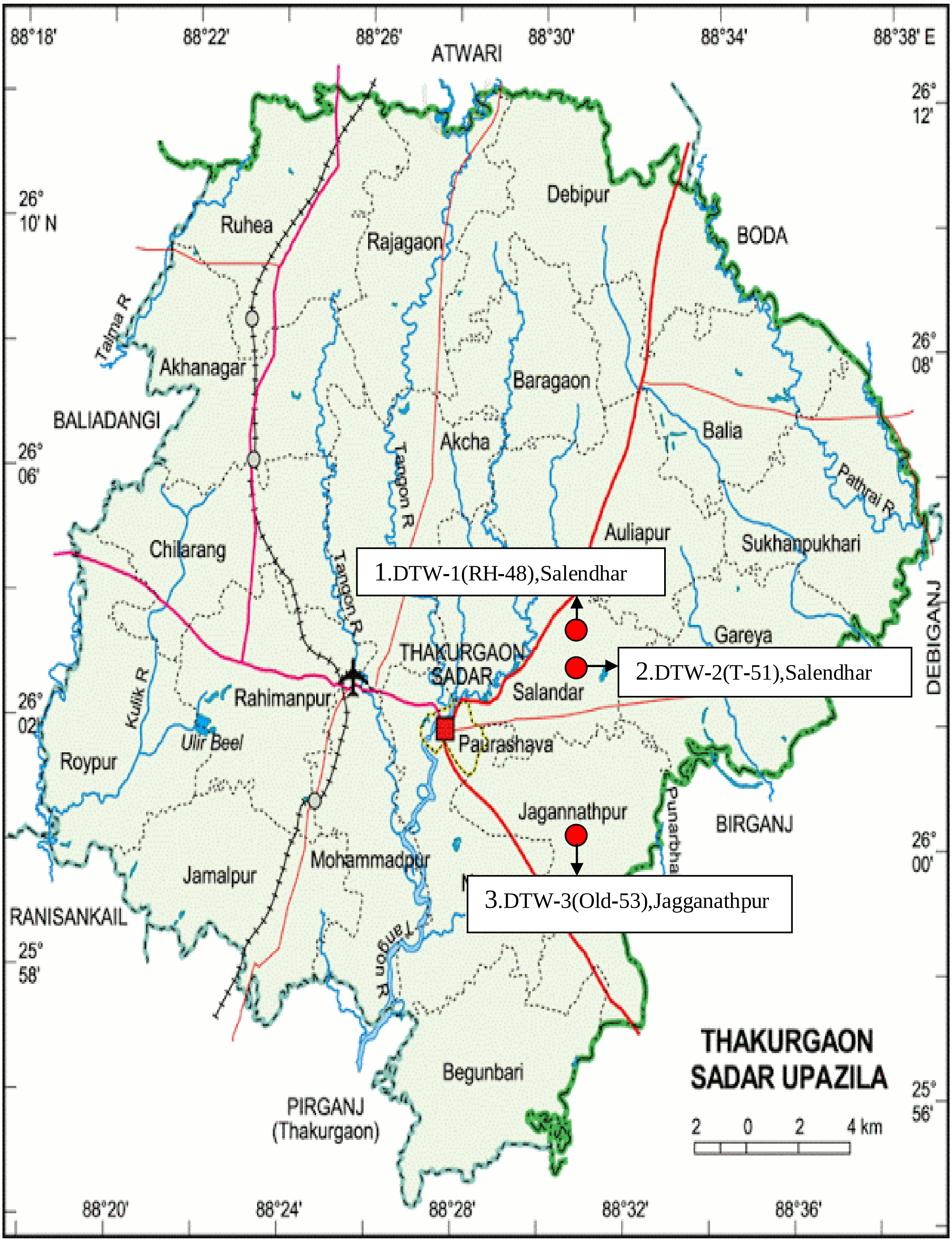

Figure 3.1: Location map of the study area.

3.3 Present Status of Water Management Practices and Identification of Constraints for Rice based Cropping System in Thakurgaon

(a) Sampling technique and sample size

There were 643 deep tubewells in Thakurgaon district during 2017-2018 Boro seasons. To fulfill the objectives of the study with minimum expenditure and time, 3 deep tubewells were selected randomly. The advantage of random sampling are: (a) convenient to draw and to execute; (b) spread the sample more evenly over the listed population and compare favorably in precision with stratified random sampling (Cochran, 1977).

(b) Methods

Mostly primary data was used for this study. Primary data was collected by carrying out field survey using pre-designed questionnaire from December 2017 to January, 2018. The generated survey data covered three major aspects: Socio-Economic Status, Crops and Agronomy, Irrigation and Water management practices and constraints.

3.4 Power requirement of prime mover (pump/motor)

Power requirement of the prime mover assuming overall efficiency of 60 % of the Pump and the efficiency of electric motor and drive as 70% (Raghunath, 1987).

$$P = \frac{\rho g Q H}{n_p n_m} \text{ -------------- hp (3.1)}$$

Where, ρ = 1000, g =9.81 m/see, Q = discharge of the pump, m^3/sec, H = suction head in m.

3.5 Computation of potential command areas for DTW projects

3.5.1 Crop water requirement of rice and potential command area

The peak water requirement of rice occure in April which is 4.8 mm/day in the study area (IWM 2005). Dependable rainfall is ignored due to short irrigation interval. The seepage and percolation losses in medium low and medium high land for Thakurgaon area was found from present study to be 11.0mm/day.

The design daily crop water requirement=peak water requirement X crop factor+S&P loss………(3.2)

Where, crop factor=1.25

Potential command area: A design discharge for deep tubewell 2 cusec and operating hr 8,10,12 hr/day.

3.6 Tubewell selection criteria

The study was conducted in 2016-2017 Boro seasons, 2017-2018 T. Aman seasons with selected deep tubewells (DTWs) at three selected locations of Thakurgaon sadar thana. One DSTWs were selected in each location. So, one DTWs in three locations of Thakurgaon sadar thana were selected to evaluate the present status of technical performance on on-farm water management.

Again three DTWs were selected to assess the impact of irrigation by using DTWs with lined channel and buried pipe method of water distribution system. Three DTWs were also selected for comparative study in different water distribution systems.

