Realizing the Potential: Using Pumps to Enhance Productivity in the Eastern Indo-Gangetic Plains

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Abstract

Eastern Indo-Gangetic Plain (EIGP) comprising of eastern Uttar Pradesh, Bihar and West Bengal in India, Nepal tarai and plains of Bangladesh, though endowed with rich water resources has very low produtivity. This region is characterized as "High potential low productivity" area. Though, the ground water development in the region has increased substantially during the last decade (19.2% and 24.2% in 1993 to 33.2 and 32.2% in 1998, respectively in the two states of Bihar and West Bengal) its utilization is poor owing mainly to improper irrigation scheduling and selection of pumps and poor pump efficiencies, unreliable energy supply, and lack of information to users. The tail reaches in most of the canal command also depend on groundwater irrigation. Pump is the predominant device used for lifting of groundwater. In the past two to three decades, pump technology has been spreading rapidly resulting in crucial transformation of the irrigated agriculture in areas such as EIGP that previously had been unable to take full advantage of the "green revolution" technology due to lack of irrigation water. The recent adoption of pump technology was far more rapid in Bangladesh, but much slower in Bihar and Nepal tarai. Density of the pumping unit in the eastern region (around 105 pumps / thousand ha) is far low as compared to agriculturally developed states–such as Punjab (225 pumps / thousand ha in 1993-94) and Haryana (148 pumps/thousand ha). This not only resulted in under utilization of ground water but also poor realization of benefits from the groundwater.

Small and highly fragmented land holdings, unreliable / erratic energy supplies, poor economic conditions and lack of infrastructure facilities are some of the reasons for under utilization of groundwater. In the EIGP, use of diesel operated pumps is predominant, as more than 90% of the pumps are diesel operated. Efficiency of pumping units is also a serious concern. Small and cost effective interventions, e.g. improvement in fittings and foot / reflux valves, can substantially increase pump efficiency. Conjunctive use of groundwater in canal command has been demonstrated to enhance the crop yields under rice-wheat system by more than two folds and encourage groundwater utilization. Groundwater market is another opportunity, which needs to be explored in large scale to provide irrigation facilities to small farm holders who can not afford tube wells/shallow tube wells and/or find it uneconomical to own it. Groundwater markets have grown in Bangladesh, West Bengal, in parts of eastern U.P. and North Bihar to a certain extent. There are also evidences to support the concept and functioning of community/group tube

wells operated by groups of small and marginal farmers in backward regions of eastern U.P. (Deoria) and north Bihar (Vaishali).

The paper presents a brief description of various efforts made to enhance productivity in the EIGP together with challenges in groundwater management including cost effective and energy efficient technologies and participatory on-farm water management.

Introduction

Pumps are widely used for extracting groundwater and lifting water from surface systems for irrigation. Pumps and tube wells technology together with government policies on subsidizing credit and rural energy supplies have led to phenomenal growth of groundwater development in India. Groundwater abstraction structures have increased from 4 million in 1951 to nearly 17 million in 1997 (Chadha, 1999). Groundwater now contributes to about 60 per cent of irrigated agriculture in India. While in Bangladesh, 90 per cent of irrigation is from groundwater, mostly through tubewells in the private small-scale sector, and shallow tube wells account for 60 per cent of the total irrigated area (Bhuiyan, 2003). Effective utilization of pumps has potential to increase the agricultural productivity as it provides greater access to water when needed and is also a cheaper means of irrigation development as compared to canal irrigation. Groundwater has emerged as the primary democratic water source and an instrument of poverty alleviation in India's rural areas (Debroy & Shah, 2002). Rapid growth of pump technology has been resulting in a crucial transformation of irrigated agriculture in areas that were previously unable to take full advantage of the "green revolution" technology due to lack of irrigation water. The recent adoption of pump technology has been rather uneven, which was far more rapid in Bangladesh and West Bengal, but much slower in Bihar and Nepal *tarai*.

