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Irrigation Institutions of Bangladesh: Some Lessons

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1. Introduction

The objective of this chapter is to highlight some issues of existing irrigation institutions and their impact on cost and price of irrigation water in Bangladesh agriculture. Water is scarce in winter and agriculture is the major water using sector for irrigation in Bangladesh. The study mainly deals with how public institutions and water markets have evolved over time in response to changes in irrigation technology and how they affect the cost and price of irrigation water. There are many government run irrigation projects in the Northwest region (NW) of Bangladesh. Recently Bangladesh Water Development Board (BWDB) has handed over these irrigation projects to water user groups (mainly medium and large farmers) for management and cost recovery.

At present there are 5 types of irrigation systems which have given rise to different institutional setups. These institutions play a crucial role in water pricing. Both government and the private sector have been practising various methods over time for water allocation to the farmers' fields. The objective of this study is to examine how these institutions have come into existence as they are responsible for shaping water prices both in the public and private sector. Currently the public sector is responsible for maintaining the surface water irrigation projects which is only 10 percent of the total irrigation. The rest is the private sector mainly groundwater irrigation using minor irrigation devices. In the NW region irrigation is almost entirely dependent on groundwater due to scarcity of surface water. In December 2007 I had a focussed group discussion in the NW region of Bangladesh and use the results to understand how irrigation institutions are working in the region and how it affects irrigation cost and volumetric price per unit of water. Farmers in Bangladesh do not pay per m^3/litre for irrigation water; they pay for pumping cost if any and labour charges when required.

Bangladesh is an agricultural country divided into 7 hydrological regions. The average annual rainfall varies from 1,200 mm in the extreme west to over 5,000 mm in the northeast (WB, 2000). About 80 percent of the total rainfall occurs during the monsoon from June to September. In the post-monsoon (October -November) and winter period (December - February) only 10 percent of the annual rainfall is available (WB, 2000). Rainfall is extremely unreliable in the subsequent pre-monsoon period (March - May). On an average there is about 10 percent of the annual rainfall in this period (WB, 2000). On the whole there is a seasonal lack of water depending on the presence and the duration of the monsoon. Water is very scarce in the south and northwest region of Bangladesh during the winter.

Being a country of 140 million inhabitants, agriculture is still the major water using sector for surface and groundwater irrigation with rice cultivation, the single most important activity in the economy. In winter more than 70 percent of crop production is *boro* rice. *Boro* rice is a major food crop which uses up a lot of water per hectare (ha) in the production process. According to one estimate of Biswas and Mondol (1993) it is 11, 500 m^3 per ha. Demand for both surface and groundwater for irrigation is on the rise in the dry season which is 58.6 percent of the total demand for water (Chowdhury, 2008) in order to feed a growing population where at least 40 million people do not have a square meal.

Between 1944 and 1999 BWDB spent more than US$1700 m on flood control drainage irrigation (FCDI) projects (WB, 2006). Recently BWDB has handed over these projects to water user groups (mainly medium and large farmers) on the basis of average pricing. This gives rise to a conflict of interests between very small, small farmers and the WUG and hence it is not functional as it should be. More over water has many other uses in the society, fisheries, navigation, mangrove forests, river morphology and not to mention household and industrial uses. Therefore during the dry season water has a high opportunity cost due to competition from all the uses in addition to upstream intervention. It is imperative that farmers pay the true opportunity costs of irrigation water from the perspective of sustainable water use.

International Rice Research Institute (IRRI) conducted an Agricultural Household Survey in Bangladesh in 2000, 2004 and 2008 for 3 crop seasons and collected data on costs of inputs (including irrigation water) and returns on investment from a nationally representative sample of 1880 farm households from 62 villages belonging to 57 of 64 districts of Bangladesh. But the data do not have any information on the volume of irrigation water used in the fields or price per unit. Irrigation is the total irrigation costs measured in BDT (Bangladesh Taka) and we do not know the price per unit of water or the number of hours the pump is used for pumping water. The data available are for total cost of irrigation per household. The costs of irrigation are basically the costs of pumping water. Farmers mainly use low lift pumps for pumping water from surface water sources and shallow and deep tube wells from aquifers and groundwater. I conducted a focussed group discussion in the Northwest region to validate the IRRI data findings about irrigation costs and gather some information about the per unit water costs/prices they bear/pay for using different types of irrigation. Focussed group discussion is useful in case of small samples as opposed to other methods for gathering information within a short time.

2. Irrigation institutions

The 5 types of irrigation systems are traditional or local method, canal irrigation project of the government, low lift pump, shallow and deep tube well. When surface water was abundant farmers solely depended on rivers, canals and ponds to irrigate their fields with traditional local methods where the maintenance cost of the apparatus and labour charges when required constituted the costs of irrigation. With the growing population and the introduction of high yielding varieties of rice the government built huge surface water irrigation projects to take care of dry season irrigation. The cost of irrigation became the maintenance of the field channels from the tertiary outlets to the farmers' fields. With the scarcity of surface water in the rivers and canals and advent of groundwater irrigation farmers started paying for pumping water which consists of maintenance of the pumps, fuel cost (electricity or diesel) and the salary of the pump mechanic if required. Farmers use low lift pump to pump water from surface water sources and shallow or deep tube wells for groundwater which are known as minor irrigation devices. The use of low lift pump is limited by the availability of surface water in the canals and rivers during the dry season. Most deep tube wells are government owned and maintained by the public authority. The rest are run on a cooperative or joint ownership. Since investment in deep tube well is lumpy in nature farmers prefer shallow tube wells. Therefore the public sector irrigation institutions are the ones that are taking care of canal irrigation projects of the government and will be discussed in section 2.1. The private sector is the groundwater irrigation using minor irrigation devices to be dealt with in section 2.2.

2.1 Public sector

In Bangladesh irrigation is mainly for *boro* rice production in addition to wheat and some other winter crops. Since the 1950s more than 600 water resources schemes have been completed (WB, 2006). These projects ranged from single structure schemes with an impacted area of less than 1,000 ha to large scale multipurpose schemes potentially impacting as much as 100,000 ha. Most were designed to provide flood control, drainage, irrigation or some combination of these. In the late 1950s the government emphasised large scale surface water development projects. Some of the biggest surface irrigation projects are GK (Ganges-Kabodak) project, Pabna Irrigation project, Meghna-Dhonogoda project, Chandpur Irrigation Project, Karnaphuli project, Kaptai project, DND project, Narayanganj-Narshingdi Project, Teesta Project etc. In the mid 80s there was a major breakthrough in HYV (high yielding varieties) rice cultivation through the innovation of Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI) and which was possible due to large surface water irrigation projects.

