The Evolution and Implications of Decreased Public Involvement in Minor Irrigation Management in Bangladesh

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INTRODUCTION

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

The start and early growth of minor irrigation relied heavily on public-agency action and support. While the public sector never actually operated more than a small number of pump schemes, agencies have until very recently been variously (and often deeply) involved in the procurement, distribution, installation and maintenance of irrigation equipment as well as in the supply of fuel/oil and spare parts. A process of minor irrigation sector privatization, however, began in the late 1970s. Since that time a number of policies have been instituted which have had the effect of pulling back the Government's involvement in minor irrigation support and boosting the scope of activity of the private sector.

This paper attempts to examine the minor irrigation sector's evolution from public to private control and assess the implications of this shift. What is the performance of a private management system in this sector in regard to productivity, equity and sustainablity?

CONTEXT OF IRRIGATION DEVELOPMENT

Physical Features

Bangladesh is formed by the delta of the Ganges, Brahmaputra and Meghna rivers. A lack of suitable reservoir locations, the complexity of the deltaic river system and the continuing decline in dry-season river flows, however, make large-scale surface irrigation difficult and such systems make up only 6 to 7 percent of all irrigated area. The country does, however, have fertile alluvial soils and good sources of groundwater. Rainfall is from 1,200 to 3,500 mm per year which is normally capable of completely recharging shallow aquifers during the rainy season from late May through mid October. There are 24,400 million cubic meters of groundwater available for development -- enough to irrigate 3.9 million hectares ([Pitman, 1993]).

Cropping System

Rice and jute are the main wet season crops. During the dry winter and spring the climate is suitable for irrigated rice as well as for wheat, pulses, oilseeds and vegetables. Given the predominance of rice in the Bangladeshi diet, rice has been the main irrigated crop of the dry season. HYV dry season rice, referred to as *boro*, is transplanted in January/February and harvested in May. With increases in minor irrigation, boro production grew at an annual rate of over 14 percent per year between 1980 and 1992 and could soon rival *aman* (rainy season rice) in amount of production. This rise of irrigated boro is a major reason for the overall growth rate of 2.86 percent in the nation's annual rice production (Figure 1), a figure slightly larger than the population growth rate.

Crop production inputs such as human labor, draft power and most seeds are generally farmer supplied in Bangladesh. With the shift to HYV technologies, however, there has been a growth in importance of such purchased inputs as chemical fertilizer, pesticides, irrigation and power tiller services, etc., which are marketed through private sector traders. There has been a concomitant rise in demand for agricultural credit, extension and marketing services which are currently being provided, to varying extents, by both the government and private sectors.

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Agrarian Structure

With a rural population of more than 800 persons per square kilometer Bangladesh is characterized by very small land holdings distributed rather unequally. Half of rural households have no land at all -- with the landless working for cash or kind wage labor. Of those with some land about 70 percent have up to one hectare, though this small farm category constitutes only 29 percent of total farm area. So-called large farms (those having over 3 hectares) cover 25 percent of the land. An average farm has 8 to 10 plots scattered over the territory of one or more villages. Roughly one quarter of the farm land is cultivated under some form of sharecropping or fixed tenancy arrangement.

Irrigation Technologies

The various minor irrigation technologies differ in coverage and other characteristics. LLPs, while mostly of 1-2 cusec capacity, range from 0.5 to 5 cusecs and lift water from ponds and streams via a suction mode. DTWS are normally of 2 cusec capacity and use a force mode turbine or submersible pump technology. STWs (of 0.5 to 0.7 cusec nominal discharge) use suction mode pumps. Taken together these motor driven minor irrigation technologies cover 2.3 million hectares (Mha) -- 82% of coverage by all irrigation technologies combined (Table 1). Of this area, STWs have 1.4 Mha, DTWs 0.4 Mha and LLPs 0.5 Mha.

EVOLUTION OF PUBLIC AND PRIVATE SECTOR INVOLVEMENT IN MINOR IRRIGATION MANAGEMENT

The development of minor irrigation in Bangladesh passed through a series of phases. At first heavily dominated by the public sector it underwent a transition period involving both public and private sectors until it is now predominantly a private sector enterprise.

Public Sector Initiation Phase: 1951 - 1974

Prior to 1950 the only irrigation in what is now Bangladesh utilized manual lifting devices such as *doons* (open-ended canoe-like devices) and swing baskets drawing on surface water sources as well as dug wells to tap shallow groundwater aquifers. In the 1950s, however, public sector attempts to modernize irrigation were institutionalized with the creation of what are now called the Bangladesh Water Development Board (BWDB) in 1959 and the Bangladesh Agricultural Development Corporation (BADC) in 1961. BWDB was primarily involved in developing canal irrigation projects but from 1962-68 it also launched a tubewell project in the northwestern part of the country using 380 four cusec DTWs. For these wells the agency provided electricity generation, pump operation and water distribution to farmers' fields. The project was heavily subsidized and bureaucratically managed and performed very poorly in terms of pump capacity utilization, irrigation coverage, water management, O&M and cost recovery from water users (GOB and FAO/UNDP, 1977; Hamid, et al, 1978; Bottrall, 1983).

BADC first entered minor irrigation through an LLP system in 1961 and a DTW program the following year. The LLPs were initially operated by BADC's own field staff with diesel fuel supplied by the agency and the farmers being required to pay water fees on a unit area basis. In 1969, BADC started renting the LLPs on a yearly basis and the farmers had to pay for fuel themselves. The DTW program began with 200 two-cusec wells in the Comilla area between 1962 and 1970. These DTWs were about 75 per cent subsidized, were much less expensive than the earlier BWDB wells, and were rented to farmers' cooperatives (KSSs). BADC supplied fuel/oil and the Integrated Rural Development Program (IRDP) organized the cooperatives. These BADC DTWs did have a better performance than the BWDB ones in terms of yield and cost recovery but well capacity was still seriously underutilized (Alam, 1975). After Bangladesh's liberation war in 1971, BADC expanded its LLP and DTW rental programs and started to include STW rentals in the early 1970s --- the latter of which was converted to a sale program after 1974-75.

