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Impact of Lined Canal on Shallow Tubewell Irrigation and Their Acceptability by the Farmers

Abu Sayed[1] *, A. F. M Saleh[2], Md. Altaf Hossain[3], Zobayer Ali Basunia[4] and Md. Afzal Hosain[5]

[1]*Department of Agricultural Engineering, Exim Bank Agricultural University;* [2]*Department of IWFM, BUET, Dhaka;* [3]*Department of Farm Structure, Sylhet Agricultural University;* [4]*Rangpur PBS-2, Paglapir, Rangpur;* [5]*WMM Division, BRRI, Gazipur-1701, Bangladesh*

**Corresponding author and Email:* abu_982@yahoo.com

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Abstract

The comparative conveyance losses between lined and unlined canals, impact of water saving on command area development and irrigation cost, and farmers' acceptability of lined canal in shallow tubewell (STW) irrigation schemes were studied during 2010-11 Boro season at three upazilas: Manikgonj Sadar of Manikgonj district, Dhamrai of Dhaka district and Mithapukur of Rangpur district. The conveyance loss was measured using inflow-outflow method and focus group discussion (FGD) was carried out with the pump owners and farmers to assess the impact of water saving on command area development and the acceptability of lined canal technology. Average conveyance losses were found to be 41, 48 and 45% in the existing earthen canals; 18, 21 and 24% in improved earthen canals; and 12, 11 and 13% in pre-cast canals at Mithapukur (M_1), Manikgonj Sadar (M_2) and Dhamrai (D) schemes, respectively. The water saving did not increase the command area in any of the schemes but reduced the irrigation time and saved fuel requirement for irrigation. On an average, 32, 23 and 30% fuel were saved by improved earthen canals where as 45, 46 and 48% were saved by pre-cast canals for $M_{1,}$ M_2 and D schemes compared to earthen canal. The benefit-cost ratios of improved earthen canals were 1.36, 1.38 and 1.30 where as 3.36, 4.28 and 3.34 by pre-cast canals for $M_{1,}$ M_2 and D schemes, respectively. The internal rate of return (IRR) from the investment on water distribution was over 50%. The lining technology was acceptable to pump owners, but did not impress the farmers who share the crop with the pump owners as price of irrigation or pay on the basis of irrigated area. In order to make the technology acceptable to the farmers, polices must be framed to share the benefits of lining by the pump owners with the farmers by reducing the price of irrigation water or through financial support of GO and NGOs for efficient use of STW irrigation system in Bangladesh.

Keywords: Lined Canal, shallow tubewell, irrigation

1. Introduction

Irrigation plays a critical role in Bangladesh through increasing the yield and cropping intensity. Out of about 8.52 Mha of cultivable land of Bangladesh, about 6.8 Mha is considered as suitable for irrigation. Presently, about 5.4 Mha has been brought under irrigation, of which more than 95% is covered by minor or small scale irrigation (BADC, 2013). Over the years, the proportion of irrigated area based on groundwater has changed significantly. The contribution of groundwater in relation to total irrigated area increased from 41% in 1982-83 to over 78% in 2013. Shallow tubewell (STW) is the main mode of extracting groundwater and, at present, 60% of the total irrigated area is based on STW (BADC, 2013). As groundwater is the only limiting resource for further intensification of agriculture, its rational use should be ensured both in terms of quality and quantity.

In Bangladesh, most of the irrigation canals are earthen because of high initial cost for the construction of lined canals. These earthen canals suffer from a number of problems like low conveyance and distribution efficiency, less irrigated area and high maintenance cost (Maniruzzaman *et al.,* 2002). The water loss through earthen canals in minor irrigation projects is a matter of great concern. As reported in the literature, this loss (mainly through seepage and percolation) is generally as high as 50% or even more of the water pumped/delivered, although it varies from soil to soil (Biswas *et al.,* 1984; Matin, 1991; Sattar *et al.,* 2002). To avoid such a huge amount irrigation water lost through canal section, alternative low cost water saving irrigation techniques are needed. A well-compacted earthen lining can be highly impermeable and is almost comparable to good concrete lining (ICID, 1967). In a study, the conveyance loss under improved earthen canal was measured only as10% (Sattar *et al.,* 2002).