These systems are being run by public agencies like BWDB, Bangladesh Rural Development Board (BRDB) etc. at the district and Upazila level. BWDB is the major public sector agency under the Ministry of Water Resources responsible for planning and execution of over 400 projects developing flood control, drainage and surface water irrigation projects. It also shares an interest in groundwater irrigation as well as in minor surface irrigation with BRDB, Bangladesh Agriculture Development Corporation (BADC) and Local Government Engineering Department (LGED). Earlier, this organization was pioneer in tapping ground water for irrigation in the northern Bangladesh; but subsequently its role in groundwater development was overtaken by BADC and later on by private sector. Major investments in the water sector are made by the Ministry of Water through BWDB and by the Ministry of Local Government and Rural Development through its LGED.

Participatory water management

In 1994 the Ministry of Water Resources formulated guidelines for people's participation in water development projects to involve local people in water resource projects with the help of officials and experts from BWDB, LGED, Water Resources Planning Organisation (WARPO), BADC, Department of Agricultural Extension (DAE), Department of Environment (DOE), Department of Forestry (DOF) and the Department of Livestock (DOL).

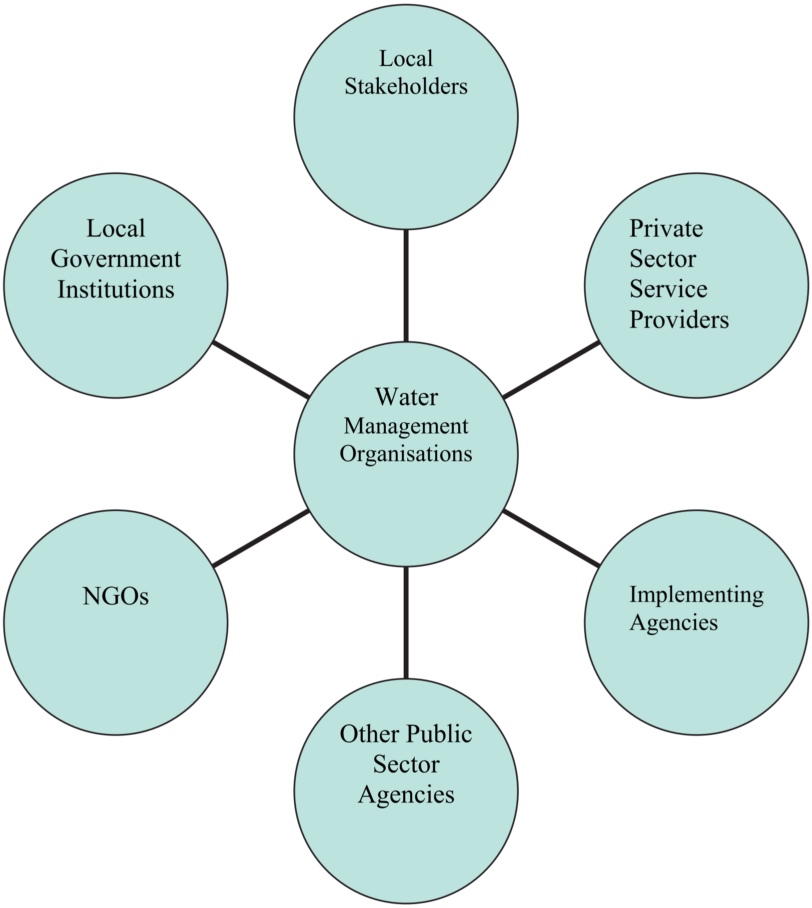

Fig. 1. Stakeholders of Participatory Water Management

Source: Ministry of Water Resources, GOB (2001)

Implementing Agencies are BADC, BWDB, LGED, Barind Multipurpose Development Authority (BMDA) and DOF. Other public sector agencies include DAE, BRDB, Forest Department (FD), DOE, BIWTA, Bangladesh Inland Water Transport Corporation (BIWTC), Department of Cooperatives (DOC), Department of Livestock Services (DLS), Ministry of Land (MOL) and Ministry of Women and Children Affairs (MWCA).

The principle that community resources must be managed by the community concerned along with local government institutions guides participatory water management. The National Water Policy emphasises the issue of participatory water management through planning, stakeholder participation, public and private management, economic and financial management and institutional policy. Local Governments (Parishads) are the principal agencies for coordinating the design, planning, implementation, and operation and maintenance (O&M) of publicly funded surface water resources development projects. The participatory process also depends on NGOs and community level self-help groups (private).

The institutional framework of participatory irrigation management (PIM) in which the local stakeholders participate commenced in 1995, introduced a three-tier management structure for irrigation systems. This involved creating tertiary-level Water Management Groups (WMGs; each consisting of nine members—three from each of three farm-size categories: 'large', 'medium' and 'small'); secondary level Water Management Associations (WMAs; consisting of 10-15 WMGs); and a Water Management Federation (WMF) at the highest level of a system. Water Management Organisations are responsible for planning, implementing, operating as well as maintaining local water schemes in a sustainable way. They also contribute towards the capital and operating costs of the scheme as decided by the Government or on a voluntary basis acting in their own interest.

Ownership of flood control drainage irrigation (FCDI) projects with command area of 1000 ha or less is gradually transferred to the local governments with the ones that are satisfactorily managed and operated by the beneficiary/community organisations. The management of public water schemes with command area of up to 5000 ha are gradually made over to local and community organisations and their O&M are to be financed by local resources. Public water schemes with command area over 5000 ha are gradually given to private management through leasing, concession, or management contract under open competitive bidding or jointly managed by the project implementing agency along with local government and community organisations.

Appropriate public and private organisations provide information and training to the local community organisations for efficient management of water resources. For minor irrigation stakeholders participation is confirmed by their willingness to commit to financial contributions before receiving services. In case of FCDI projects water rates are charged for O&M as per government rules. Water charges realised from beneficiaries for O&M in a project are retained locally for the provision of services within that project. Some use an informal structure while others use a formal structure with legally registered organisations according to the guidelines for participatory water management.