Public Sector Domination Phase: 1974-1979

A second phase of public sector control may be characterized by government attempts to rationalize its minor irrigation program so as to lighten the budgetary and management burden of running an expanded number of pump schemes. By 1980 there were roughly 10,000 DTWs, 35,000 LLPs and 22,000 STWs (Figure 2). BADC maintained its monopoly control over DTW and LLP procurement, installation and rental. However, for LLPs the agency stopped providing a pump operator -- which necessitated direct farmer input into O&M activities. Also, STW subsidies were dropped to a very low level and a credit program for STW purchase was put into place through the Bangladesh Krishi Bank.

Private Sector Expansion Phase: 1979-1984

From the late 1970s through the early 1980s there was a continued effort to decrease public sector involvement in /minor irrigation and a gathering momentum in private sector activity. The equipment rental programs were recognized as being too expensive for the public budget and as providing insufficient incentive for farmers to improve capacity utilization ([Biswas et al. 1978]; GOB/WB, 1982; Bottrall, 1983). Subsidized spare parts and repairs were also seen as creating a disincentive to the development of local repair facilities and manufacture of spare parts. As a result, there were simultaneous moves to discontinue LLP and DTW rental programs (though remnants of the DTW program lasted several more years) and shift to selling both new and old LLPs and DTWs to groups in the private sector. BADC continued its control of deep tubewell siting and installation and the provision of DTW spare parts and mechanical services through the late 1980s. For STWs, the boost of liberalized credit, decreases in import duties and the involvement of the private sector in equipment importation all led to a rapid increase in the number of wells. By 1983-84 the number of STWs was 120,000 -- though it was felt that progress could have been even faster if it had not been for cumbersome loan and tubewell sanctioning processes and failures within the agency bureaucracies which still provided spare parts and various other support services (Hamid, et al. 1982).

A Return Towards Public Sector Control: 1984-1987

In the 1983 dry season there was a greater than expected drawdown of groundwater in a number of northern districts (Gill, 1983). The alarm at this event seems to have triggered a response from the public sector that may have been partly a reaction to the erosion of agency control over minor irrigation during the previous decade. Actions taken in 1984 and 1985 included: a) a ban on STW sales in 22 northern sub-district areas; b) an embargo on the importation of the small diesel engines used in STWs; c) standardization of engine brands; and d) formulation of the Groundwater Management Ordinance imposing a mechanism of spacing requirements on all tubewells. In addition, agricultural loan disbursements were decreased following prior irregularities and large loan repayment defaults. STW engine distributors and importers were also vilified (Palmer-Jones, 1988). The result of these various actions was that STW expansion slowed in 1984 (Alam, 1984) and practically stopped during 1985 through 1987. Meanwhile, the groundwater level in the northern districts affected in 1983 had returned to normal in 1984 before any of the changed policies had taken effect.

More Private Sector Liberalization and Expansion: 1987-

The slow growth of the minor irrigation sector of the previous years prompted the government to remove the restrictions imposed earlier. In 1987 the ban on importation of small diesel engines was removed. In 1988-89 import duties on irrigation equipment were eliminated and the regulations on engine standardization and tubewell siting were rescinded. Private importation and sales of STWs and LLPs picked up sharply, though there was a temporary slow-down following a doubling of diesel fuel prices at the time of the Gulf War. There has been a maturing of the equipment market as it has spread from its earlier concentration in the national and regional centers to more fully serve district and sub-district areas. There has also been a proliferation of spare parts shops, repair workshops and private mechanic services at the local level.

DTW growth, however, has proven to be unsustainable in an unsubsidized environment. Major donors had continued to support large subsidies for this technology throughout the 1980s despite their poor economic showing and their frequent placement in areas best suited to STWs (Hanratty, 1983; Johnson, 1985). More recently, both donor and Government policy has turned against DTW subsidies. New DTWs are no longer being purchased. In addition, without an active DTW sales and installation program there has been concern in some regions about the adequate provision of spare parts and major repair facilities for existing engines and pumps. BADC has fully withdrawn from DTW support and the transition to complete private sector responsibility has been slow.

PERFORMANCE OF MINOR IRRIGATION PRIVATIZATION

The minor irrigation sector's transition from public to private control is now at a fairly advanced state of completion. What, then, has been the sectoral performance record that has accompanied this transition?

Growth in Irrigation Coverage

After 1979 the growth of STWs was very strong -- except for the period from 1984-87 when multiple government controls were imposed. Between 1979 and 1984 the number of STWs rose from 22,000 to 147,000 -- an annual rate

of 46% (Figure 2). Sales were almost non-existent in 1985 and 1986 and picked up only marginally in 1987. With the abolishment of the government's restrictive measures in 1987 and 1988, sales again rose and STW numbers swelled at an annual rate of 14%, growing from 159,000 in 1987 to 349,000 in 1993. The growth rates of area irrigated under STWs closely reflected those for STW numbers and by 1993 these wells served 1.4 million hectares (Table 2).

During this same period the number of LLPs (and associated command area) rose at 4.3% a year to a total of 52,000 (496,000 ha) in 1993. DTWs, all installed under heavily subsidized donor programs through BADC and BWDB, rose at a 5.5% rate to 26,000 in 1993 -- covering 437 thousand hectares.

By 1993, the three motor-driven minor irrigation technologies covered 2.3 million ha -- 26% of the nation's net cropped area, 34% of potential irrigable area and 82% of actual irrigated land. Seasonally, the growth in coverage has led to an increase in boro rice production from 2.6 million MT in 1981 to 6.8 million MT in 1992, an average rate of increase of 9.1% (Figure 1). Although the *aman* (rain-fed) rice crop still accounted for 51% of total rice production in 1992, boro's share of production had risen from 19% to 37% in the preceding decade. The expansion of minor irrigation during this period has provided the possibility of supplemental irrigation during aman, contributing to increases in its yield. In addition, diversification of such crops as vegetables, pulses, fruits, oilseeds and tubers has been promoted by the availability of irrigation.