3.6.1 Measurement and computation of technical parameters.

Three pumps in three locations were selected for the study. Technical information of pump, motor and tubewell was recorded from field visits. DTW discharge, field channel length, operating hours, and electricity requirement were measured or obtained from the available record. The make an investigation of DTW, HP, pre-paid meter, avometer, static rod, pre-paid card and delivery pipe diameters and outlet pipe of the pumps were also measured and collected from the BMDA. The static water level of the DTWs were also measured using static rod. Existing deep tubewells irrigation practices and management principles were also recorded.

3.6.2 Deep Tubewell discharge measurement

Three DTWs in three locations were selected. There are a good number of water measuring devices available that can be used to measure the well discharges not directly from the well but from the irrigation channels and ditches served by the wells. These devices are mainly weirs, notches, orifices, flumes etc. There are a few methods of measuring discharges directly from irrigation wells. In this study piezometric height was used for DTW discharge measurement which was measured by BMDA.

3.7 Information related to tubewells used in the study area

The farmers in the study areas was using DTWs of various model. The common type of pump and motor made of China and India were used by the authority.

The DTWs were equipped with 20-30 HP motor, discharge capacity 2.00 cusec. The indicator switch indicates the head 24.38-45.72m (80 ft-150ft). Pre-paid meter was used to operate the pump with pre-paid card. The static rod was used to measured the static water level by Avometer or Multimeter after submersed the rod into water near the pump and the static water level was measured 18ft 11 inch (Figure 3.2).

Pump

Indicator switch and pre-paid meter

Avometer or multimeter

Static rod

Figure 3.2: Pump, Indicator switch, Avometer, Static water level

The pre-paid card was used to operate the pump to scratch the card into the pre-paid meter. The diameter of the head tank was 1m and the height was 12 ft (3.66m) which was help to lift water 14 ft high from the normal surface of the land it was help to reduced friction loss, land undulation and maintain the head. The diameter of the delivery pipe, pump delivery pipe dia. 5 inch, first delivery pipe dia.6 inch, second delivery pipe dia.8 inch and the out let pipe dia. 10 inch which was delivered water to the lined channel or to the field (Figure 3.3).

Pre-paid card

Head tank

Delivery pipe

Outlet pipe

Figure 3.3: Pre-paid card, head tank, delivery pipe, outlet pipe

The air vent pipe diameter 10 inch (250 mm) which release the air from the underline pipe to maintain the pressure (Figure 3.4).

Air vent pipe

Figure 3.4: Air vent pipe

3.8 Technical information of buried pipe

3.8.1 Buried pipe selection

On the basis of cost, durability, pipe thickness, ease of operation and maintenance of a pipe can be selected.

3.8.2 Pipe length selection

In this experiment two different lengths of pipe of similar diameter (250 mm) were used. The pipe length were 100 and 125 m. These pipes are generally used by the farmer in the selected project areas for water conveyance and their performances related to the ease of operation, labour requirement, area coverage and time saved were observed. On the basis of these criteria the required length was chosen.

3.8.3 Land occupied by lined channels

Length and width of lined channels and field channels were identified and measured in consultation with the scheme manager and pump operator. The same parameter for the field channels under buried pipe distribution system were also measured in the fields.

3.8.4 Economic Performance of major Crops

There are various methods to calculate profit from a crop. In this study, the fixed cost such as rent, taxes and interest on value of land have not been added in the cost, only the Variable costs, are taken in this calculation. The cost of human labour, animal power, seeds, manure, fertilizer, pesticides, irrigation cost and interest on operating capital have been taken in the calculation of cost and yield of main product and by-product have been added in the calculation of gross return Cost data were collected from the field as well as from other sources, such as DAE office, project managers and the local markets.

3.8.4.1 Benefit-Cost Ratio (BCR)

Benefit-Cost Ratio (BCR) has been calculated by dividing the benefit by the cost.

3.9 Economic Performance of Buried pipe system

Benefit- cost ratio is widely used to justify the economic viability of an irrigation project. In this study, the ratio was calculated from the selected schemes by dividing the incremental benefit of buried pipe systems over that of lined channel system by their incremental cost.

BCR = Incremental benefit/ Incremental cost ……………….. (3.3)

3.9.1 Cost

The annual cost of the buried pipe system includes the fixed cost and annual operation and maintenance cost. The fixed cost was obtained from the depreciation and the interest on investment for deep tubewell, buried pipe and lined channel systems. The depreciation was calculated using the following equation (Michael, 1981).

$D=(P-S)/L$ ---------- (3.4)

Where D = depreciation, Tk/year

P = initial cost of the system, Tk.

S = salvage value, Tk.

L = life of the system, year

The initial costs of deep tubewell, buried pipe line and lined channels were obtained from the either pump or scheme managers. The salvage value was considered higher for buried pipe and earthen channel system and 10 percent of deep tubewell purchase price (Singh, 1977). The life of a DTW is considered 20 years with buried pipe line and 10 years with lined channel system and those of buried pipe and lined channels are taken as one year and 50 year (Ahammed, 1984 and Gisselquist, 1989) respectively. The interest on investment was calculated by the following equation (Singh, 1977):

$$I=\{(P-S)/2\}\ i \quad \text{-----------} \ (3.5)$$

where, I= interest on investment, Tk/year

P = initial cost of the system. Tk.

S = salvage value, Tk

i = bank interest rate, 16 percent year.

3.9.2 Benefit

The benefits of the buried pipes were calculated from the additional area that could be irrigated by using the water saved per hectare. The net return per hectare was obtained as the difference of the gross return and the production cost.

Thus, knowing the incremental benefit and the incremental cost, the system benefit cost ratio of the buried pipe method of water distribution system was obtained from equation 3.3.

3.10 Comparative Study for different Water Distribution Systems at DTW Irrigation Project

This study was undertaken to compare the conveyance loss, command area and cost effectiveness of different distribution systems. This study was carried out in Boro season, 2017-2018 at three selected DTWs, Thakurgaon. At least 30m improved lined channel was prepared at DTW site. The following types of conveyance system were used in the Project areas to evaluate the conveyance losses.

TEC = Earthen channel (lined channel)

TLC = Improved lined channel (compacted and constructed with design dimension)

TBP = Buried pipe (25 cm diameter line system)

Actual discharges of the DTWs were measured in 15 days interval during the whole irrigation season by piezometric height. Conveyance losses in the ordinary lined channel, improved lined channel and buried pipe were measured by inflow-outflow method. In this method for ordinary lined channel and improved lined channel, two standard V-notch were used. Before connecting the buried pipe the pump discharge was measured by V-notch. After connecting the buried pipe with the pump inlet, the discharge at the outlet of the buried pipe was measure the outlet discharge by a piezometric height. The differences of these discharges were taken as losses for buried pipe.