The command area of STWs, which is the main mode of minor irrigation, has been steadily declining. In the early eighties, it was 4 ha, but in the recent years, it has come down to about 2.13 ha (BADC, 2013). The reasons for this decrease in command area are not well documented. As a follow up of the plan on improvement of the farm channels, the government has recently taken up the AETEP (Enhancement of Agricultural Production and Rural Employment through Extension of Agricultural Engineering Technologies Project) under the Department of Agricultural Extension (DAE) to persuade the farmers to use improved or lined canal, so as to enhance the command area. Under this program, the DAE with the help of Upazila Agricultural Office has taken up pilot projects in each upazila to improve three earthen canals and construct one pre-cast lined canal in farmers' fields per year (AETEP, 2005). In this context, it is necessary to know the impact of the canal improvement and lining by AETEP on the irrigation development and management, and acceptability of the technologies by the farmers. The main objectives of the study were: (1) to assess the impact of water saving by canal lining on command area development and irrigation cost, and (ii) to determine the economic benefits and farmers' acceptability of lined/improved canal. The overall objective was to attain increased water use efficiency and water productivity.

2. Materials and Methods

The Department of Agricultural Extension is involved in experimentation of improved water distribution system in order to develop different low cost canals for minor irrigation schemes. As of now, the DAE through its AETEP has implemented several new technologies in respect of lining of irrigation canals. These linings are superior to the traditional earthen canal, especially in respect of efficiency. In this study, the linings recommended by AETEP were constructed and field tested in order to assess their impacts over the traditional earthen canals. The study was undertaken in 2010-11 Boro season at three upazilas: Manikgonj sadar of Manikgonj district, Dhamrai of Dhaka district and Mithapukur of Rangpur district. Nine improved earthen canals, three pre-cast lined canals and six existing earthen canals under STW were selected for field study.

2.1. Method of measurement of conveyance loss

In this study, inflow-outflow method was used for conveyance loss measurement. The inflow-outflow method was widely used by most of the researchers in Bangladesh for its simplicity and accuracy (Dutta, 1991; Sattar *et al*., 2002; Maniruzzaman *et al*., 2002). This method is very suitable to measure the canal water loss than, unlike ponding method, the irrigation can continue while the discharge measurements are taken. The results obtained by inflow-outflow method are more reliable than the other (Ponding method and Seepage Meter method) methods (Shahid *et al*., 1991). Consequently, the inflow-outflow method was employed for this study. There are various types of water measuring device by which flow of water can be determined. In this study, cut-throat flume was used for discharge measurement. The most obvious advantages of cut-throat flume are its economy, accuracy and field suitability.

2.2. Determination of conveyance loss

Conveyance loss of water was calculated as:

$$CL = \{(Q_1-Q_2)/L\} \times 100 \quad \ldots \quad \ldots \quad (1)$$

where, CL is the conveyance loss in the canal in lps/100m, Q_1 is the flow at the inlet in lps, Q_2 is the rate of flow at the outlet in lps and L is the distance between the two canal sections in m.

Water loss of respective canal was measured with cut-throat flume under two conditions. These were: (i) natural condition (existing earthen canal), and (ii) improved condition (after compaction and lining)

2.3. Land occupied by canal

In Kharif season, most of the farmers leveled down their earthen canal to grow Aman paddy. They generally do not provide supplementary irrigation to Aman crop. But, when improved earthen canals are constructed, they are not leveled down, as such; the land required for the construction of the canals goes out of production. To measure the area of land occupied by canal, length and width of the main canal were measured in consultation with the scheme manager and pump operator.

2.4. Economic analysis

An economic analysis was carried out for the distribution system of irrigation water in order to ascertain the profitability of the lining technology. For this purpose, discounting method of the appraisal technique was used. By discounting, future cash flows are reduced to their present worth. For measuring the relative worthiness of the system, three alternative discounted measures namely, net present worth (NPW), benefit cost ratio (BCR) and the internal rate of return (IRR) were used.

2.5. Field survey

Field surveys were carried out in each of the upazilas to assess the impact of water saving on command area development and the acceptability of lined canal technology by the farmers. Participatory rural appraisal (PRA) approach was used for collection of socio-economic data. Focus group discussion (FGD) was used for socio-economic data and information collection. Each FGD involved 9-11 persons. Average age of the farmers was 34 years and all of them were male. For collection of socio-economic information, 9 (nine) FGDs were conducted in the selected study areas. Three FGDs were conducted with the pump owners and other six with the irrigation farmers.