BADC during its programme to expand groundwater irrigation required WUGs to be formed. The Barind Multipurpose Area Development Project has successfully used cooperatives for water management. The Ministry of Agriculture has a shared experience in participatory management under National Minor Irrigation Project (NMIP) where beneficiaries voluntarily re-excavated canals to support LLP irrigation. The Department of Public Health Engineering has also introduced participatory management to support rural water supply and sanitation program. An important development in participatory management has been in Small Scale Water Resources Development Project of LGED. The beneficiaries have participated in the water management projects right through its initiation by making a percentage payment toward investment and for operating and managing the project entirely by them.

Much effort was given in the past two decades to review stakeholders' participation under the Dutch aided Early Implementation FCD projects, and IDA (International Development

Assistance)/CIDA (Canadian International Development Assistance) assisted small-scale FCDI projects. This initiative was later enforced through Flood Action Plan (FAP) studies and the System Rehabilitation Project (SRP) of the BWDB. Lately, the LGED started developing small irrigation projects having an area less than 1000 ha in order to improve efficiency and coordinate better with other infrastructure building efforts.

However, except for a very few, the experience of participatory management has been a mixed one. Progress in creating and developing these user groups has been slow, and the irrigation sector continues to be managed at all levels by public-sector agencies. Perhaps, it is due to some gap at the initial stage of the project preparation where it might not have been possible to involve the beneficiaries at all stages of project cycle. Although the guidelines for participatory water management are an excellent starting point to promote local stakeholder involvement in water management infrastructure these are inadequate in promoting meaningful participation (WB, 2006). Rather than establishing the mechanisms to improve agencies ability to respond to local stakeholders, the guidelines encourage the participation from the perspective of achieving the objectives of the executing agencies.

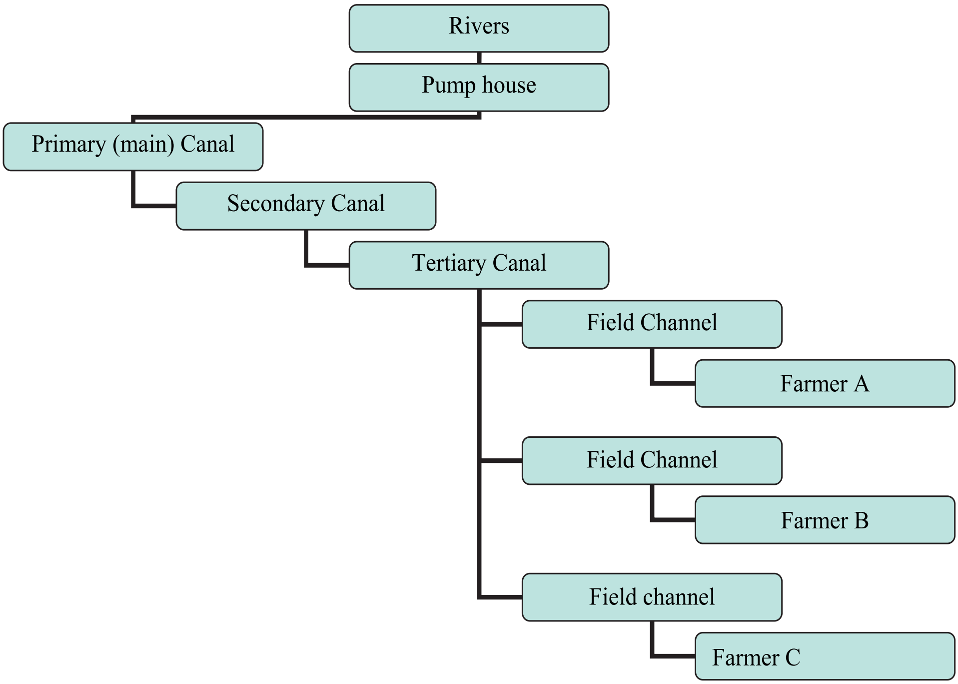

Fig. 2. National Surface Water Irrigation Distribution Systems

Individual farmers get water in their fields through the field channels. Farmers are responsible for maintaining the field channels from the tertiary canals.

Some case studies

There are 3 types of institutional models for large scale surface water irrigation schemes in Bangladesh. The BWDB controls Meghna-Dhonagoda Project and Pabna Irrigation Project down to the tertiary outlets and work with the registered user groups organised in several tiers under the cooperative system. The user groups collect water charges and participate in overall scheme management and operation and maintenance. Asian Development Bank (ADB) supports these schemes. Also irrigation schemes are managed by an authority like BMDA.

Pabna Irrigation and Rural Development Project (PIRDP) is located on the floodplain of the Brahmaputra and Hurasagar rivers (west-central Bangladesh). This project aimed to provide flood control, drainage, and irrigation facilities. The total project area is 186,000 ha and the area irrigated is 145,000 ha. 77 percent of the total rainfall occurs between mid June and mid October. Rice is the major crop grown on 64 percent of the total cropped area. Other crops are pulses, potato, jute, sugarcane, vegetables, onion, wheat and oilseeds. Land is inequitably distributed average landholding is 0.92 ha. 6% of landowning households own 25% of the available land and 14% households are landless. 78% households own 1 ha of land or less. The average annual incomes of small-, medium-and large-scale farmers are USD 487, USD 846 and USD 1,347, respectively. The net value of crops produced per ha is USD 203. The net benefit of irrigation is USD 125/ha. The irrigation benefits mainly result from access to water and use of HYV technology on the irrigated land. Farmers with very small landholdings (less than 1 ha) obtained higher yields per ha than larger landholders. This is because the land-poor farmers use the available water more efficiently, grow HYVs of rice on a greater proportion of their land, and irrigate more intensively than farmers with more land.

Only 2 of the 365 WMGs formed have been registered with the government. These groups do not assess or collect irrigation charges, or dictate how the revenues are spent. These functions are still being performed by the BWDB. Since user groups have not yet taken on this role, as originally envisioned, collection rates remain very low, 9% of the target. Water charges are not based on the volume of water used, but on (1) the area irrigated (irrespective of the size of the farm), and (2) the type of crop grown (depending upon its water requirements). Charges average around BDT 540/acre (USD 22.39/ha).

The **Thakurgaon Irrigation Project** consists of a cluster of deep tube wells and is transferred to a private company established by the local stakeholders who sells water on a pay as you use system. The project is now running successfully where payments are made in advance to pump operators at a specified unit rate and they provide water to the farmers within the command area according to the terms of payment on a first come first served basis. The system provides for long term management, operation and maintenance for the equipment.