3.11. Water Requirement of Boro Rice and T. Aman cultivation under DTW irrigation projects in Thakurgaon

This study was undertaken to determine water use efficiency for different water regimes, number of irrigation and amount of water needed to achieve optimum yield. This study was carried out in medium low land during boro season and T. Aman of 2016-2017 and 2017-2018 at one selected DTW, Thakurgaon. Experiment was conducted with the following four treatments

T_1 = continuous standing water, 7 cm;

T_2 = Irrigation with a depth of 7 cm after 3 days of disappearing of standing water;

T_3 = Irrigation with a depth of 7 cm after 5 days of disappearing of standing water;

T_4 = Irrigation with a depth of 7 cm after 7 days of disappearing of standing water.

Treatments were replicated three times with Boro rice and T. Aman. Randomized Complete Block Design (RCBD) was used in this experiment. Forty five days old seedling was used and planted with a spacing of 20 cm×l5 cm. The fertilizer was applied at the rate of 270, 130, 120, 70, 10 kg/ha of Urea, Triple super phosphate, Murate of Potash, Gypsum and Zinc sulphate respectively. The applied irrigation water was measured. Rainfall was measured in the experimental site with a rain gauge. A spacing of 1 meter was maintained in between two adjacent treatment plots to avoid the interference of water from one treatment to another. Experiment was conducted within a farmer’s managed DTW project in Thakurgaon.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Performance measurement of farmers managed irrigation system

To study the existing irrigation and water management practices and constraints to the use of deep tubewell's water by the farmers, a sample of 3 deep tubewell from Thakurgaon, 150 farmers were selected. Primary data was collected by carrying out field survey from December 2017 and January 2018.

4.2 Cultivable land and area under irrigation

Average cultivable area (ha) was 1.58 in Thakurgaon Sadar Thana respectively (Table 4.1). Average irrigated area (ha) of Boro and T. Aman crops were 2.96 and 1.33 for Thakurgaon Sadar thana under three DTWs, (Table 4.1).

Table 4.1. Average cultivated and irrigated areas (ha) of farmers using Deep tubewell, Thakurgaon, 2017-2018.

No. of DTWs	Average cultivable area per DTW (ha)	Average Irrigated area(ha)	
		T. Aman	Boro
DTW-1 (Rh-48)	0.56	1.05	0.44
DTW-2 (T-51)	0.52	1.00	0.42
DTW-3 (Old-53)	0.50	0.91	0.47
Average	1.58	2.96	1.33

Total irrigation area under DTWs in Thakurgaon was 68375 ha. The cultivable areas (ha) of Thakurgaon sadar was 55110 respectively. Tottal no of deep tubewells were operated respectively 643 during 2017-2018 T. Aman and Boro season in Thakurgaon (Table 4.2).

Table 4.2. Irrigation coverage in T. Aman and Boro season of 2017-2018 by DTW irrigation (BMDA, 2017-2018).

Area(ha)		Mode of irrigation	Crop wise irrigation coverage
Total area	Cultivable area	DTW	Rice
(ha)	(ha)	(nos.)	(ha)
68375	55110	643	23230

4.3 Crops grown in DTW irrigation Project area

Different crops such as T. Aman, Boro, Wheat, Potato, Vegetables and Maize were grown in the study area. About hundred percent farmers of Thakurgaon sadar thana grow T. Aman and Boro rice (Figure 4.1). From these, figures it appears that potato and maize cultivation was increased at Thakurgaon sadar thana (Appendix 1).

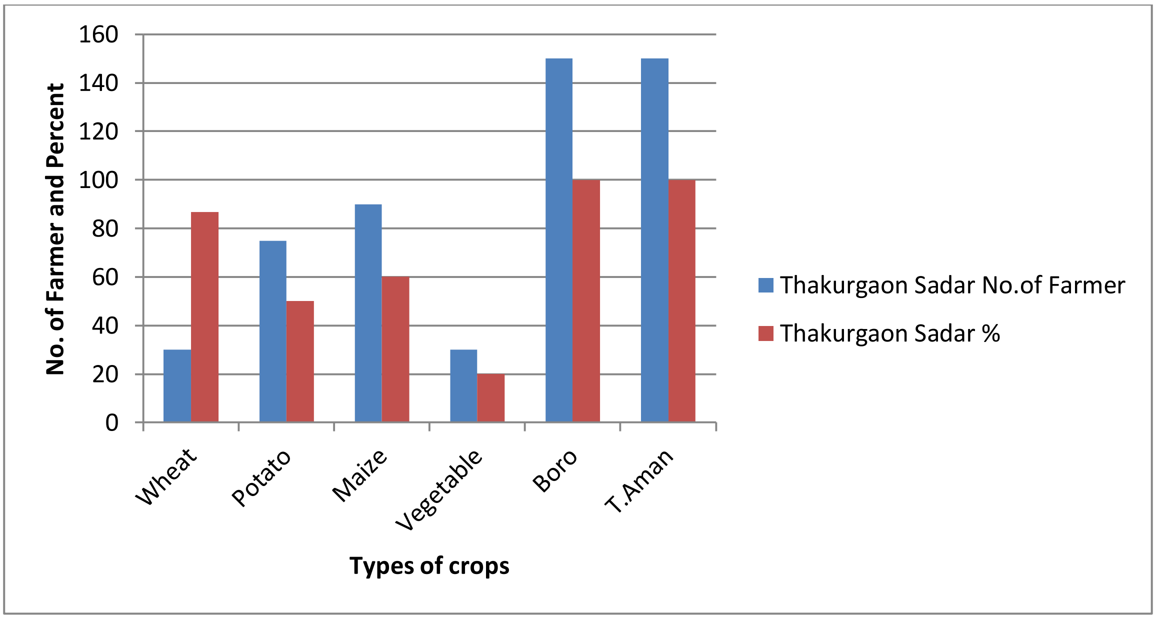

Figure 4.1: Types of crop grown by the farmers in DTW area in Thakurgon, 2017-2018.