3. Results and Discussion

3.1. Water loss in earthen canal

The conveyance losses of the existing earthen canals of the selected study schemes ranged from 6.9 to 8.2 lps per 100 m (Table 1). Considering the pump discharge, the conveyance loss varied from 37 to 53%. The average conveyance losses of Mithapukur, Manikgonj and Dhamrai scheme are 7.7, 7.4 and 7.5 lps/100 m, respectively, which were about 41, 48 and 45% of the pump discharge, respectively. This is in agreement with the findings of Sattar *et al.* (2002). They found loss rates of 5.25 to 6.44 lps/100m, which was, on an average, 42% of the pump discharge in the north-western region of Bangladesh. Maniruzzaman *et al*. (2002) also found the loss of 6.08 to 7.74 lps/100 m at Kapasia in Gazipur District. The results of the study indicated that nearly 50% of the pumped water is lost before arriving at the farmers’ fields.

3.2. Water loss in improved earthen canal

The conveyance losses of the improved earthen canals varied from 3.0 to 4.5 lps/100 m (Table 1). Considering the pump discharge, the conveyance losses varied from 14 to 26%. In the study schemes, the average conveyance loss was 3.6 lps/100 m, which is 21% of the pump discharge. This is similar to the findings of Sattar *et al*. (2002) who reported loss rates of 3.67 to 3.97 lps/100m. Maniruzzaman *et al.* (2002) also found the conveyance loss as 3.7 to 4.8 lps/100 m.

3.3. Water loss in pre-cast canal

The conveyance losses of the pre-cast canals varied from 2.5 to 2.9 lps/100 m (Table 1). The average loss per 100m is 12% of the pump discharge. Conveyance losses mainly occur in this canal due to evaporation from the canal. Karim (2004) reported that the conveyance losses of the pre-cast canals in three different schemes in Bogra were 2.3 to 2.6 lps/100 m, which is similar to the results of this study.

3.4. Impact of lined canal system

The purpose of lining is to save water by reducing the conveyance loss. It is generally assumed that the water saved through lining would be used to irrigate additional area. But, for the schemes under the study, the command areas remained unchanged after introduction of the improved water distribution system. In the study area, more shallow tubewells are operating than are needed. There is no additional land to be brought under cultivation and also the existing agricultural land is declining on account of increased use of land for other purposes. As a result, the command area under each STW with lining remained the same even though there was water saving compared to pre-lining condition.

3.5. Water saved by improved earthen canal and pre-cast canal

The results of field measurements on the water saved by using improved earthen canal and pre-cast canal as compared to the existing earthen canal are presented in Table 2. The water saved varied from 21 to 27% by improved earthen canal and from 29 to 37% by pre-cast canal over earthen canal. Sattar *et al.* (2002) found that the water saved varied from 29 to 38% by improved earthen canal over earthen canal. The water saved also varied from 6 to 11% by pre-cast canal over improved earthen canal. The variation of the results indicated that, on average, water could be saved up to 24 to 33% by adopting lined canal method instead of the traditional earthen canal system.

3.6. Time saved by improved earthen canal and pre-cast canal

As mentioned earlier, the saved water through lining was not used for expanding the command area. Instead, the pumps were operated for fewer hours in order to irrigate the same command area. It was observed from the selected study schemes that the time saved over earthen canal varied from 20 to 27% by improved earthen canal and from 40 to 45% by pre-cast canal (Table 3). In a similar study, savings of 28% time by improved earthen canal and 48% time by pre-cast canal over earthen canal were observed (Sattar *et al.*, 2002). The time saved also varied from 18 to 30% by pre-cast canal over improved earthen canal. The results indicated that, on average, the irrigation time could be saved by 24 to 43% by adopting lined canal method instead of the traditional earthen canals.

3.7. Fuel saved by improved earthen canal and pre-cast canal

Relatively less hours were required to irrigate the same command area of lined schemes and less amount of fuel was required as compared to improved earthen canal. It was observed from the selected study areas that fuel saved varied from 23 to 32% and 45 to 48% (Table 4) in improved earthen canals and pre-cast canals, respectively. Table 4 also shows that the fuel saved varied from 20 to 30% by pre-cast canal over improved earthen canal. The results indicated that, on average, fuel could be saved up to 28 to 46% by adopting improved earthen canal and pre-cast canal instead of the earthen canal (Table 4).