In case of **Muhuri Irrigation Project** there is no functioning organisation of local stakeholders and also there is no opportunity for minor irrigation development. Therefore large scale surface water management infrastructure is the only alternative and the project infrastructure provides farmers with flood control and access to surface water for irrigation through a network of secondary channels. As the system does not extend to the tertiary level and beyond development costs are lower but farmers are responsible for obtaining, operating and maintaining their own pumps to abstract water from these channels and for the associated field distribution systems. However the major infrastructure constructed was of good quality and continues to function effectively and provide the anticipated benefits.

At present the best institutional model is the ADB financed Small Scale Water Resources Development Sector Project which provides flood control, drainage or irrigation infrastructure to subproject areas less than 1000 ha. These projects rely heavily on local stakeholders' initiative to identify interventions, ratify engineering designs, demonstrate commitment to operate and maintain the infrastructure by contributing a specified amount of funds in advance of physical construction. The projects are implemented by the LGED with support from the ADB and the Government of Netherlands. In some cases low quality infrastructure, shortcuts in the development process and inconsistency are responsible for failure. In order to make water management investments pro local stakeholders' financial responsibility, decision-making authority and accountability must be transferred to local stakeholders and their representatives – the local government. Investments have to be structured so that service agencies are obligated to cater the end users requirements.

2.2 Private sector groundwater irrigation

After 1974 many surface water irrigation projects like the GK project became ineffective due to operation of the Farakka Barrage. Also these projects had long gestation periods, suffered from management and maintenance problems and were unpopular with farmers because the distribution canals took up scarce land. In 1980s, there was a surge in private sector involvement in ground water extraction mostly by shallow tube wells. At present the role of BADC is very minimal. Over time the government shifted emphasis to small scale projects, fielding power pumps to lift surface water from creeks and canals and tube wells for extraction of groundwater. Since then many farmers switched to 2 rice crops and vegetables and other crops which require much less water instead of 3 rice crops during the *boro* season and also moved to shallow tube wells instead of deep tube wells. This was the time when government emphasised groundwater irrigation.

Private sector groundwater development for irrigation has been instrumental in expanding agricultural output. It is also recognised that the development of groundwater for irrigation has virtually required no public sector financing in contrast to a huge capital cost of surface water systems ranging from USD 500 to 1800 per ha. Capital investment in the Teesta Project was about USD 250 m in 1985 to develop 100,000 ha of irrigation. It is further recognised that farmers readily mobilise the financial and technical resources to operate and maintain groundwater irrigation infrastructure whereas in surface water systems, in most cases the cost of irrigation user fee collection has exceeded the fees collected. The NWMP also notes that irrigation intensities are low on the 15 major existing irrigation schemes. On the whole, the large scale surface water irrigation projects do not have a good performance record. Minor irrigation is a source of net revenue (diesel tax revenue less electricity subsidies). Diesel is used to power about 90 percent of pump sets and irrigates 70 percent of the area. Electricity powers the rest. Present price policy subsidise electricity while diesel is taxed. As the end user farmers own the equipment and usually provide irrigation water to neighbouring plots at competitive prices. Infrastructure quality, management and operation, maintenance and benefits are not issues. The individual owners ensure that their requirements for the equipment and its use are met.

Irrigation has expanded to more than 50 percent of cultivated land (Hossain et al, 2007) and is provided through minor irrigation devices such as low lift pumps (LLP), shallow tube wells (STW) and deep tube wells (DTW). Initially LLPs, DTWs and STWs were supplied by Bangladesh Agricultural Development Corporation (BADC) a public sector organisation.

Since the early 1980s the government has privatised the procurement and distribution of minor irrigation equipments, reduced import duties and removed the restriction on the standardisation of irrigation equipments. As a result farmers have made substantial investment in shallow tube wells and power pumps contributing to rapid expansion of irrigation facilities since the mid-1980s. The area irrigated by tube wells expanded from 53, 000 ha in 1973 to 3.3 m ha in 2000 (Hossain et al, 2007). Shallow tube wells and power pumps accounted for 71 percent of total irrigated area in 2000. Small scale private investment on low lift pumps and tube wells and development of a competitive market for water transactions from tube wells to small and marginal farmers accelerated rapid expansion of irrigation. The diffusion of modern variety *boro* rice is strongly related to groundwater irrigation expansion. After the privatisation of minor irrigation LLPs and STWs became more popular compared to DTWs which required high initial investments.

Bangladesh is a delta composed of ridges and troughs. Soil texture is heavy on troughs and light on ridges. Plots on high land have different cropping patterns due to different soils, flooding regimes and access and returns to irrigation sources compared to medium and lowland (Palmer-Jones, 2001). Water loss from canals is high on more elevated land with light textured soils. Low land is suitable for rice cultivation since it is permanently waterlogged. Returns to irrigation are spatially variable due to soil and hydro-geological characteristics.

Modern irrigation mainly consists of STW which has almost replaced LLPs and is gradually displacing DTWs which are economically and socially unfavourable. The remaining DTWs although initially set up as either formal or informal cooperatives have become privately owned.

There are various institutional forms of ownership and management of STW. Many STWs are jointly owned by relatives, neighbours or friends. Usually a pump operator is engaged for the whole irrigation season who may also be the owner or one of the users for a fixed seasonal fee in cash or kind. In many places water is paid by one fourth of the gross crop harvested and delivered to the tube well owner. A large part of capital costs and operation and maintenance costs come from outside the village like business, service and remittances.

In Bangladesh informal water markets for irrigation have developed quickly with the rapid expansion of tube well irrigation over the last decade. In case of shallow and deep tube wells, the owners of the irrigation equipment enter into deals for irrigation services with neighboring farmers in addition to using the equipment for irrigating their own land. With the expansion of water markets in the private sector, the pricing system has also undergone changes to suit varying circumstances. There is no single rate or uniform method for payment of irrigation water. Per hectare water rates vary not only from one area to another but also depend on the type of well within a particular area (Biswas and Mandal, 1993).

In the initial stage, the most common practice was sharing one-fourth of the harvest with the owner of the equipment in exchange for water. That gave way to a flat seasonal fee, the rate depending on the availability of electricity and the price of diesel. In recent years, the market has moved toward fees per hour of tube well operation. In Bangladesh, the major source of irrigation is the shallow tube wells and power pumps mostly run by diesel as many places in rural Bangladesh still do not have electricity connection. Diesel pumps usually have higher costs and lower water extraction capacity than electricity operated pumps (Wadud and White, 2002). Diesel being a major agricultural input in the cultivation of *boro* rice, the cost of *boro* cultivation is very sensitive to the price of diesel.