4.4 Land type used for growing T. Aman and Boro rice

T. Aman and Boro rice

Farmers used different types of land such as high, medium, and low for growing rice and non rice crops in the study area. According to FAO (1988) High, Medium and Low land classified as follows: High lands are above normal flood level, although sometimes flooded within the fields by rain water. Medium high land becomes shallowly flooded (30—90 cm) during the spell of heavy monsoon rainfall for a period of 30 to 80 days and Low land is flooded up to between 90 — 180 cm during the flood season Forty nine percent farmers of Thakugraon sadar grow T. Aman rice in high and medium land (Appendix 2). It shows that most of the farmers of the study area cultivate T. Aman rice in high and medium land. About eighty seven percent farmers of Thakurgaon Sadar grow boro rice either in medium, both medium and low land (Appendix 2). Most of the farmers of the study area grow Boro rice either in medium or both medium and low lands.

4.5 Area under T. Aman and Boro rice

T. Aman and Boro rice

Areas (ha) used for T. Aman crops were 2.96 respectively for Thakurgaon sadar thana under three deep tubewells (Table 4.1). Similarly mean areas (ha) for Boro rice were 1.33 respectively for Thakurgaor sadar in selected 3 deep tubewells area.

4.6 Potential command area for Boro rice and T. Aman in DTW project area

Potential command area was calculated by using methods described in Chapter 3. Actual command area (ha) for DTW-1, DTW-2 and DTW-3 were 24, 25 and 24 for boro rice and T. Aman in DTW project area in Thakurgaon sadar thana. Considering the designed discharge, it was possible to increase the daily operating hours. The farmers in Thakurgaon area was found to operate the pumps for the period of 8, 10 and 12 hrs/day than the potential command area was double than the present situation (Appendix 3).

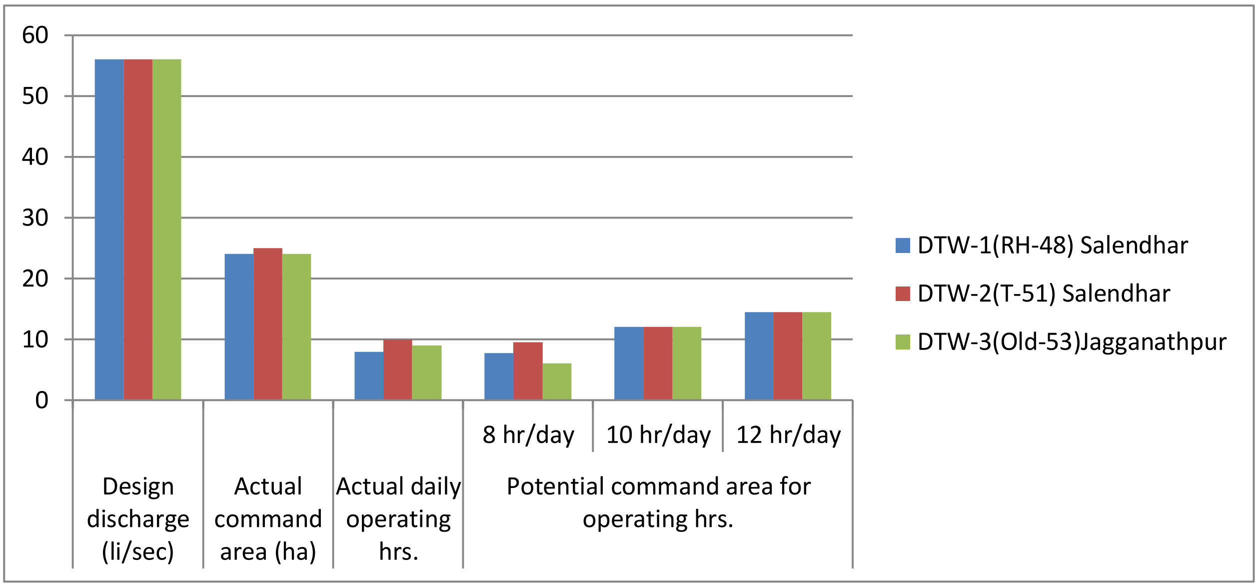

Figure 4.2: Actual and Potential command area for Boro and T. Aman rice in Thakurgaon area.

4.7 Technical Information related to Water Distribution System in the Deep Tubewell Project areas

Average horse power of the pump in the selected DTWs of Thakurgaon sadar were 30, 20 and 20 respectively.

Hundred percent of farmers of Thakurgaon sadar thana used underline pipeline as a distribution system. About hundred percent selected farmers of Thakurgaon Sadar thana opined that they received enough water from the respective DTW for T. Aman and Boro rice. It showed that the selected DTWs of Thakurgaon were in very good condition. Average maximum depth of groundwater table during dry period in Thakurgaon sadar thana was 5.29 m. It showed that peak depth of ground water table was within the suction limit of DTW.

4.8 Power requirement of motor to operate the Pumps in the field

Average horse power of the motor to operate the pumps in the selected three DTWs of Thakurgaon sadar were 30, 20 and 20 respectively (Table 4.3). Actual horse power required by the motor to operate the pump for deep tubewell having discharge of 2 cusec (0.056m^3/sec or 56 l/sec).

Table 4.3 Actual Horse Power required by motor to operate the Pump for same discharges.

DTWs	Discharge Q (m^3/sec)	Head H (m)	Horse power of Pump
DTW-1 (RH-48)	0.056	24.38	30
DTW-2 (T-51)	0.056	27.43	20
DTW-3 (Old-53)	0.056	45.72	20

4.9 Farmer's Views about Uses of UPVC pipe

Most of the farmers of Thakurgaon sadar reported that the prices of UPVC pipes respectively varied from Tk/m. 30 - Tk. 40.0. Most of the farmers of Thakurgaon sadar thana informed that life of UPVC pipe range from 30-40 years. Most of the farmers using UPVC pipe indicated several advantages related to the use of UPVC pipes. The advantages of using UPVC pipe were (i) no conveyance loss (ii) easy to irrigate high land. (iii) quick water distribution (iv) no maintenance cost (v) 100% efficiency (vi) land can not be waste . Most of the farmers provided some suggestions about the successful use of UPVC pipes which are (i) Field demonstrations on UPVC pipe use is needed (ii) UPVC pipe should be made easily available in the market. Maximum number of pumps also indicated specific advantage of UPVC pipe which are (i) no conveyance loss (ii) easy to irrigate high land/undulated land (iii) can be easily handled (Appendix 4).