Table 1. Water losses in earthen canal, improved earthen canal and pre-cast canal of the study schemes

Schemes	Conveyance loss in earthen canal/100m				Conveyance loss in improved earthen canal/100m				Conveyance loss in pre-cast canal/100m	
	lps	avg.	% of discharge	avg.	lps	avg.	% of discharge	avg.	lps	% of discharge
M_1	7.2	7.7	44	41	4.3		24			
	8.2		38		3.7	3.7	17	18	2.6	12
					3.3		14			
$\mathbf{M_2}$	7.6	7.4	53	48	3.0		23			
	7.2		43		3.3	3.6	14	21	2.5	11
					4.5		26			
D	6.9	7.5	53	45	3.3		24			
	8.2		37		4.0	3.4	25	24	2.9	13
					3.0		23			

M_1**:** Mithapukur, M_2: Manikgonj Sadar, D: Dhamrai

Table 2. Impact of improved earthen canal and pre-cast canal on water saving

Schemes	Water saved by improved canal over earthen canal (%)	Water saved by pre-cast canal over earthen canal (%)	Water saved by pre-cast canal over improved earthen canal %
Mithapukur	23	29	6
Manikgonj sadar	27	37	10
Dhamrai	21	32	11
Average	24	33	9

Table 3. Impact of improved earthen canal and pre-cast canal on time saved over earthen canal

Schemes	Average time saved by improved canal over earthen canal		Average time saved by pre-cast canal over earthen canal		Average time saved by pre-cast canal over improved earthen canal	
	h/hec	(%)	h/hec	(%)	h/hec	(%)
Mithapukur	75	27	110	40	35	18
Manikgonj sadar	60	20	129	44	71	30
Dhamrai	74	24	140	45	66	28
Average	69	24	126	43	57	25

h = hour, hec = hectare

Table 4. **Impact of improved earthen canal and pre-cast canal on fuel saving**

Schemes	Average fuel saved by improved canal over earthen canal		Average fuel saved by pre-cast canal over earthen canal		Average fuel saved by pre-cast canal over improved earthen canal	
	Litter(l)/hec	(%)	l/hec	(%)	l/hec	(%)
Mithapukur	100	32	142	45	42	20
Manikgonj Sadar	76	23	156	46	80	30
Dhamrai	106	30	170	48	64	26
Average	94	28	156	46	62	25

Table 5. Land occupied by canal at the selected schemes

Schemes	C.A	Canal area		Total area		% C.A	Production loss	
		Main canal length (m)	Width (m)	m^2	hec		kg/hec	Tk/hec
Mithapukur	3.86	370	1.38	511	0.0511	1.32	205	2460
Manikgonj Sadar	2.87	281	1.38	388	0.0388	1.29	155	1860
Dhamrai	3.43	317	1.38	437	0.0437	1.23	175	2100

Table 6. Economic analysis of improved earthen canal

Schemes	Establishment cost (Tk)	Life span (Year)	Total Benefit (Tk)	NPW (Tk)	BCR	IRR (%)
Mithapukur	11800	3	16600	7545	1.36	Over 50
Manikgonj Sadar	10625	3	15120	7068	1.38	Over 50
Dhamrai	11750	3	15680	6054	1.30	Over 50

Table 7. Economic analysis of pre-cast canal

Schemes	Establishment cost (Tk)	Life span (Year)	Total Benefit (Tk)	NPW (Tk)	BCR	IRR (%)
Mithapukur	37000	15	20320	94689	3.36	49.78
Manikgonj Sadar	37000	15	29120	152947	4.28	Over 50
Dhamrai	37000	15	20160	93571	3.34	49.67

3.8. Discussion on impact of lining

Construction of improved water distribution system is an integral part of command area development activities. Lining of irrigation canals offers one of the best opportunities to expand command area. But, it was observed from this study that although 24 to 33% water was saved by lined canal but command area did not increase. Instead, it was observed that the farmers/pump owners were irrigating the same area with fewer pumping hours and requiring less fuel. On average, 24 to 43% less time was required to irrigate the same command area by improved earthen canal and lined canal over traditional earthen canal. Similarly, the average amount at fuel saved varied from 28 to 46% by improved earthen canal and lined canal over traditional earthen canal. Thus, the lined canal system not only saved conveyance loss but also saved fuel cost, maintenance cost and reduced the time required for irrigation. The average savings in diesel fuel varied from 94 to 156 liters per irrigated hectare (Table 4) in the case of a STW command area.