Type	STW		DTW	
Name	Shallow tube well		Deep tube well	
Description	Shallow well with suction mode pump		Usually turbine type pump (in large diameter) well 150-300m deep	
Energy	Diesel	Electricity	Diesel	Electricity
Nominal Capacity (litres/second)	12	12	50	50
Overall efficiency	25%	35%	35%	35%
Energy Cost (BDT) per ha	4,040	1,570	5,410	2,950
Total cost (BDT) per ha	6,990	3,770	12,940	8,930

Note: Irrigated area assumes 10 hours pumping daily and energy costs are based on diesel fuel costs of BDT 14/litre and electricity at BDT 25/KWh. Capital cost is annual equivalent capital cost at 12% discount rate divided by the command area. 1 USD = 69 BDT (Bangladesh Taka).
Source: WARPO (1999).

Table 1. Estimated Total Costs for Different Well Technologies

For Bangladesh the cost of production is higher for the *boro* rice than for the *aman* variety of rice. A major factor behind the high unit cost of *boro* rice cultivation in Bangladesh is the high cost of irrigation compared to the other countries in the region. Bangladeshi farmers have to spend about USD 51 in irrigating one-hectare land whereas the irrigation costs are about USD 32 in Punjab, India (Hossain and Deb, 2003). The cost of MV *boro* irrigation is even higher in Bangladesh; it is USD 117.6 per ha (Hossain and Deb, 2003). In Bangladesh, irrigation costs account for 28 percent of the variable costs of rice cultivation.

Further, in Bangladesh there has been a rising dependence on groundwater due to lack of surface water in the recent past. Overexploitation of groundwater for irrigation and other purposes has lowered the water table in many parts of the country below the suction level of the tube wells. The result is the increased costs for irrigation. Based upon the field study, NWMP (National Water Management Plan) estimates of operating costs for supplying 11,000m^3 of water (the typical gross demand for 1 ha of *boro* rice) are given in Table 1. The costs of diesel operation are substantially higher than electricity. Part of this is due to the generally lower efficiency of diesel-powered pump sets, but the major cause is that diesel fuel is taxed whereas electricity is charged at a price lower than its production cost. On the other hand, India provides heavy subsidy on electricity that lowers the cost of irrigation. In Indian Punjab electricity is provided free for tube well irrigation and the farmers are also provided free water from irrigation canals.

The present government policy for water management is the conjunctive use of surface and groundwater. Government and donors agree on policies to promote the expansion of irrigation from groundwater using tube wells provided by the private sector. According to the National Water Policy water should be used most economically. Farmers do not pay for volume used for irrigation but pay for the operation and maintenance. They pay for digging canals, diesel, electricity, labour charges for running pumps etc. At present 90 percent of total irrigation of 4.5 m ha is from groundwater, the rest is from surface water mainly

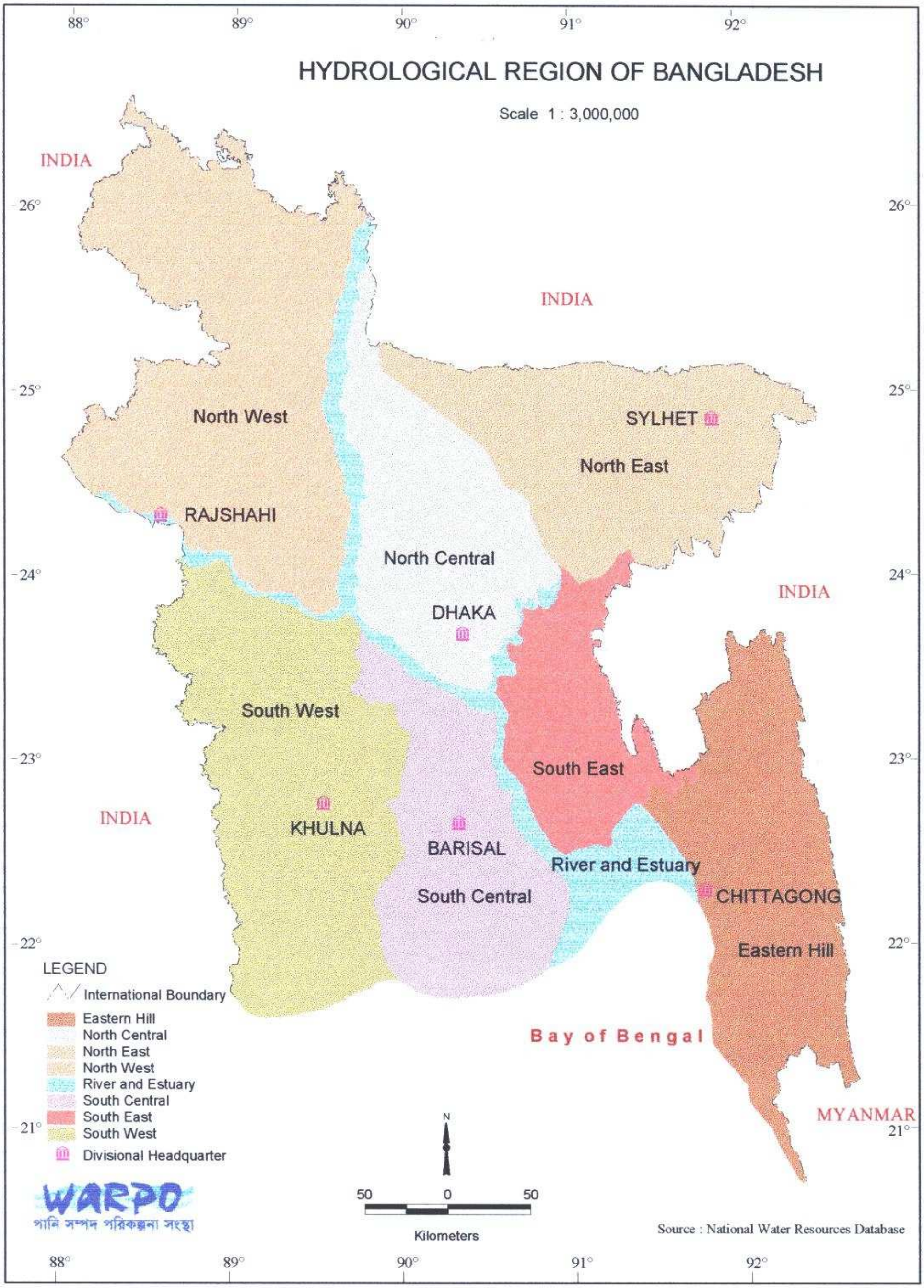

Fig. 3. Hydrological Regions of Bangladesh

because during the irrigation season (winter) there is no surface water due to upstream use. Mining and over-extraction is lowering groundwater table which is recharged only during floods. The National Water Management Plan emphasises to improve management of existing surface water irrigation schemes. It would support minor irrigation through improvement of shallow tube well and deep tube well diesel engine fuel efficiency, introduction of lower cost pump sets and improvement of irrigation distribution to reduce losses in water short areas.