Range of Equipment Choice

The move to the private sector along with the dropping of standardization requirements opened the market to equipment of a wider range of price and scale. When given the choice, prospective pump owners largely opted for the much cheaper (though less durable) Chinese engines over the choices previously forced on them through standardization policies. These less expensive engines, despite the farmers' awareness of their higher periodic repair costs, would appear to have better fit prospective pump owners' financial conditions than did the more costly ones. In addition, many farmers began to choose from the newly available range of horsepower open to them and thus were better able to fit the scale of engine to the amount of land (often fragmented) they wished to irrigate.

Spare Parts and Servicing of Irrigation Equipment

As BADC withdrew from supplying spare parts and providing repair services there was growth in private sector activity in these areas -- particularly in serving STWs and LLPs. Private workshops grew in most district towns and many sub-district centers and the number of mechanics in those centers as well as in the villages has also risen. Local manufacturers began to produce pumps and spare parts. In 1994 there does not seem to be a shortage of spare parts at the district and local levels. The quality and expected life of many of the popular inexpensive domestically produced parts, however, is less than those of imported ones.

DTW repair has become more of a problem since the withdrawal of BADC. The private sector supply of spare parts for DTWs is not as widespread as it is for STWs and LLPs. In addition, the specialized equipment needed for some types of DTW repairs is not fully available in the private workshops.

Capacity Utilization of Equipment

The operation of DTWs was primarily through a rental arrangement from BADC until the early 1980s when both new and used wells were offered for subsidized sale. As the rental wells sold very slowly, there were up to 12,000 DTWs under BADC's rental program for a further decade. In practice, the rental arrangement left the management of these wells almost wholly in the hands of some of the DTW users. BADC continued to be formally responsible for repairs and the irrigators for paying their rent -- though in a large number of cases these obligations were not fulfilled. Very often this situation resulted in poor tubewell maintenance as the locus of responsibility became blurred. It is perhaps partly for this reason (as well as due to the greater average age of the rental wells) that during the 1980s a trend seems to have developed in capacity utilization of DTWs (Figure 3). At the beginning of this period there was little difference in irrigated coverage between private and rental wells, with the rental wells perhaps showing a slightly better record. Later in the decade it became more and more common for private DTWs to have larger command areas.

STWs, though serving less land in absolute terms, have always displayed a higher proportionate coverage of their technically feasible command areas than have DTWs. Reasons for this may include:

a. Being unsubsidized, there has been an incentive for STW owners to cover as much land as possible.

b. As STWs are small and flexible they can easily be moved to places where they are best suited, even after their original installation -- a characteristic not shared by DTWs. In some areas STW engines are used for more than one boring, increasing their capacity.

c. Management of their relatively small areas is easier than for DTWs which typically have potential command areas which include the land of well over 100 irrigators.

Over time, for all types of minor irrigation equipment, there has been a slight downward trend in irrigation coverage per machine. Part of this trend can be explained by declining prices of rice and simultaneous increases in the cost of diesel and of inputs such as fertilizer. In some areas the rapid increase in minor irrigation equipment has led to competition for the command area -- with the more flexible and more easily managed STWs often "stealing" land not only from other STWS but often from what had earlier been DTW command areas as well. In some years in some places the number of pumping wells may also have caused a sufficiently large seasonal drawdown of the water table so as to affect the area covered. Overall, the reduction in irrigated coverage has been more pronounced among DTWs (both privately and publicly owned) than for STWs and LLPs.

Reliability/ Adequacy of Irrigation Water

It is very possible that the reliability and adequacy of the supply of irrigation water in part depends on private, and particularly on unsubsidized, ownership. One comparison between technologies showed that STWs (which are both privately owned and almost fully unsubsidized), due to their ease of management and relatively small command areas and volumes of water, had a better management performance ratio (the ratio between the total water applied and the amount of water demanded by the crops) than did DTWs (Dutta, 1993). Within a small sample of DTWs another comparison found that private wells provided water in a more timely and adequate manner than did rental wells (Hakim et al, 1991).

O&M Cost, Water Charge, Yield of Boro Rice

The costs of inputs to privately owned and operated minor irrigation equipment create a high cash need during the irrigation season. In 1991 this cash need increased dramatically as the price of diesel doubled during the Gulf war and has never returned to its prewar levels (Table 3). To meet these cash needs most minor irrigation charges have been high. Private wells, both STWs and DTWs, have in many cases had somewhat higher water fees than have rental DTWs. As a one-fourth crop share has been the most common fee arrangement during boro, the better water delivery of most private wells has been associated not only with better yields (which also depend on input use and soil quality) but also to a higher value of the water charge.

Profitability of Irrigated Boro Rice

The question of profitability is crucial to the sustainability of irrigated agriculture. While estimates vary, the authors' own calculations based on various assumptions regarding input and output quantities and prices show that irrigated boro cultivation is still normally profitable (Table 4). Profits have, however, declined during the 1980s due to rises in input costs relative to the price of rice (Mandal, 1989). Labor and irrigation costs together account for two thirds of the total cost of production so major increases in the prices of these inputs can greatly depress boro rice profitability. Returns to individual tubewell owners, therefore, can be quite unstable from year to year. These returns depend on area irrigated as well as on input costs. Farmers' demand for irrigation coverage fluctuates in response to the profitability of their crops, particularly of rice. For example, the authors found that in areas of Faridpur district the 1994 irrigation coverage of many wells was 25-30 percent less than that of the previous year because the 1993 price of paddy had been exceptionally low (Tk 4000/MT) and had discouraged farmers from planting boro in 1994. By contrast, in the Nilphamari area a high tobacco price in 1993 (Tk 32,000/MT) induced farmers to greatly increase their demand for irrigation in 1994 -- though a large reported drop in tobacco price in 1994 is likely to again change that story in 1995.