3.9. Economic analysis

Economic analysis of lined canals in shallow tubewell irrigation schemes was performed by calculating the Net Present Worth (NPW), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR). The costs of lining are the construction costs, the operation and maintenance costs and the benefits of lining are the savings due to less amount of fuel required for the operation of the schemes.

3.9.1. Cost of construction

The study concentrated on two major water distribution systems, namely (i) unlined irrigation canal (existing earthen canal) and (ii) lined canal irrigation system with improved earthen canal and pre-cast concrete slab. Various components of investment, operation and maintenance costs of earthen canal and lined canal systems were identified. The construction costs vary with the prevailing cost of materials, labor and other charges. The cost is usually expressed on a unit length basis such as cost per meter length and in terms of cost per unit area of the surface area of the canals.

Most of the farmers involved in the construction of earthen canal are of the view that earthen canal requires minimum time and cost for construction. The cost of earthen canal is more or less the same in the three schemes and is around Tk.18 per running meter. The cost of improved earthen canal is higher than earthen canal and is around Tk.25 per running meter. The pre-cast concrete slab, which is reportedly more convenient for construction and popular as well, needs more care during installation work and regular maintenance. The cost of pre-cast canal is around Tk.185 per running meter.

3.9.2 Expected life of canal lining

When annually maintained and repaired, the improved earthen canals are assumed to have a three years life span (AETEP, 2005). A - 15 year project life span is assumed for pre-cast canal (AETEP, 2005). As the traditional earthen canals are prepared every year, they have a life span of one year.

3.9.3 Operation and maintenance costs

Earthen canal systems do not require maintenance cost because they have a life span of one year. Improved earthen canals require a cost of Tk.5 per running meter for first year and Tk.12 per running meter for second and third years, mainly for removing grass and silts and repairing leaks and weak points. Less amount of cost (Tk.5 per running meter per annum) is required for annual repair only for plastering of pre-cast canals. There is no widening in pre-cast canal and no removal or grass or silt is required.

3.9.4. Land occupied by canal

The average area under the canal varied from 1.0 to 1.4% of the command area. This is in agreement with the results reported by Mridha (1993). Average land occupied by canal at the selected schemes is given in Table 5. The table also provides the loss of production (in Tk.) considering the average Aman yield of 4 ton/hec and price of paddy as Tk. 12/kg.

3.9.5. Net present worth

The Net Present Worth **(**NPW) value was calculated for improved lined canals and pre-cast canals of shallow tubewell irrigation system of the selected schemes. The results are given in Tables 6 and 7. From the tables, it is found that NPW of Mithapukur, Manikgonj sadar and Dhamrai is Tk. 7545, 7068 and 6054, respectively for improved earthen canal, and Tk. 94689, 152947 and 93571, respectively for pre-cast canal at 12% discount rate.

3.9.6. Benefit cost ratio

The Benefit Cost Ratio (BCR) for improved earthen canals was found to be 1.36, 1.38 and 1.30 for Mithapukur, Manikgonj sadar and Dhamrai schemes, respectively at 12% discount rate (Table 6). The BCR for pre-cast canals was also found to be 3.36, 4.28 and 3.34 for Mithapukur, Manikgonj sadar and Dhamrai schemes, respectively at 12% discount rate (Table 7).

3.9.7. Internal rate of return

The Internal Rate of Return **(**IRR) value was calculated for improved lined canals and per-cast canals of irrigation systems in the study area. The IRR was over 50% for Mithapukur, Manikgonj and Dhamrai schemes for improved earthen canals (Table 6). It was 49.78%, over 50 and 49.67% for pre-cast canals for Mithapukur, Manikgonj and Dhamrai schemes, respectively.

3.10. Acceptability of lined canal by the farmers

3.10.1. FGD information from pump owners

As for the lined canal, all the pump owners expressed their complete satisfaction as it reduced water loss, fuel cost and maintenance cost. Regarding the pump owners, preference for different types of canal innovated by the AETEP, 70% expressed their views in support of the pre-cast canal irrigation system and 30% for improved earthen canal. Regarding their preference for pre-cast canal, they cited several reasons. These are, in descending order of importance, (a) negligible water loss, (b) less maintenance cost, (c) reduction in fuel cost and (d) reduction in time required in reaching water from the sources of supply to the farthest plot of scheme. Regarding improved earthen canal, the respondents pointed out as many as four advantages over earthen canal. These are: (a) reduction in wastage of irrigation water, (b) reduction in fuel cost, (c) reduction in time required in reaching the water from the source of supply to the farmers' field and (d) less maintenance cost.