4.10 Benefit Cost ratio for T. Aman and Boro rice

An undiscounted benefit cost ratio (BCR) is a relative measure, which is used to compare benefits per incremental unit cost. It is the ratio of gross returns and gross costs. It appears from the Figure4.3 average BCR of Thakurgaon sadar thana for T. Aman are 2.55. On the other hand, the average BCR of Thakurgaon sadar thana for Boro 1.19 (Appendix 5).

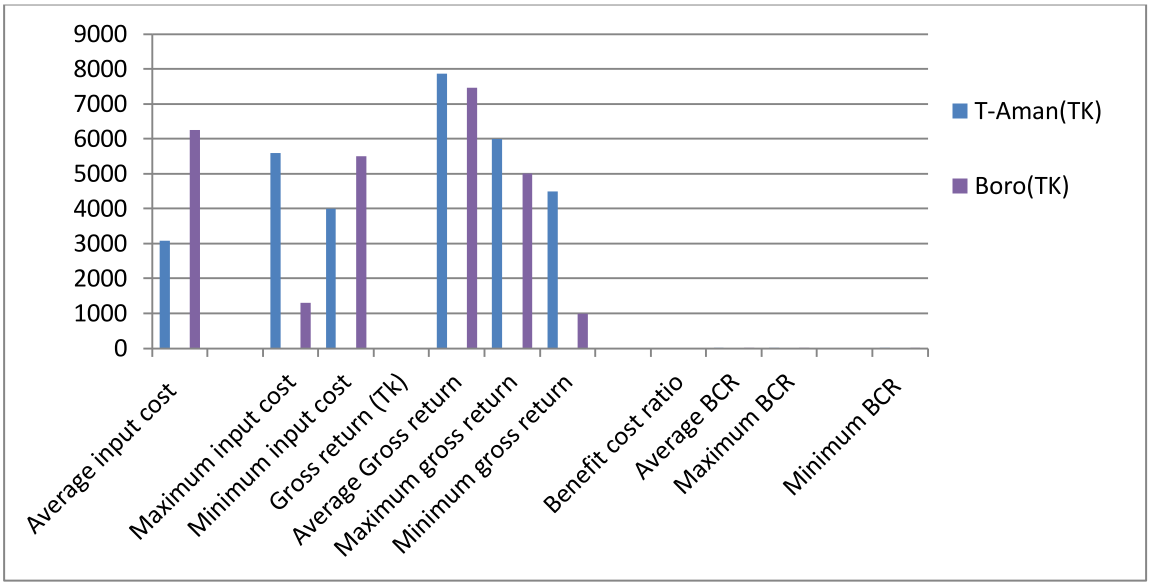

Figure 4.3: Benefit cost ratio for T. Aman and Boro rice of farmer's using deep tubewell, Thakurgaon sadar thana, 2016-2017

4.11 Incremental benefit from buried Pipe line irrigation system

The incremental benefit of buried pipe line irrigation system obtained by multiplying the irrigated area into the difference between the net benefit for irrigated condition and non irrigated condition (Table 4.4). The incremental benefit was too high due to DTW Buried pipe line irrigation system.

Table 4.4. Incremental benefit from buried pipe line irrigation system

Irrigation Wells	Irrigated area (ha) by buried pipe	Net benefit per ha (Tk) for irrigated Condition		Net benefit per ha (Tk) for non irrigated condition		Total Incremental benefit (Tk)
		Boro	T. Aman	Boro	T. Aman	
(a)	(b)	(c)	(d)	(e)	(f)	g =b{(c-e)+(d-f)}
DTW-1 (RH-42)	0.75	12737	4399	0.0	3931	9903.75
DTW-2 (T-51)	0.50	14405	4399	0.0	3931	7436.50
DTW-3 (OLD-53)	0.50	16389	4399	0.0	3931	8428.50

4.12 Conveyance loss

There was no conveyance loss in case of BMDA buried pipe line distribution system.

4.12.1 Comparative Study for different Water Distribution systems at DTW Irrigation Project, Thakurgaon

Conveyance losses for different water distribution systems are shown in Table 4.5 at Thakurgaon. Conveyance loss was measured three times for three DTWs. Conveyance losses varied from 19.25 to 22.44 l/s/100m and average loss 20.67 l/s/100m for earthen channel which was 34 to 40% of the actual DTW discharge and average was 37% of the actual discharge of DTW; for improved lined channel it varied from 16.67 to 18.97 l/s/100m which was 30 to 34% of the DTW discharge and average loss was calculated 18.14 l/s/100m which was 31% of DTW discharge. For buried pipe line it varied from 0.26 to 0.30 l/s/100m, which was only 0.46 to 0.54 % of the DTW discharge and average loss was 0.28l/s/100m which was 0.49% of DTW discharge. So, that the conveyance loss for buried pipe line was too lower than the other two distribution system.

Table 4.5 Conveyance losses for different water distribution systems in Thakurgaon, 2017-2018.

Irrigation Wells	Actual DTW Discharge	Conveyance loss					
		Earthen channel (ordinary) T_{EC}		Improved lined Channel (compacted) T_{LC}		Buried pipe line (25 cm diameter line system) T_{BP}	
	(l/s)	l/s/100m	%	l/s/100m	%	l/s/100m	%
DTW-1 (RH-48)	56	20.32	36	16.77	30	0.27	0.48
DTW-2 (T-51)	56	19.25	34	16.67	30	0.30	0.54
DTW-3 (OLD-53)	56	22.44	40	18.97	34	0.26	0.46
Average	56	20.67	37	18.14	31	0.28	0.49

The conveyance water saved by improved lined channel and buried pipe line over that of the ordinary earthen channel was 13 to 18% and 98 to 99%, and the average was calculated 17% and 99% respectively (Table 4.6). In buried pipe line the conveyance water saved more than the other two system. Water travel time was measured for each distribution system and time saved due to introduction of buried pipe distribution systems was calculated. Average conveyance time was 16.3, 8.4 and 3.1 min/l00 m for farmer's earthen channel, improved lined channel and buried pipe line respectively. The average conveyance time saved due to use of buried pipe and improved lined channel are respectively around 80-82% and 49-51 % and average 81% and 49% in respect to that of ordinary typical earthen channel (Table 4.7).