Eastern Indo-Gangetic Plains (EIGP) comprising of eastern UP, Bihar and West Bengal in India, Nepal tarai and Plains of Bangladesh are endowed with rich water resources as compared to Western Indo-Gangetic Plains (WIGP). Although, the level of groundwater development has shown increasing trend, however, it is far below the western IGP. Rice-wheat is the predominant cropping system in EIGP, with low level of productivity. For example, in Bihar, the combined rice-wheat productivity is 3.6 t/ha as against the national average of 4.7 t/ha. This region is, therefore, popularly known as "High Potential Low Productivity" area. Adoption of pumps and tubewells for groundwater utilization together with improved water management practices and energy efficient water delivery/devices hold potential for increasing agricultural productivity and livelihoods of poor farmers in the eastern IG Plains.

Overview of Indo-Gangetic Basin (IGB)

The Indo-Gangetic Basin (IGB) spans Pakistan, India, Nepal and Bangladesh and lies mostly in the Indus-Ganges-Brahmaputra plain, which extends 3,200 km between the mouth of the Ganges River, to the east, and that of the Indus, to the west. The basin, among the world's largest and most productive basins, forms the floor beneath the "roof of the world", the Himalayas. IGB provides the economic base for agriculture, forestry, fisheries, livestock, including urban and industrial water requirements for about a billion people. Given the diversity of agro-climatic, social and economic conditions in the four riparian countries and home to the earliest river valley (Indus valley) civilizations as well as the present-day economic dynamism taking off in South Asia, the basin is a study of contrasts and opportunities in all respects. The total basin area is 225.2 million ha and the net cropped area is 114 million ha. The population of IGB is 747 million as per 2001 census. Rural population in Bangladesh, India, Nepal and Pakistan is 79.9, 74.5, 86.0 and 68.0 per cent, respectively of the total population. About 30.5 percent population in IGB is below poverty line. High population growth rates in all countries remain a cause for concern in terms of water and food security, poverty alleviation and resource conservation. Around 91.4 percent of the annual water use is for agriculture purposes followed by 7.8 per cent for domestic use in IGB.

The per capita water availability in the Indian portion of the Indo-Gangetic basin under the projected water demand by 2025 is going to be reduced to the level that it will become a water stressed area (i.e. having per capita water availability < 1700 m^3). The level of groundwater development is more (77.7%) in Indus than in Ganges (33.5%) basin.

In general, the IGB exhibits high potential but with only low-to medium actual primary productivity of agriculture, forestry, fisheries, and livestock. However, conditions are extremely heterogeneous; as a result, the problems and challenges vary in the Upper Catchments (UC), Western Indo-Gangetic Plains (WIGP), and Eastern Indo Gangetic Plains (EIGP). The future strategy should be focused to check water table decline and enhance ground water recharge in the western IGB; ensure development and utilization of ground water in eastern IGB including multiple water use; conjunctive use of ground water – ground water, rain water, surface water and marginal quality water, ground water – energy nexus, water pricing, energy policies and institutional issues in ground water management and governance; and design of technologies to reduce groundwater pollution, and enhance water productivity.

Status of Ground Water Development in EIGP

Ground water development in the EIGP is quite low as compared to other parts of the country, while the recharging capacity is better due to good rainfall and alluvial soils. Only 19.2% of available ground water was developed in Bihar and 24.2% in West Bengal till 1993. This level rose to around 33% for both the states by 1998, which is far less than the safe exploitation level of 65%. Whereas in the WIGP states (Punjab and Haryana), the ground water development has already crossed the critical limit of 85% and in some of the pockets, ground water mining is occurring due to over-exploitation.

Ground water development is largely done through private resources, by individual farmers, group of farmers, or by some enterprise rather than government. However, government policies certainly have great impact, as evidenced by rapid growth of ground water development in eastern Uttar Pradesh as compared to other states of eastern India. This has been primarily due to a number of government policies, for example, free boring scheme and subsidy on other programmes which were offered to small and marginal farmers matching with their socio-economic needs (Ballabh and Choudhary, 2002).