3. Study area: Northwest region

The objective of this study is to measure the volume of irrigation water and find the actual price of irrigation water per unit used by farmers for alternative modes of irrigation in the Northwest region (NW) of Bangladesh. Water is most scarce in the Northwest and Southwest region during the dry season due to low annual rainfall. The problem is more complicated in the Southwest region due to water logging and salinity intrusion from the Bay of Bengal in addition to low annual rainfall. Hence I have chosen the Northwest region in order to isolate the impact of dry season scarcity of water from other seasonal and environmental problems. Previous studies (Chowdhury, 2005; Linde-Rahr, 2005) used total irrigation costs instead of water as a physical input since there was no information on the price per unit of water or volume of water used in the dataset. Through focussed group discussion we collect data on volume of water used in irrigation in addition to costs of irrigation in 3 districts of the NW region.

Bangladesh is an agricultural country divided into 7 hydrological regions. Northwest region encompasses the Rajshahi Administrative Division of 16 districts and is bounded by the Brahmaputra and Ganges rivers. Apart from Rajshahi Rangpur, Dinajpur, Bogra and Pabna are the main urban centres. Average rainfall is about 1700 mm but its south western part in the Barind zone is one of the driest in Bangladesh with average rainfall below 1400 mm. The Barind Tract is the driest part of the region where surface water supply is very limited. The tract extends over Rajshahi, Dinajpur, Rangpur and Bogra districts of Bangladesh and Maldah district of West Bengal, India. The temperature varies between 6 and 44 degree Celsius. Apart from the monsoon from mid June to mid October the climate is very dry. The high Barind is the only elevated land.

The Barind Tract is distinguished by hard red soils and older alluvial deposits which are different from other parts of Bangladesh. The main clay minerals are kaolinite, chlorite, smectite, and mica-smectite interlayered phases. The Barind clay contains an average total organic carbon content of 0.05%. The agro climatic conditions of the Barind region are highly favourable for irrigation but required an enormous government support before this potential could be realised.

Irrigation in the northwest region is almost entirely dependent on groundwater. Its net cultivable area is 2.35 m ha. The region is highly developed agriculturally with the largest irrigated area of all regions supplied mainly by shallow tube wells. Initial experiments with tube well irrigation began in the 1960s with the Thakurgaon Deep Tube well Project in the northwest. Due to STW pumping irrigation seasonal water table decline is widespread. The southern part of this region is very flood prone. Some of the country’s biggest flood control drainage and irrigation schemes are located in this area. These are Teesta Barrage, Pabna Irrigation Project, and the Barind Multipurpose Development Authority (BMDA). BMDA includes a deep tube well irrigation component.

In the 1990s except the special case of the Barind project government withdrew any involvement in groundwater irrigation. An independent autonomous body, the Barind Multipurpose Development Authority was established to implement the projects under the direct supervision of the Ministry of Agriculture. The main objective was to improve the quality of life of the people by ensuring year round irrigation, augmentation of surface water resources, improvement of agricultural support services etc. Currently the Barind aquifer is supplying sufficient water for extensive irrigation. The project is developed with meagre international support either in terms of experts or finance. There are active staffs, good management and farmers participate enthusiastically because their well being is greatly enhanced by these developments.

Variety	Classification	Growth duration (days)	Yield per ha (ton)
BR29	medium fine	165	7.5
BR16/Shahi balam	fine	165	6
BR14/Gazi	medium coarse	160	6
BR11/Mukta	medium coarse	145	6.5
BR28	medium fine	140	5
BR1/Chandina/Chaina	coarse	150	5.5
BR9	medium coarse	155	6
BR36	fine	140	5

Table 2. *Boro* Rice Varieties

There are 18 varieties of *boro* rice being cultivated in the Northwest region. I classify them into 3 broad categories fine, medium and coarse with the help of Bangladesh Rice Research Institute Scientists. Although evapo-transpiration is the true water requirement for crop growth crop water requirement for rice equals seepage, percolation and evapo-transpiration. Rice plants require continuous water in addition to land preparation. About 200 mm (heavy soil) to 250 mm (light soil) water is required for land preparation in *boro* rice cultivation. Therefore irrigation water requirement for *boro* rice is 3 times higher than non-rice crop like wheat and maize. Usually the seepage and percolation rate in rice fields varies from 4 to 8 mm per day (Rashid, 2008). Seepage and percolation rates are higher for light than heavy soil.

The rate of water requirement varies with atmospheric condition (temperature, rainfall), soil type, crop age, duration of the crop growth, land elevation and water management status in the plot. No irrigation is required before 10-15 days of harvest. Water balance studies show that much more water is supplied by irrigation than is required for evapotranspiration, seepage and percolation. According to one BRRI study 4,000 litres of water is used as irrigation for per kg *boro* rice in farmers' field compared to 2,000 litres in an experimental plot. Irrigation water requirement for *boro* rice production also varies with the varieties of longer duration.

Rice variety	Growth duration (days)	Water required for heavy soil (mm)	Water required for light soil (mm)
BR28 (medium duration)	140	995	1355
BR29 (long duration)	160	1205	1640

Table 3. Water Requirement for *Boro* Rice under Continuous Standing Water

	Boro rice	Wheat/non-rice cultivation	STW (shallow tube well)	DTW (deep tube well)
Northwest region	BDT 7000-8000 per ha	BDT 50-60 per hour		
Dinajpur	BDT 2500 per ha*	BDT 35-45 per hour *	BDT 30-60 per hour for wheat	
Rajshahi	BDT 7000 per ha**	BDT 1852 per ha**	BDT 50 per hour ***	BDT 75-80 per hour***

Source: As available from various BARC (Bangladesh Agricultural Research Council) Reports, 2001.
* in a village in Dinajpur district (NW region).
** Barind area (NW) in 1998-99.
*** In *boro* season.