Access of the Poor to Irrigation

With the expansion of minor irrigation there has been an expressed concern as to who has gained access to the benefits of this technology. Small farmers constitute a large proportion of the total irrigators in the typical pump command area but together irrigate only a much smaller proportion of the land. This unequal share of small farmers to irrigated land is structurally embedded in the existing inequality of land ownership distribution. For DTWS it is also

possible that the high transactions costs of organizing big water groups may put small farmers within a well's nominal command area at a relative disadvantage in regard to gaining access to irrigation water. DTW owners may, in places, prefer to attain their actual irrigation coverage by serving a smaller number of relatively large land holders rather than a larger number of small farmers. This latter consideration is unlikely to be very large, however, as plot location relative to the pump site is also important. Nearby plots, whatever their owners' farm size, suffer less conveyance loss than do plots farther away.

When small farmers are looked not only as farmer irrigators but also as possible tubewell owners, the access question becomes more encouraging. Early results from a minor irrigation privatization study with which the authors are involved show that in the Bogra and Comilla areas, where private STWs have expanded very rapidly and intensively, a very high proportion (60% in Bogra and 80% in Comilla) of sample STW owners are small farmers who cultivate an average of only 1 hectare of land and sell water to other farmers. In Faridpur and Hobigonj, where STW irrigation has so far developed less intensively, a much smaller proportion of STW owners are small farmers (Figure 4). A study by Mandal (1993) also demonstrated that small and medium farmers have gradually been gaining access to ownership of STWs since the time when the private sector took over the equipment trade. Small farmers' choices and options to buy irrigation equipment have considerably widened with the liberalization of import rules permitting the sale of low-cost small engines (mainly from China).

The growth in small tubewell owners has greatly decreased the danger of what were earlier described as "landlords cum waterlords." Instead, small operators irrigate whatever land they have, sell water to other farmers and earn only normal profits (after capital and input costs as well as risk are considered). Many of these people have begun to supplement their income with other irrigation related activities -- as mechanics, drillers and spare-parts traders.

THE FUTURE: A CONTINUATION OF PRIVATE DEVELOPMENT OR A RETURN TOWARDS PUBLIC CONTROL

The transition from public to private control in the minor irrigation sector has, overall, had very positive results in the nature and pace of expansion of STWs and LLPs. Development has been rapid and small farmers would appear to be gaining access to the technology as they have been able to purchase inexpensive equipment of a scale that fits their needs and without having to undergo the transaction costs of dealing with public sector agencies. Private pumps seem also to be associated with a somewhat better delivery of water -- though, of course, at an unsubsidized water charge.

There are some unresolved issues, however. Public sector support to a privatized minor irrigation sector is currently underdeveloped. Such supports as aquifer and market information services, training, and better credit facilities could facilitate the functioning of private sector minor irrigation management. Also, the functioning of existing DTWs (even if few unsubsidized new DTWs are likely to be installed) is something of a concern. The better provision of major repair services for this technology may be of help.

Recently, concerns have also been expressed in some quarters regarding the possible negative impact of increased groundwater extraction through the private sector's expansion of tubewells. By these views, unregulated extraction of groundwater may lead to land subsidence, lowering of the underground water level, and a drying of drinking water pumps and surface water sources. The extent and duration of such damage is in some dispute -- though most of Bangladesh's shallow aquifers would appear to fully recharge each year and periods and places of seasonal excessive drawdown appear to be small. Particularly among some agency personnel, however, there are strong preferences for reimposing regulatory measures on groundwater exploitation (the Groundwater Management Ordinance of 1985 has been kept in abeyance but has not actually been abolished).

From the same sources there has also been an expressed concern to protect the prospective pump owners from unstandardized engines. There is an assumption that farmers purchasing irrigation equipment are unaware that the inexpensive imported engines which now prevail in the market are less durable and require more repairs than other options. In the field, however, farmers are found to be fully aware of the durability characteristics of their engine options. For them it would appear that lower initial cost and the availability of a variety of scales of engines are of most importance in fitting their needs.

While the development of public policy on these issues in the near future is not clear, the pro-regulation and pro-standardization positions are likely to get serious attention. From this paper's earlier examination of the evolution of minor irrigation privatization it was clear that whenever there was an increase in regulation and control from the public sector, the result was very sluggish growth in minor irrigation -- greatly retarding the transformation to a more profitable, equitable and productive agriculture. The costs associated with the (so far) limited and infrequent instances of excessive drawdown should be weighed against the likely large negative side effects of attempting to solve the problem through regulation. Similarly, a standardization position should take into account prospective pump owners' financial

Table 1. Amount of minor irrigation equipment operated and total area irrigated in 1992-93 in Bangladesh.

Irrigation Technology	No. of equipment operating	Area irrigated (ha)	% of total area irrigated by minor irrig.
STW	338,281	1,349,839	50.5
DSSTW	10,594	42,359	1.6
STW TOTAL	348,875	1,392,198	52.1
LLP (<1 CFS)	12,338	44,139	1.7
LLP (1 CFS)	15,429	105,961	4.0
LLP (2 CFS)	24,084	336,065	12.5
LLP (3-5 CFS)	366	9,843	0.4
LLP TOTAL	52,217	496,008	18.6
DTW	25,714	436,857	16.4
TREADLE PUMP	114,421	19,448	0.7
ROWER PUMP	8,307	975	0.04
HAND TUBEWELL	11,990	1,990	0.07
TOTAL MOP	134,718	22,413	0.8
ARTESIAN OR TRADITIONAL	713,660	323,034	12.1
TOTAL MINOR IRRIGATION	1,275,184	2,670,510	100.0 (of minor irrigation)
In Addition			% of all irrig. area
CANAL IRRIGATION	-	172,805	6.0
NATIONAL TOTAL	-	2,843,315	100.0

STW = Shallow Tubewell
DSSTW = Deep set Shallow Tubewell
LLP = Low Lift Pump
DTW = Deep Tubewell
MOP = Manually Operated Pump

Source:
1) DAE/ATIA (1994)
2) BBS (1992) SYB

Table 2: Total Area Irrigated by Different Irrigation Technologies from 1982-83 to 1992-93 in Bangladesh.