As regards the acceptability of the lined canal, 90% of the respondents expressed their views in favor of it and indicated their inability to afford it from their own because of the lack of proper knowledge, capital and technical support. According to them, if technical support is ensured by DAE and other relevant agencies of government and non-government organizations, they are interested to take loan from Bank/NGO for the development of lined irrigation canal in their schemes.

3.10.2 FGD information from general farmers

As for the lined canal, all the farmers also expressed their satisfaction as it reduced water loss, fuel cost and maintenance cost. But, they informed that lined canal is not beneficial to the farmers and did not show their interest to lined canal as an improved technology. The farmers reported that irrigation systems are mostly dominated by the pump owners who operate pumps according to the farmer's supplied fuel or own supplied fuel. Mainly, irrigation charge is paid by the farmers as output based crop share payment system. This is the most common water pricing system in Manikgonj sadar, parts of the Dhamrai and Mithapukur upazilas.

It is reported that in case of electricity operated schemes, farmers pay one-fourth of their total crop from the land that is equivalent to Tk. 9000/ha (900 kg rice/hec). In case of diesel run modes (fuel given by the pump owner), farmers pay one third or one-fourth of their total crop. In some places of Dhamrai and Mithapukur upazilas, farmers pay Tk. 40/decimal and Tk.60/decimal for electricity mode and diesel mode STW, respectively. In these schemes (crop share and area based pricing), the lined canal is not beneficial to farmers as they have to pay the same amount of water charge in every season whether the canal is improved or not. In these cases, lined canals are beneficial only for the pump owners. Although the lined canals require less water withdrawal, less irrigation time, less fuel and less maintenance cost, such benefits are not shared by the pump owners with the farmers. In the study areas, on average, 94 l/hec and 156 l/hec fuel were saved by improved earthen canal and pre-cast canal, respectively. Most of the farmers have no interest on lined canal since the positive impact/benefit of a lined canal is only enjoyed by the pump owners. On the other hand, when farmers themselves pay for fuel as irrigation charge (in case of diesel run modes), lined canal is beneficial to farmers. This is because the farmers save their fuel from every irrigation (at the rate of 1.0 to 1.3 litters per irrigation depending upon the distance of paddy field from STW).

During the FGDs, it was observed that all the farmers (even those providing fuel as price for irrigation) were unwilling to give land for the construction of lined canal (especially improved earthen canal). This is because for the construction of the improved earthen canal, a considerable amount of land and a lot of earth are required. The farmers usually do not agree to provide that much of land or provide earth from their land for construction. The reasons for not providing either land or earth is that they do not want to lose the cultivable land with a consequent lose of production to some extent. To gain the profit out of improved earthen canal or lined canal, the canal needs to be in the field without destruction. But, as paddy cultivation is done in two seasons, the farmers usually level down the irrigation canals that are made in Boro season to increase the area of cultivation during Aman season.

It was evident from the FGDs that the canal lining has only benefited the pump owners. Although a section of the farmers (providing diesel as price for irrigation) have been benefited by canal lining, they were unwilling to provide land and earth for construction of irrigation canal. All other farmers have neither been benefited by lining nor are interested about the new technology. In future, if DAE is to replicate the technology in new schemes, it should ensure that the benefits of lining are shared by the pump owners with the farmers by reducing the price of irrigation water or reducing their share of crop taken as irrigation fee.

4. Conclusions

The highest of 48% water loss and saving of irrigation water (37%) were found by earthen canal and pre-cast canal, respectively in Manikgonj sadar. The pre-cast canal on average, saved 43% and improved earthen canal saved 24% irrigation application time as compared to earthen canal. The pre-cast canal and improved earthen canal also saved 46 and 28%, respectively, of fuel cost and, consequently, saved the operation and maintenance cost. But the saved water through lining was not however used for expanding the command area. Among the two types of lined canals, the values of the economic indicators used (BCR and NPW) were the highest for pre-cast concrete lining. The lined canal technologies offered by the AETEP are only acceptable to pump owners and only those farmers who pay the price of irrigation by supplying the fuel. The technologies are not acceptable to the majority of the farmers who pay out irrigation charge on the basis of crop share method and area based cash payment method. Based on the technical and economic performances, it can be concluded that lined canal technologies are suitable for shallow tubewell irrigation schemes. But, in order to make the technologies acceptable to the farmers, the benefit of lining must be shared among the stakeholders (pump owners and farmers).

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