Table 4. Cost of Irrigation in BDT for different Districts of NW region

Irrigation cost is different for different crops. Most popular is one-fourth of the crop share for irrigation in paddy cultivation. Pump owners provide the fuel and oil. Since it leads to a flat seasonal fee and sometimes overuse of water resulting in higher marginal cost per unit water extraction, it is important that we have information on volume of water used in irrigation in farmers' field.

4. Methodology: Focussed group discussion

International Rice Research Institute (IRRI) conducted an Agricultural Household Survey in Bangladesh in 2000, 2004 and 2008 for 3 crop seasons and collected data on costs of inputs (including irrigation water) and returns on investment from a nationally representative sample of 1880 farm households from 62 villages belonging to 57 of 64 districts of Bangladesh. But the data do not have any information on the volume of irrigation water used in the fields or price per unit. Irrigation is the total irrigation costs measured in BDT (Bangladesh Taka) and we do not know the price per unit of water or the number of hours the pump is used for pumping water. The data available are for total cost of irrigation per household. The costs of irrigation are basically the costs of pumping water. Farmers mainly use low lift pumps for pumping water from surface water sources and shallow and deep tube wells from aquifers and groundwater. I conducted a focussed group discussion in the Northwest region to validate the IRRI data findings about irrigation costs and gather some information about the per unit water costs/prices they bear/pay for using different types of irrigation mentioned earlier. Focussed group discussion is useful in case of small samples as opposed to other methods for gathering information within a short time.

The task was to collect some samples of data on water costs/prices per acre for *boro* rice from representative farmers who are using 5 different types of irrigation options in the NW region. These irrigation modes are low lift pump, shallow tube well, deep tube well, canal irrigation project of the government and local or traditional irrigation system. Data were collected on farmers’ use of irrigation water, volume, price they pay for hiring pumps, if they own pumps its cost of operation run by diesel or electricity, daily hours of pumping water during the irrigation season, capacity of pumps to extract water per second in litres etc. If it is a government owned irrigation project then the same information is collected on low lift pumps and other modes of irrigation the farmers are using. I also gathered information on the water table there. Three districts are Rangpur, Rajshahi and Pabna.

Rangpur represents northern range or highland, Rajshahi is from Barind Tract representing medium high land and Pabna represents lowland. In Rangpur besides the private sector there is Teesta irrigation project. In Pabna district there are government run irrigation projects like Pabna irrigation project plus privately owned pumps. Pabna Irrigation Project is mainly based on surface water irrigation. In Rajshahi the major irrigation projects are run by the Barind Multipurpose Development Authority. From these 3 districts 15 farmers using 5 different types of irrigation options were interviewed. Thus the focussed group discussion is for 15 farmers. The results are summarised in the following table.

District	Village	Respondent	Land under boro rice	Harvest	Irrigation type	No of irrigation	Inches of water per bigha	Cost of Irrigation	Energy source
Rajshahi	Achua taltola	1	1 acre	45 maunds	Deep tube well	13	2.5	BDT 3600 per acre	Electricity
Rajshahi	Moishalbari	2	1.67 acre	75 maunds	Shallow tube well	15	1.5	BDT 3600 per acre	Electricity
Rajshahi	Moishalbari	3	2 acre	72 maunds	Low lift pump	15	1.5	BDT 4500 per acre	Electricity
Pabna	Bhabanipur	4	0.33 acre	25 maunds	Deep tube well	65	3	1/4th	Electricity
Pabna	Jobedpur	5	3.33 acre	200 maunds	Deep tube well	120	3	BDT 6000 per acre	Electricity
Pabna	Jobedpur	6	1 acre	36 maunds	Shallow tube well	75	2	1/4th	Electricity
Pabna	Sonatola	7	3.67 acre	308 maunds	Low lift pump	105	3	BDT 3600 per acre per m+1500	Diesel
Pabna	Sonatola	8	2.33 acre	180 maunds	Traditional method	100	2.5	BDT 1500 per month	
Pabna	Nandanpur	9	1.33 acre	65 maunds	Canal irrigation	65	4	BDT 540 per acre	
Rangpur	Shyampur	10	5 acre	60 maunds	Deep tube well	20	2	BDT 700 per acre+m salary	Electricity
Rangpur	Pakuriasharif	11	1 acre	100 maunds	Deep tube well	30	3	BDT 3181.81 per acre	Electricity
Rangpur	Godadhar	12	5.5 acre	280 maunds	Shallow tube well	35	3	BDT 2800 per acre	Electricity
Rangpur	Nabanidas	13	3 acre	225 maunds	Shallow tube well	45	4	BDT 4545.45 per acre*	Electricity and diesel
Rangpur	Dighaltari	14	2 acre	100 maunds	Shallow tube well	64	5	BDT 3600 per acre per week	Diesel
Rangpur	Dighaltari	15	3.33 acre	250 maunds	Canal irrigation	30	5	BDT 900 per acre	Hand tube well

*BDT 2727.27 per acre if run by electricity
1 maund =28 kg
1 hectare = 2.47 acre
1 acre = 3 bigha
1 bigha-inch = 20,588 litres

Table 5. Results from my Field Study in the Northwest Region

In Rajshahi most of the irrigation pumps are installed and maintained by the BMDA. We interviewed farmers in 2 villages of Godagari Upazila using STW, DTW and LLP in Sharmongla canal irrigation project. The Barind Authority owns the DTW and the LLP. The LLP user here incurs more cost than the DTW and the STW users per acre. All the pumps are run by electricity. We did not however find anyone using traditional or local irrigation method in Rajshahi.

In Pabna I interviewed 6 farmers and found that two farmers pay the irrigation cost in terms of crop (1/4th). Here we find a very high frequency of irrigation in case of one DTW user and in general all 6 farmers compared to the farmers of Rajshahi and Rangpur. These farmers are producing BR29 and IRRI29 *boro* varieties which have longer duration. The soil quality may be also lighter than that in Rangpur and Rajshahi which requiring more water. DTW has the highest cost of irrigation. Electricity or diesel cost and the monthly wages of the pump operator constitute the total costs of irrigation for those who are using DTW, STW and LLP. Traditional method and canal irrigation system are cheaper modes of irrigation. In Rangpur the frequency of irrigation is found lower than Pabna but higher than in Rajshahi. I interviewed 6 farmers in Rangpur. Here we found an interesting case where one farmer who is running a STW for irrigation is using both electricity and diesel in the absence of electricity. In this case it is noteworthy that irrigation cost is less than double when he has to use diesel as fuel instead of electricity.