Years	Area Irrigated ('000 ha)					
	STW	DTW	LLP	TRADITIONAL	CANAL	TOTAL
1982-83	371.5	234.3	337.1	405.5	160.3	1508.7
1983-84	480.0	263.2	342.0	372.3	136.4	1593.8
1984-85	586.4	286.9	351.3	384.1	147.3	1756.0
1984-86	586.4	303.9	356.1	314.0	163.1	1723.5
1986-87	639.4	317.7	385.7	326.2	155.4	1824.4
1987-88	753.1	344.8	401.8	433.4	114.9	2048.0
1988-89	941.3	380.4	482.4	391.3	169.6	2365.0
1989-90	1037.2	384.1	484.0	477.9	176.4	2559.6
1990-91	1078.5	365.4	513.1	498.2	172.8	2628.0
1991-92	1233.9	433.8	500.2	316.5	172.8	2657.2
1992-93	1392.1	436.7	496.2	322.9	172.8	2820.7

Note: These calculations are based on assumed average command areas of 4 ha per STW, 17 ha per DTW and 9.5 ha per LLP. This assumption is somewhat unrealistic because the average command areas per unit of equipment are very likely to have declined over the years due to: a) competition (or encroachment) for irrigable plots between units; and b) the introduction of smaller engines for use with both STWs and LLPs in recent years.

Source: David (1994)

Table 3. Yield of Boro rice, O & M Costs and Water Charge in the Boro Season

Management system/ Technology	Area irrigated (ha/well)	Yield (MT/ha)	Average O & M cost (Taka/well)	Average O & M cost (Taka/ha)	Average water charge (Taka/ha)	Water charge as as % of O & M cost
Rental DTW (Rajshahi)						
1990	21.6	3.4	36390	1685	3272	194
1991	15.6	4.6	51591	3320	4026	121
Private DTW (Rajshahi)						
1990	23.7	4.8	37921	1602	3928	245
1991	18.01	5.6	62534	3472	6621	190
Private & Rental DTW (Tangail)						
1990	15.78	4.4	37520	2378	5610	236
Private & Rental DTW (Jhenidah)						
1990	19.00	4.29	39980	2104	3490	166
Private STW (Tangail)						
1990	4.28	4.6	12800	2990	5665	196
Private STW (Jhenidah)						
1990	2.52	4.7	7749	3075	6414	208

Notes:

a. Currently 1 US $ = Approx. Taka 40

b. Diesel price was raised by the government from Taka 6.90/liter to Taka 14.14/liter

c. One-fourth share of the crop was paid as water charge for Tangail DTWs and STWs

Sources:

i. Data for Rajshahi DTWs are from Hakim, et al, 1991.

ii. Data for Tangail and Jhenidah STWs and DTWs were compiled from a Field Survey conducted by Mandal in 1990.

Table 4: Estimated Costs and Returns of Tubewell Irrigated HYV Boro Paddy per Hectare (at 1994 prices).

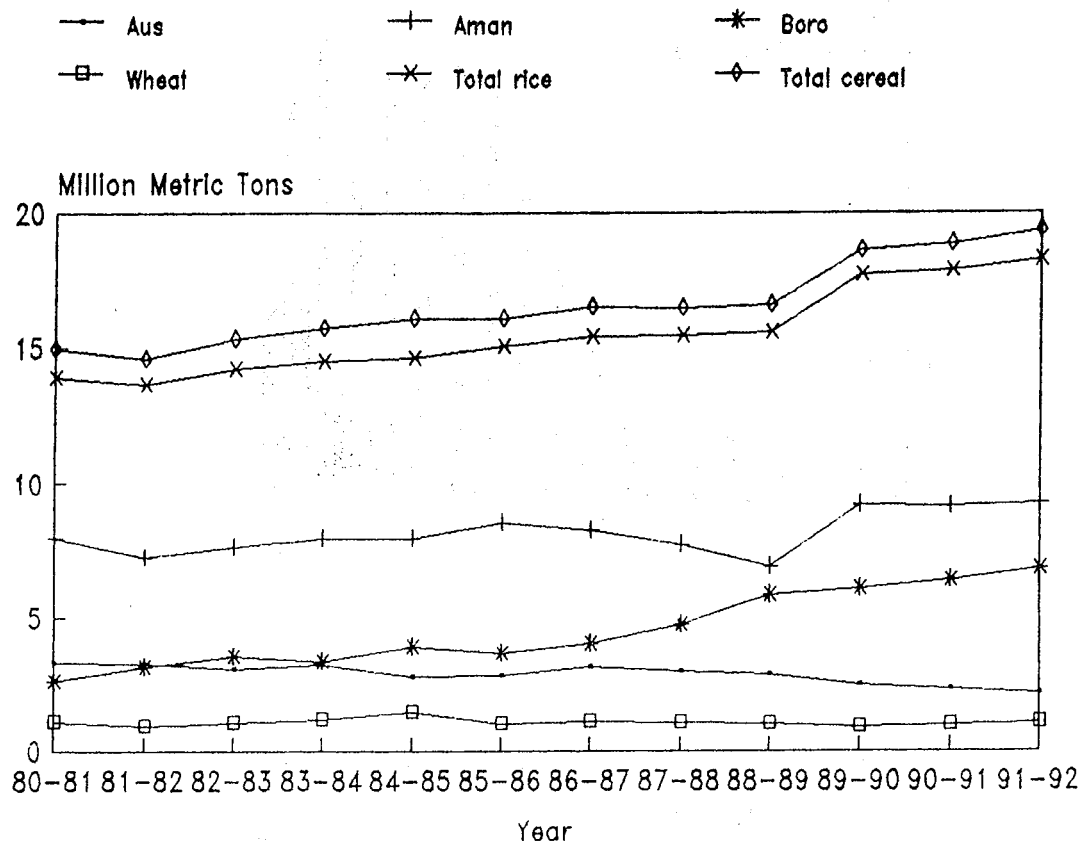
Items	Quantity	Value (Taka)	% share of total return
A. Total Returns		26940	100
Paddy	4.2 MT X Taka 6200/MT	26040	97
Straw	3.0 MT X Taka 300/MT	900	3
B. Total Costs		19263	72
Labor	200 manday X Taka 40/day	8000	30
Tillage	45 bullock pairday X Taka 50/pairday or power tiller services	2250	8
Seedling	Assuming some home grown & some purchased seedlings	800	3
Fertilizers:			
Urea	240 kg X Taka 6/kg	1440	6
TSP	126 kg X Taka 8/kg	1008	4
MP	40 kg X Taka 8/kg	320	1
DAP	5 kg X Taka 9/kg	45	0
Pesticides	-	400	1
Irrigation	Assuming cash payment in 3 installments	5000	19
C. Net Returns (A - B)		7677	28