Table 4.6 Savings of conveyance time and Water losses due to improved lined channel and buried pipe over the ordinary earthen channel, Thakurgaon, 2017-2018.

Irrigation Wells	Actual DTW Discharge (l/s)	Conveyance loss (l/s/100 m)			% water saved over earthen channel by	
		Earthen Channel T_{EC}	Improved lined channel T_{LC}	Buried pipe line T_{BP}	Improved lined channel	Buried pipe line
DTW-1 (RH-48)	56	20.32	16.77	0.27	18	99
DTW-2 (T-51)	56	19.25	16.67	0.30	13	98
DTW-3 (OLD-53)	56	22.44	18.97	0.26	16	99
Average	56	20.67	18.14	0.28	17	99

Table 4.7 Savings of Water travel time due to introduction of improved lined channel and buried pipe over the ordinary earthen channel, Thakurgaon, 2017-2018.

[Irrigation Wells	Water travel time (min/l00m)			% Water travel time saved by	
	Earthen channel T1	Improved lined channel T2	Buried pipe line T3	Improved lined channel	Buried pipe line
DTW-1 (RH-48)	16.8	8.6	3.3	49	80
DTW-2 (T-51)	15.9	7.8	3.1	51	81
DTW-3 (OLD-53)	16.8	8.8	2.9	46	82
Average	16.3	8.4	3.1	49	81

Table 4.8. Irrigation time at a different types of channel

Irrigation Wells	Irrigation time (hr/ha)			% time saved over earthen channel by	
	Earthen channel T1	Improved lined channel T2	Buried pipe line T3	Improved lined channel	Buried pipe line
DTW-1 (RH-48)	22.73	16.13	8.92	29	61
DTW-2 (T=51)	19.23	14.49	8.46	25	56
DTW-3 (OLD-53)	21.74	15.63	8.87	28	59
Average	21.23	15.42	8.75	27	59

For Thakurgaon DTWs site, time required for irrigation coverage varied from 19.23 to 22.73 hr/ha and average 21.23hr/ha for typical earthen channel but for improved lined channel that varied from 14.49 to 16.13 hr/ha, average was 15.42 hr/ha and for buried pipe line distribution system, time for irrigation coverage was 8.46 to 8.92 hr/ha and average was 8.75 hr/ha (Table 4.8). Buried pipe line System was save more water and time than the other two system.

4.13 Water Requirement of Boro Rice and T. Aman Cultivation under DTW in irrigation projects Takurgaon

The study was undertaken to determine optimum water requirement for Boro rice and T. Aman. The study was conducted with four different irrigation treatments as described in section 3.9.

4.13.1 Water use and Water productivity

The amount of water required for growing period during 2017 and 2018 under different treatments presented in Figure 4.4 and 4.5. In 2017, 800,770,600 and 630 mm irrigation water together with 246 mm rain water were used in treatment T1, T2, T3 and T4 respectively for T. Aman. In 2018, rainfall was 0.0 mm during the Boro growing season. In addition to this rainfall 800, 750, 700 and 560mm irrigation water were used for boro rice. Water productivity for the treatments T1, T2, T3 and T4 were found to be 4.80,6.21,6.75 and 5.51 kg/ha-mm respectively during the year 2017 for T. Aman and in 2018, the productivity were found to be 8.01,8.23, 8.01 and 8.77 kg/ha-mm respectively for T. Aman for the above treatments. Maximum Water productivity of 6.75 kg/ha-mm was observed for treatment T3 and 8.77 kg/ha-mm for treatment T4 during 2017 and 2018 (Appendix 6 and 7).

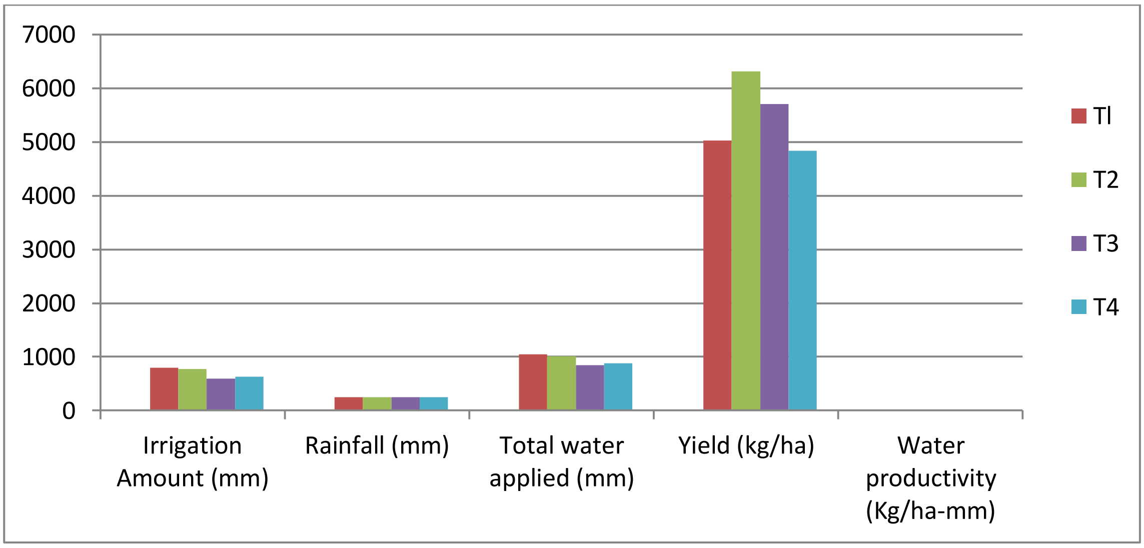

Figure 4.4. Effect of different water treatments on the yield of T. Aman, Thakurgaon, 2017