Lessons from the focussed group discussion

According to this field research one can get the information on water volume in two ways. One is from the horsepower of the pump, the number of hours the machine is run and another way is the number of inches of water on the plot. As it is not possible to know the level of efficiency of the pumps that are operating it is more reliable to measure the quantity of water used from the number of inches of standing irrigation water on the field. We did not however find anyone using traditional or local irrigation method in Rajshahi.

It is obvious from these interviews that farmers cannot reveal the amount of water withdrawn per minute or hour when they are running the pumps to irrigate their fields. However one can estimate the amount of water from the inches of standing water on their fields each time they irrigate their plots which is clear from this small sample survey.

Farmers prefer traditional method to government canal irrigation project to STW to LLP to DTW the cost of whichever is less. Electricity run pumps always cost a bit more than half the amount of diesel run ones. The use of traditional/local method, canal irrigation project and LLP depends on the availability and proximity of surface water. When groundwater is the only choice STW is preferred to DTW from the view point of least cost as investment in DTW is lumpy in nature. DTW is beyond the means of the poor mass of the farmers to be single owners. But in some cases DTW can be cheaper to an individual due to large economies of scale. Government run/maintained DTWs cost less to farmers than DTWs run on the basis of joint ownership and the rented ones. Cost of irrigation for pumps is the energy cost and the salary of the pump manager if hired or maintained by the government. The monetary cost has to be weighed against pump management and electricity availability.

For traditional (local) irrigation method the cost of irrigation is the maintenance of the apparatus and the cost of hired labour if any. For the government run canal irrigation methods the farmers usually pay a fixed amount per unit of irrigated land per crop during the season and in case of participatory water management water user groups pay for maintenance of field channels plus management cost in some cases. It varies from case to case. It is more reliable to measure the amount of irrigation water in terms of bigha inch water and the number of times the rice field is irrigated. In many cases farmers or even some pump managers cannot tell the level of efficiency of the pumps they are running. Only farmers who also happen to be pump owners/managers at the same time could give us accurate information about the age and the durability of the irrigation pumps.

5. Conclusions

Farmers in Bangladesh do not pay for use of per unit of irrigation water. When surface water was abundant farmers solely depended on rivers, canals and ponds to irrigate their fields with traditional local methods where the maintenance cost of the apparatus and labour charges were the costs of irrigation. For the government run canal irrigation methods the farmers usually pay a fixed amount per unit of irrigated land per crop during the season and in case of participatory water management water user groups pay for maintenance of field channels plus management cost in some cases. It varies from case to case. With the advent of groundwater irrigation cost of irrigation consists of maintenance of the pumps, fuel cost (electricity or diesel) and the salary of the pump mechanic when required. Farmers use low lift pump to pump water from surface water sources and shallow or deep tube wells for groundwater. The use of low lift pump is limited by the availability of surface water in the canals and rivers during the dry season. Since investment in deep tube well is lumpy in nature farmers prefer shallow tube wells. In case of shallow tube wells the energy cost (electricity or diesel) is the main component of irrigation cost. As electricity is not available in all the villages farmers have to depend on diesel to run irrigation pumps to a large extent. Hence the price of diesel in the international market plays a crucial role in cost of irrigation for the private sector.

The main challenge of public sector irrigation institutions is to design proper incentives for all stakeholders to participate in the participatory water management network. Successful water management practice for irrigation will depend on equitable participation of all groups of farmers as water user groups in management and cost recovery. Introduction of rice varieties that require less water for irrigation per ha is mandatory. Government should give incentives or price support for wheat and maize production so that farmers diversify towards these crops that require much less water per ha for irrigation compared to *boro* rice. In order to run the pumps with electricity stability in power supply is a must that will reduce the cost of irrigation as well as cost of cultivation drastically. In this endeavour there is no alternative to 100 percent rural electrification. More case studies or field research with large samples will demonstrate the actual status of irrigation institutions from the perspective of policy design and implementation specially if successful examples are identified and replicated elsewhere.

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7. Appendix

Questionnaire

First part of the questionnaire constitutes socio-economic information of the farmers.
Name of the respondent
Relationship with the household head
Gender
Age
Village
Union
Upazila
District
Level of education
Other occupation of the household and the members
Total land owned by the household
Per capita annual income of the household
Village with electricity connection: yes/no
Second part includes farming and irrigation related information.
Total land cultivated
Terms of lease: own, shared, leased in, leased out
Crops produced
Area under boro rice cultivation
Type of boro rice (variety)
Quantity harvested in kg
Quantity sold in kg
Price obtained per kg
Source of irrigation (own tube well, shared tube well, hired tube well, low lift pump, shallow tube well, deep tube well, government irrigation canal project, local irrigation system)
Type of tube well (submersible or non submersible)
Name of owners (both own and joint)
Year of installation
Depth of bore hole, filter and pump
Depth of water level
Horsepower of the pump
Cost of installation
Whether run by diesel or electricity
Costs of diesel or electricity
How the energy costs are shared
Whether labour/mechanic is required to pump water (yes or no)
If yes, his charges
The depth of water in inches on the ith irrigation

Number of hours on the ith irrigation taken to flood the field to reported number of inches
Terms of irrigation when the source is a shared tube well
Terms of rent when the pump is hired
Distance of the plot from the irrigation source

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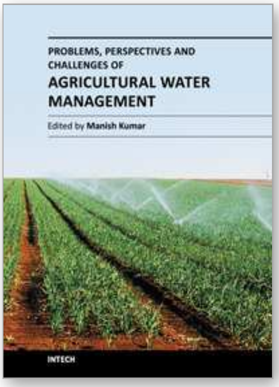

Problems, Perspectives and Challenges of Agricultural Water Management

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Food security emerged as an issue in the first decade of the 21st Century, questioning the sustainability of the human race, which is inevitably related directly to the agricultural water management that has multifaceted dimensions and requires interdisciplinary expertise in order to be dealt with. The purpose of this book is to bring together and integrate the subject matter that deals with the equity, profitability and irrigation water pricing; modelling, monitoring and assessment techniques; sustainable irrigation development and management, and strategies for irrigation water supply and conservation in a single text. The book is divided into four sections and is intended to be a comprehensive reference for students, professionals and researchers working on various aspects of agricultural water management. The book seeks its impact from the diverse nature of content revealing situations from different continents (Australia, USA, Asia, Europe and Africa). Various case studies have been discussed in the chapters to present a general scenario of the problem, perspective and challenges of irrigation water use.