Currently 1 US $ = Approx. Taka 40

Sources:

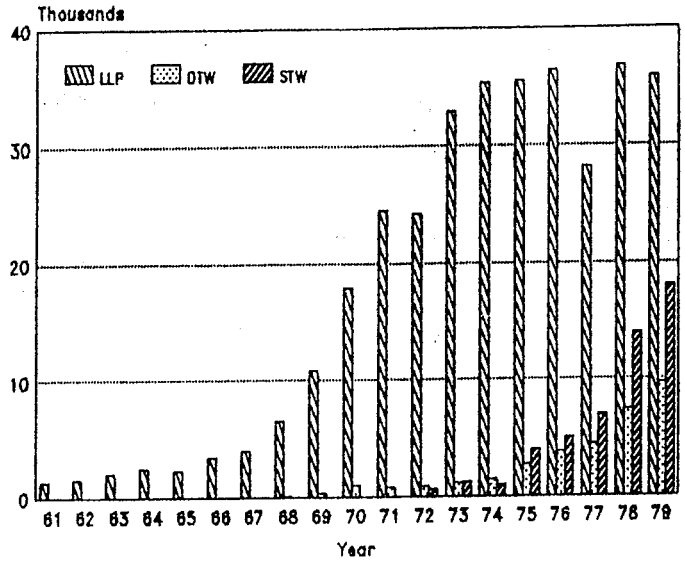
Estimates are based on data regarding physical input and output quantities from the Agro-Economic Research Unit (1988), Gisselquist, 1991 and several recent M.Sc. Agricultural Economics theses submitted to BAU, Mymensingh. The input and output prices, and the needed adjustments in input and output quantities are based on the authors' field trips to different districts during the 1994 irrigation season.

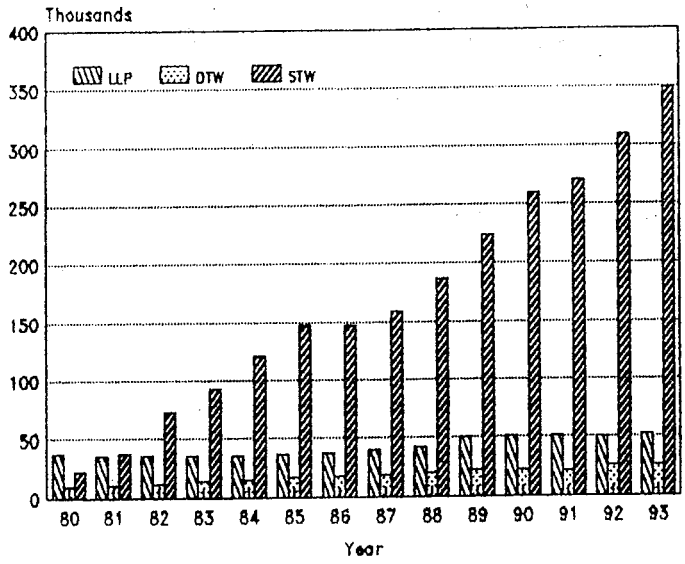
Figure 1. Total cereal production in Bangladesh, 1980-81 to 1991-92.



Sources: BBS, 1990; 1992; 1993; Khalil, 1991.

Figure 2. Number of minor irrigation equipment in Bangladesh, 1961-62 to 1992-93.