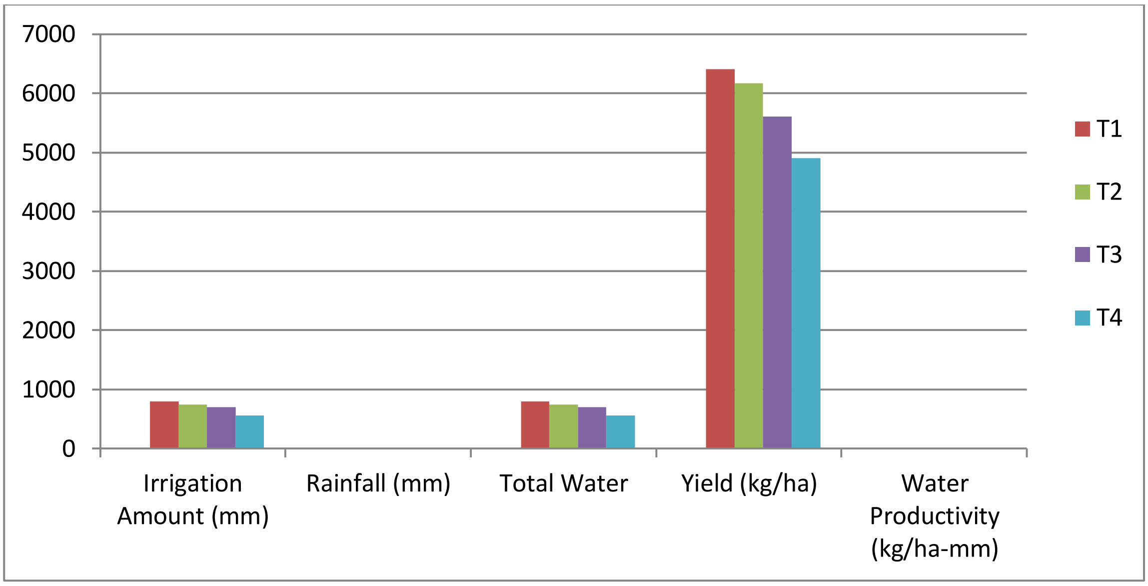

Figure 4.5. Effect of different water treatments on the yield of Boro, Thakurgaon, Boro season, 2018

4.14 Crop Production Problems for Irrigated rice crops

Two basic factors are applicable to the objective of increasing crop production. One is the crop area increment and the other one is per hectare yield increment. The critical factor for yield increase per unit land area include availability of adequate water, HYV seeds, fertilizer, disease and insect controlling chemicals and also a favorable market.

The average yield of T. Aman as mentioned by the farmer's was less than 3.0 t/ha (rainfed condition). The Average yield of T. Aman with 1 or 2 supplemental irrigations was 4.5 t/ha. The limitation to increase the boro area in the dry season and lower yield of T. Aman were explored with the farmers. The farmers indicated some serious Problems that limit the increase yield of T. Aman and Boro rice from 150 farmers. Among those, the two most -commonly mentioned problem are (i) high cost of fertilizer, insecticide, pesticide, seed and (ii) unfavourable weather boro and T. Aman cultivation.

The solution to the above problems as suggested by the farmers of the selected areas of Thakurgaon sadar was the availability of fertilizers and chemicals with low cost. Irrigation cost/ha for Boro season varied from Tk. 3000 - Tk. 3500 during 2017 & 2018 Boro crop seasons. Again sixty percent farmers of Thakurgaon sadar thana suggested that there should be short duration T. Aman varities available in these area. According to the report of farmers that the drought occurred during early stage (transplanting &

vegetative stage) as well as reproductive stage of T. Aman crop. Most of the times delayed application of supplemental irrigation during T. Aman season lowered the expected yield.

About hundred percent selected farmers of Thakurgaon Sadar thana informed that they received enough water from the respective DTWs for T. Aman and Boro crops. It also appeared from survey that the selected DTWs of Thakurgaon was in very good condition. More than ninety percent farmers from selected DTWs used supplemental irrigation in T. Aman and Boro rice for attaining high yield. Hundred percent of fanners of Thakurgaon sadar thana used buried pipeline as water distribution system.

Constraints like unfavourable weather for T. Aman and Boro cultivation can be solved by adopting suitable water management practices. Most serious problem, seepage losses, can be minimized by using buried pipe. A study has been undertaken by BMDA to evaluate the performance of the newly introduced buried pipe method of water distribution reported that (i) land saved by buried pipe was 2 to 5 percent of the command area (ii) about 56 to 61 percent time was saved due to use of buried pipe and consequently saved labour and increased the command area of about 40 to 50 percent. During T. Aman drought ocures at vegetative as well as reproductive stage. So, supplemental irrigation should be applied if drought occures during T. Aman cultivation.

Other constraints reported by the farmers of three selected DTWs from 150 farmers for irrigated rice crop were high price of fertilizer, insecticide, seed. Quality not properly maintained of seed and pesticide, low fertility of land, unavailability of HYV T. Aman, low organic matter contents present in the land, tillage and labour problem during transplanting and harvesting (Table 4.9) was one of the most serious problem in Bangladesh.

Table 4.9. Constraints as reported by farmers for irrigated rice crops, Thakurgaon, 2017-2018

Factors	Thakurgaon Sadar	
	No of farmers	Percent
High price of fertilizer and quality not properly maintained	90	60
High price of Insecticide	120	80
High price of seed	100	66.67
Good quality of seed not available	55	36.67
Low yield of boro and T. Aman	13	8.67
Low fertility of land	20	13.33
Unavailability of HYV T. Aman	20	13.33
Low organic matter Contents	15	10
Tillage and labour problem during transplanting and harvesting of T. Aman, Boro	120	80

CHAPTER V

SUMMARY AND CONCLUSIONS

On the basis of the present study, the following summary related to irrigation practices and water management can be drawn for Thakurgaon area:

Average cultivable area (ha) of interviewed DTWs under deep tubewell Irrigation Project was 1.58 in Thakurgaon thana respectively. On the other context, average irrigated area (ha) of T. Aman and Boro crops were 2.96 and 1.33 for Thakurgaon sadar thana under three DTWs respectively. It is indicated that farmers of study areas used DTW throughout the year for T. Aman and Boro rice. Most of farmers of the study area were found to cultivate T.Aman rice in medium high and high land, whereas Boro rice was grown in medium high and medium low land areas.

Potential command area was calculated by using methods described in Chapter 3. Actual command area (ha) for DTW-1, DTW-2 and DTW-3 were 24,25 and 24 for boro rice and T. Aman in DTW project area in Thakurgaon sadar thana. Considering the designed discharge, it was possible to increase the daily operating hours. The farmers in Thakurgaon area was found to operate the pumps for the period of 8, 10 and 12 hrs/day than the potential command area was double than the present situation.

Average benefit/ cost ratio (BCR) for T. Aman and Boro rice under three selected deep Tubewell Projects was found 2.55 and 1.19.