The "Million Shallow Tubewell" scheme launched by the Government of India also created some impact in increasing the ground water utilization. Under this scheme, 377,111 shallow tubewells were to be dug out up to 2004-2005 in Bihar, out of which 56% of the target has been achieved by November 2004. Such efforts and government policies did help to some extent in increasing the ground water utilization.

Ground water level in EIGP is relatively high. Fig.1 shows the percent distribution of villages under different ranges of ground water depth. Although, the Bihar data includes plateau region of Jharkhand (undivided Bihar), even then more than 45% villages have ground water below 10 m. In West Bengal, 68% of villages have ground water below 10 m. This indicates the large potential of developing groundwater through shallow tubewells in the eastern region.

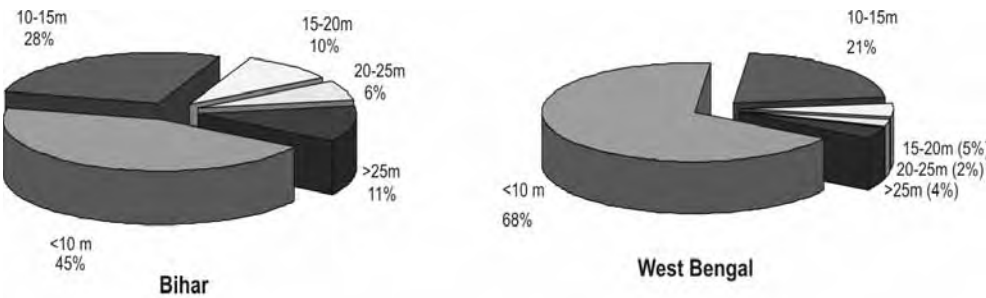

Figure 1. Distribution of number of villages in Bihar (undivided) and West Bengal under different range of depth of ground water level

Growth of Pumps

The number of pumps available in the eastern region is far less than those of Western IGP. The scenario for electrical pumps is shown in Fig.2. The electrical pumps available in 1998 in the eastern region were less than 20 per 1000 ha of net sown area as compared to 165 in southern region. As per minor irrigation census (1993-94), the pump density in Bihar and West Bengal was around 105 per 1000 ha, while it is 225 /1000 ha in Punjab (Fig.3). The number of diesel pumps are far more than electric pumps in Bihar and West Bengal, while the scenario is opposite for western IGB states. This is mainly because of government policy towards subsidizing the electricity and reliability/poor availability of electricity in eastern states with problems of high/low voltage, frequent breakdowns/cuts, etc. This compelled farmers to go for diesel pumps, whose operational cost is not subsidized and moreover availability of diesel in remote areas becomes problem. This is one of the major reasons of low pump density in eastern region. After 1990, the pump growth was much slower as nearly 1500 pumps were added each year in West Bengal and Bihar, while in smaller western IGB states such as Punjab and Haryana this was much higher (Fig.4).

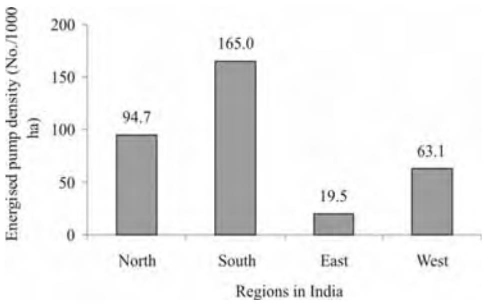

Figure 2. Electric pump density in India (1998)

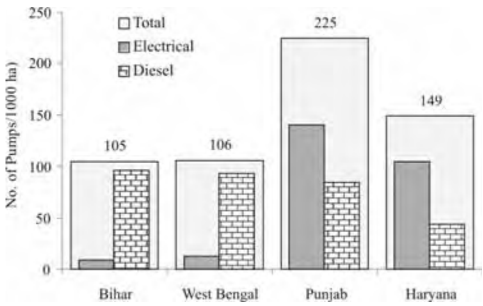

Figure 3. Density of electric and diesel operated pumps in selected states of IGP

In Bihar, the proportion of electricity consumption in agriculture sector increased steadily up to 20.4% of electricity generated / or supplied in the state (during 1991), but thereafter, it dropped to 12.5% during 1996 and remained at 14.3% even during 1999 (Fig. 5). As the electricity availability dropped, at several locations the electrical distribution network became defunct and the wires were stolen. In West Bengal, the consumption of electricity for agricultural purposes is less than 10%, and farmers mostly depend on diesel-operated pumps.