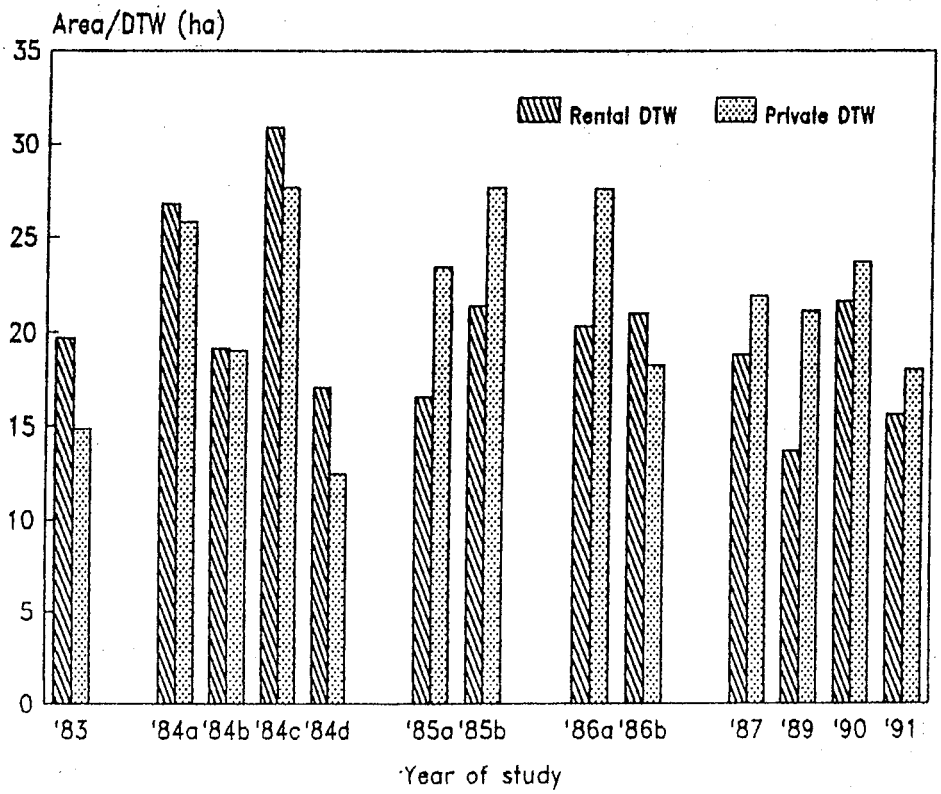




Note: Years refer to financial years, e.g., 80 refers to 1979-80 and so on.

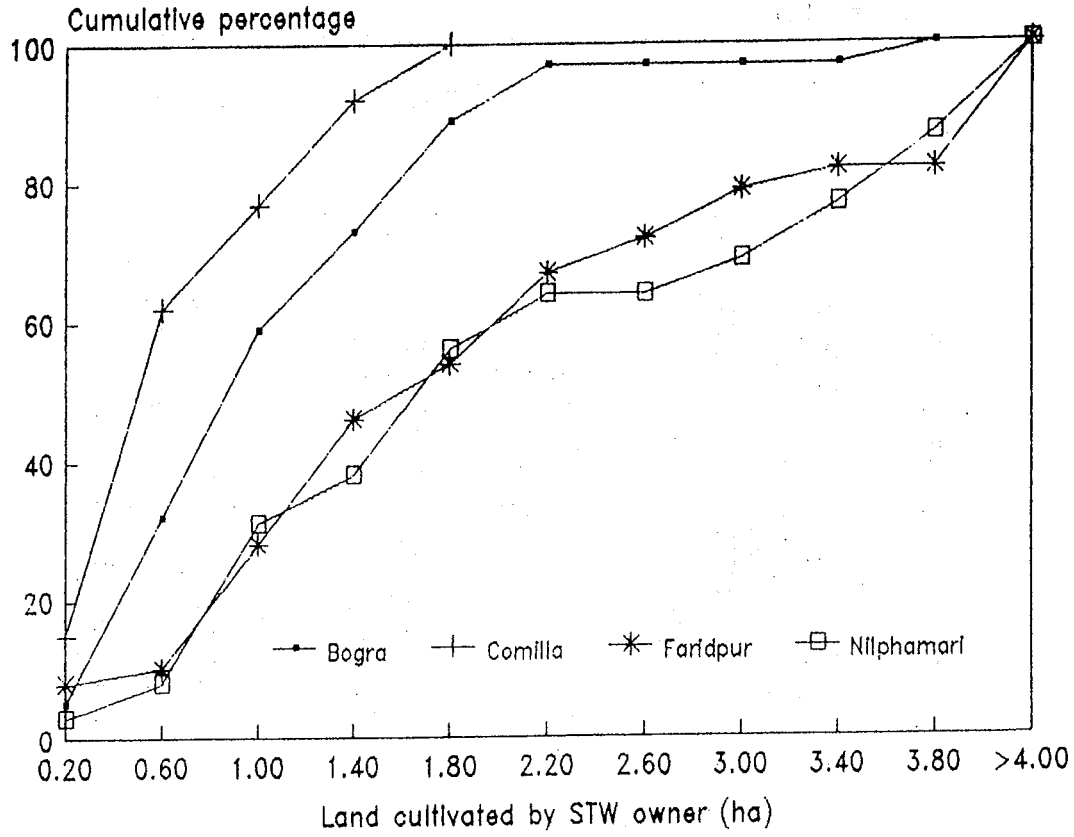
Sources: Hanratty, 1993; Gisselquist, 1991; David, 1994; Hamid, 1991; BBS, 1993; AST, 1989, 1991; DAE/ATIA, 1994.

Figure 3. Irrigated boro area per DTW (ha).



Note: '83 refers to 1983 and so on.

Figure 4. Land cultivated by STW owners (ha).



Source: Preliminary calculation from IIMI/BSERT Data, 1994.

References

Agricultural Sector Team (AST). 1989. Census of minor irrigation equipment. Bangladesh-Canada Agriculture Sector Team.

Agricultural Sector Team (AST). 1991 Census of lift irrigation, 1991.Bangladesh-Canada Agriculture Sector Team.

Agro-Economic Research Unit. 1988. Cost of cultivation of boro paddy, 1986-87. Summary report. Ministry of Agriculture, Government of the People's Republic of Bangladesh.

Akteruzzaman, Md. 1990. A comparative economic study on productivity and equity performance of deep tubewell irrigation under different management systems in a selected area of Comilla district. Unpublished M.Sc. Agricultural Economics Theis. Mymensingh : Bangladesh Agricultural University, Mymensingh.

Alam, Mahmudul. 1975. Capacity utilization of deep tubewell irrigation in Bangladesh : a time series analysis of Comilla thana. The Bangladesh Development Studies, 3(4) : 495-504.