The incremental benefit from buried pipe line irrigation system obtained by multiplying the irrigated area into the difference between the net benefit for irrigated and non irrigated condition and the net return was increased per ha (Tk) for irrigated condition than non irrigated condition. The incremental benefit was too high due to DTW buried pipe line irrigation system.

There is no conveyance loss in case of buried pipeline for earthen channel conveyance loss was 34-40%, improved lined channel 30-34% and for buried pipe line 0.46-0.54, and the average was 37%, 31% 0.49% which was approximately null for buried pipe line.

For improved lined channel water distribution system, saving of irrigation water and distribution time and increase of irrigated area respectively were 13-18 %, 25-29 % and

46-51 % in comparison to that earthen channel and average were 17%, 27% and 49%. Similarly for buried pipe distribution system, the above parameters were respectively 98 - 99 %, 56-61 % and 80 - 82 % and average were 99%, 59%, 81% in comparison to that of earthen channel system.

Water productivity for the treatments T1=Continuous standing water,7cm, T2=Irrigation with a depth of 7 cm after 3 days of disappearing of standing water, T3=Irrigation with a depth of 7 cm after 5 days of disappearing of standing water and T4=Irrigation with a depth of 7 cm after 7 days of disappearing of standing water were found to be 4.80, 6.21,6.75 and 5.51 kg/ha-mm respectively during the year 2017 for T. Aman and in 2018, the productivity were found to be 8.01, 8.23, 8.01 and 8.77 kg/ha-mm respectively for T. Aman for the above treatments. Maximum Water productivity of 6.75 kg/ha-mm was observed for treatment T3 and 8.77 kg/ha-mm for treatment T4 during 2017 and 2018.

Farmers in the study areas complained about some factors that limit to the success of crop production: like high price of fertilizer, seed and insecticide. The other limiting factors were: low quality of HYV T. Aman seeds and labour crisis during transplanting and harvesting of T. Aman, Boro. Unfavourable weather for T. Aman and Boro cultivation can be solved by adopting suitable water management practice. Land saved by buried pipe was 2-5 percent of the command area and about 56-61 percent time was saved due to use buried pipe line and consequently saved labour and increased command area of about 46-51 percent. More than sixty percent farmers from the selected DTWS reported that high price of fertilizer and quality not properly maintained, eighty percent of farmers was said that the price of insecticide was high, sixty seven percent farmers reported that price of seed was too high, thirty seven percent farmers reported that good quality of seed was not available, Low yield of Boro and T. Aman was reported from nine percent farmers, more than fourteen percent farmers reported that low fertility of land and unavailability of HYV T. Aman, ten percent farmer reported that low organic matter contents in the soil, eighty percent farmers reported that tillage and labour problem during transplanting and harvesting of T. Aman and Boro season.

CHAPTER VI

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APPENDICES

Appendix 1: Types of crop grown by the farmers in DTW area in Thakurgon sadar thana, 2016-2017.

Types of Crops	Thakurgaon Sadar	
	No. of Farmer	%
Wheat	30.0	86.7
Potato	75.0	50.0
Maize	90.0	60.0
Vegetable	30.0	20.0
Boro	150.0	100.0
T.Aman	150.0	100.0

Appendix 2: Types of land used for growing T. Aman and boro rice by the farmers, Thakurgaon sadar thana, 2017 – 2018.

Types of land used for Growing T. Aman and Boro Rice	Thakurgaon sadar	
Boro Rice	No	Percent
i) High	3	2.0
ii) HighMedium	2	1.3
iii) Medium	8	5.3
iv)Medium+Low	120	84.8
v)High+Medium+Low	3	2.0
vi) Low	5	3.3
vii) No response	2	3.3
Total	151	100.0
T. Aman		
i) High	3	2.0
ii)High+Medium	71	47.0
iii) High+ Low		
iv)Medium	8	5.3
v) Medium + Low	5	3.3
vi) High+ Medium + Low	61	40.0
vii) Low	0	0.0
vii) No response	2	1.3

Appendix 3: Actual and Potential command area for Boro rice in Thakurgaon area.

Location and Tubewells	Design discharge (li/sec)	Actual command area (ha)	Actual daily operating hrs.	Potential command area for operating hrs.		
				8 hr/day	10 hr/day	12 hr/day
DTW-1(RH-48) Salendhar	56.0	24	8	7.77	12.09	14.50
DTW-2(T-51) Salendhar	56.0	25	10	9.50	12.09	14.50
DTW-3(Old-53)Jagganathpur	56.0	24	9	6.07	12.09	14.50

Appendix 4: Farmer's views about uses of UPVC pipe for irrigation of Thakurgaon district, 2017-18.

Advantage of pipe		
	Respondents	%
a)approximately no conveyance loss	100	100
b) Easy to irrigate high land/ higher topography	82	54.0
c) No need of field channel	27	18.0
d) Quickly water moves	4	3.0

Appendix 5: Benefit Cost ratio for T. Aman and Boro rice of farmers using deep tubewell, Thakugaon, 2017-2018

Input cost (Tk)	T. Aman (TK)	Boro(TK)
Average input cost	3085	6258
Maximum input cost	5591	1300
Minimum input cost	3990	5500
Gross return (Tk)		
Average Gross return	7876	7471
Maximum gross return	6000	5000
Minimum gross return	4500	1000
Benefit cost ratio		
Average BCR	2.55	1.19
Maximum BCR	1.07	3.85
Minimum BCR	1.13	0.18

Appendix 6: Effect of different water treatments on the yield of T. Aman, Thakurgaon, 2017

Treatments	Irrigation Amount (mm)	Rainfall (mm)	Total water applied (mm)	Yield (kg/ha)	Water productivity (Kg/ha-mm)
Tl	800	246	1046	5020	4.80
T2	770	246	1016	6310	6.21
T3	600	246	846	5710	6.75
T4	630	246	876	4830	5.51

Appendix 7: Effect of different water treatments on the yield of Boro, Thakurgaon, Boro season, 2018

Treatments	Irrigation Amount (mm)	Rainfall (mm)	Total Water applied (mm)	Yield (kg/ha)	Water Productivity (kg/ha-mm)
T1	800	0.0	800	6410	8.01
T2	750	0.0	750	6170	8.23
T3	700	0.0	700	5610	8.01
T4	560	0.0	560	4910	8.77