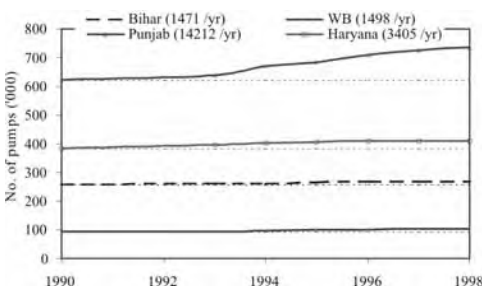

Figure 4. Growth of electric pumps between 1990 and 1998

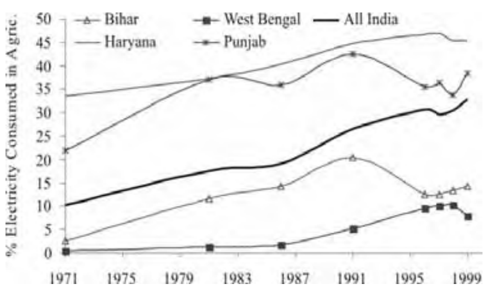

Figure 5. Growth of electricity consumption in agriculture

Simple Measures for Improving Pumping Efficiency

Efficiency of pumping units plays an important role in adoption of pumps and its utilization for groundwater development. A wide variety of pumps are available in the market. However, cheaper pumps are mostly low priced, but are of low efficiency. Low efficiency of pumping units is also responsible for excessive energy consumption, reduced irrigation efficiency and low productivity but, due to lack of knowledge and considering the subsidy in the electricity, most of the farmers prefer to go for cheaper pumps. These pumps give poor discharge even with higher horse power (hp) capacity pumps. It is, therefore, important that awareness is created about use of efficient pumps. This requires knowledge about the parameters to be considered for selection of pumps and, how the efficiency of the pumps can be enhanced.

The energy consumption depends mainly on pump discharge, height of water lift, time of operation and efficiency of pumpset (pumps, drive and motor/

engine, and their installation). If certain rectification measures are carried out for improving the efficiency of pumping unit then the potential energy saving (PES) in percent may be worked out as

$$PES = 100\left[1 - \frac{Y_2}{Y_1}\frac{\eta_1}{\eta_2}\frac{R_1}{R_2}\frac{H_2}{H_1}\right] \qquad \ldots(1)$$

The subscript 1 and 2 refer to the values before and after the rectification. Hence, to save energy efforts are required to:

i) improve the performance rating R (ratio of amount of fuel theoretically used by the pump to actually used) such that $R_2 > R_1$;
ii) reduce the water lift head H ($H_2 < H_1$);
iii) reduce depth of irrigation Y ($Y_2 < Y_1$); and
iv) increase irrigation efficiency (η).

In order to improve the performance rating, pump efficiency standards need the substantial improvement and enforcement to discourage substandard pumps being sold in market. The efficiency standards should also consider allowance for the effect of deterioration in pump efficiency with time and anticipated unfavorable conditions such as higher suction lift, and poor quality water (Sant and Dixit, 1996). Development of energy efficient components of pumping unit under the prevailing conditions of the farmers' field, development of well designs, and construction methodology with minimum losses and less chances of failures, are the challenges for the research and developmental units of government and industrial agencies.

From a user point of view, after selection of pump, it is important that it is installed properly with correct fittings and accessories, and appropriate suction lift. However, the suction lift varies with changing water table in the field conditions. Under aegis of AICRP on "Optimisation of Ground Water Utilisation through Wells and Pumps", several studies have been conducted to investigate the reasons for lower efficiencies of the pumps at different locations in India. The major reasons for low efficiency of pumps, as identified in these studies are listed in Box 1.