Alam, Jahangir. 1984. Evidence of the causes of low sale of STW irrigation sets in 1983-84 : Implications for policy and research. Dhaka : Bangladesh Agricultural Research Council.

Bangladesh Bureau of Statistics (BBS). 1993. Statistical yearbook of Bangladesh, 1992. Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh.

Bangladesh Bureau of Statistics (BBS). 1992. Yearbook of Agricultural Statistics of Bangladesh, 1992. Dhaka : Bangladesh Bureau of Statistics.

Bangladesh Agricultural University (BAU). 1985. Evaluating the role of institutions in irrigation programme. Workshop proceedings, IWM-11. Bangladesh Agricultural University, Mymensingh.

Bangladesh Bureau of Statistics (BBS). 1990. Statistics Yearbook of Bangladesh. Dhaka : Bangladesh Bureau of Statistics.

Bashar, M.A. 1987. Farm survey data. Department of Agricultural Finance, Bangladesh Agricultural University, Mymensingh.

Biswas, M.R. [et al.] 1985. An investigation into the factors affecting the command area of different irrigation facilities in Bangladesh. Research report. Mymensingh: Bangladesh Agricultural University and Bangladesh Agricultural Research Council.

Bottrall, Anthony. 1983. Review of irrigation management practices in Bangladesh. Dhaka : Bangladesh Unnayan Parishad.

David, W.P. 1994. Minor irrigation development in Bangladesh. Background paper No. 4. Paper presented at the DAE/ATIA workshop in Research to Promote Intensive Irrigated Agriculture. Khamarbari, Dhaka.

Directorate of Agricultural Extension (DAE/ATIA). 1994. 1992-93 census of minor irrigation in Bangladesh. Ministry of Agriculture/FAO.

Dutta, S.C. 1993. On-farm irrigation management for diversified crops. In : M.R. Biswas and M.A.S. Mandal. (ed.). Irrigation Management for crop diversification in Bangladesh. Dhaka : University Press Limited.

Gill, Gerard J. 1983. The demand for tubewell equipment in relation to groundwater availability in Bangladesh. Dhaka : Bangladesh Agricultural Research Council.

Gisselquist, David. 1991. Development potential of minor irrigation in Bangladesh. A report prepared for the Agriculture Sector Team. Dhaka.

Government of Bangladesh (GOB)/ World Bank. 1982. Bangladesh minor irrigation sector. Dhaka : Planning Commission, Government of the People's Republic of Bangladesh.

Government of Bangladesh (GOB) and FAO/UNDP. 1977. Irrigation policy. Working paper VIII. Dhaka. Government of the People's Republic of Bangladesh.

Hakim, M.A., M.A. Ghani and D.E. Parker. 1991. Deep tubewell irrigation under alternate management. Paper presented at the IIMI/BRRI/IRRI workshop on Applied Research for Increasing Irrigation Effectiveness and crop Production. Dhaka; Bangladesh, 8-9 October 1991.

Hamid, M.A., S.K. Saha, M.A. Mannan and A.J. Khan. 1978. Irrigation Technologies in Bangladesh. Rajshahi: Department of Economics, Rajshahi University.

Hamid, M. A. 1991. A data base on agriculture and foodgrains in Bangladesh. Dhaka.

Hamid, M.A., M.K. Mujeri, M.R. Hasan, M. R. Islam and M.S.Islam. 1982. Shallow tubewells under IDA Credit in Northeast Bangladesh. Rajshahi: Department of Economics, Rajshahi University.

Hamid, M.A. 1993. Improving the access of the rural poor to groundwater irrigation in Bangladesh. In : Friedrich Kahnert and Gilbert Levine (ed.). Symposium on groundwater irrigation and rural poor: Options for development in the Gangetic basin. Washington D.C.: World Bank.

Hanratty, Martin. 1983. Minor irrigation development in Bangladesh. USAID, Bangladesh.

International Irrigation Management Institute and Bureau of Socio-Economic Research and Training. 1994. Field data from a study on privatization of minor irrigation. IIMI, Dhaka.

Johnson III, Sam H. 1985. Economic and technical criteria for location of deep and shallow tubewells. WM-15-85. Dhaka: Bangladesh Agricultural Research Council and International Agricultural Development Service.

Khalil, Md. Ibrahim. 1991. The agricultural sector in Bangladesh a database. Dhaka : USAID.

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

Mandal, M.A.S. 1984. Farm survey data on deep tubewell command areas, 1983-84. Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh.

Mandal, M.A.S. 1993. Groundwater irrigation in Bangladesh : access, competition and performance. In: Friedrich Kahnert and Gilbert Levine (ed.). Symposium on groundwater irrigation and rural poor: Options for development in the Gangetic basin. Washington : World Bank.

Mujibullah, M.d. 1987. A comparative study of deep tubewell irrigation performance under different irrigation and management practices in some selected areas of Gazipur district. Unpublished M.Sc. Agricultural Economics Thesis. ymensingh : Bangladesh Agricultural University, Mymensingh.

Palmer-Jones, R.W. 1988. Groundwater irrigation in Bangladesh. Draft report for the Agricultural Sector Review. Government of the People's Republic of Bangladesh/UNDP.

[Pitman, G.T.Keith. 1990]. National Water Plan in Bangladesh, 1985-2005 : the role of groundwater in irrigation development. In: Friedrich Kahnert and Gilbert Levine (ed.). Symposium on groundwater irrigation and the rural poor: Options for development in the Gangetic basin. Washington : World Bank.

Quasem, Md. Abdul. 1985. Impact of the new system of distribution of irrigation machines in Bangladesh. The Bangladesh Development Studies 13(3 & 4) : 127-140.

Shikder, P.K. 1986. A comparative economic study of private and rented deep tubewells in some selected areas of Mymensingh and Tangail districts. Unpublished M.Sc. Agricultural Economics Thesis. Mymensingh : Bangladesh Agricultural University, Mymensingh.