Box 1. Major reasons for low efficiency of pumps.

- Mismatch of selected units with the well conditions.
- Mismatch of the drive units with the pump requirement.
- Excessive length of delivery pipe.
- Excessive suction lift.
- Use of inefficient foot valves (offer very high head loss).
- Use of reducer at the delivery side (use of 10 x 8 cm nipple at the outlet of delivery pipe of 10 cm diameter pump).
- Poor quality of pipe fittings with unnecessary short radius bends.
- Loose foundation causing excessive vibrations during operation.
- Lack of technical service and awareness to the farmers on purchase, selection, installation and operation of pumps.

The efficiency of the tested pumps from field installations, were found to vary depending upon the make of the pump, its installation and fittings, and operating conditions (Fig. 6).

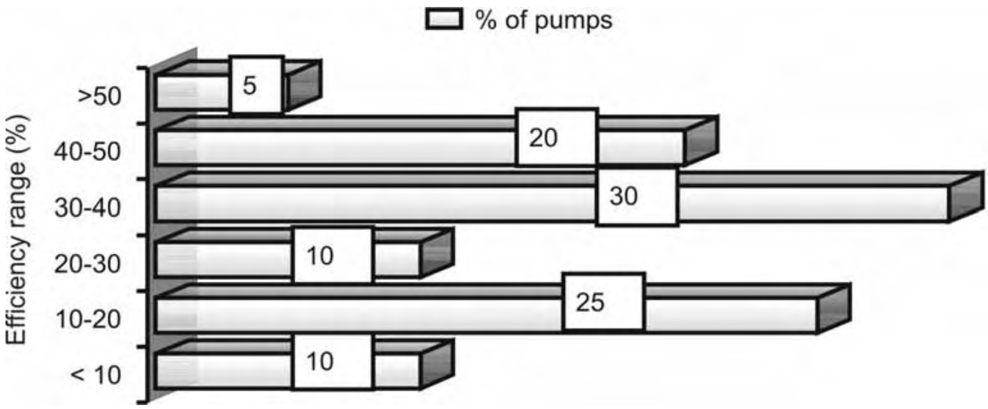

Figure 6. Proportion of pumps under different efficiency range

More than 35% of pumps were found to have efficiency less than 20%. All the low performing pumps were found to have problem either with their fittings, poor condition of foot valve, improper installation and suction lift. These pumps were found to respond substantially to small rectification measures in terms of increased discharge as well as efficiency (Table 1).

Table 1. Comparative performance of pumping units before and after rectification (Jabalpur, 1998)

Make	Year*	HP	Discharge, L/s			Efficiency, %			Rectification Measures*			
			Before	After	%	Before	After	%	S	F	L	FT
I	1989	5	6.35	8.15	28.3	21.95	28.01	27.6	-	Y	Y	Y
II	1993	5	7.00	11.80	68.6	24.50	41.4	69.0	1.70	-	Y	Y
III	1991	5	5.50	8.60	56.4	17.14	26.81	56.4	0.40	Y	Y	Y
IV	1996	5	7.00	8.60	22.9	18.20	23.42	28.7	-	Y	Y	Y
V	1992	5	5.00	7.10	42.0	24.21	34.38	42.0	1.20	Y	Y	Y
VI	1996	5	8.00	9.85	23.1	20.30	25.32	24.7	-	-	Y	Y
VII	1987	5	3.60	5.25	45.8	10.54	15.37	45.8	-	Y	Y	Y
VIII	1990	5	4.50	7.30	62.2	8.71	14.23	63.4	0.90	Y	Y	Y
IX	1992	5	6.00	8.65	44.2	16.88	24.34	44.2	1.00	Y	Y	Y
X	1996	7.5	11.50	14.96	30.0	18.40	23.28	26.5	-	Y	Y	Y
Average			6.45	9.03	40.0	18.08	25.66	41.9				

S – Suction head reduced (m); F – Foundation improved; L – Leakage stopped; FT – Excessive fitting removed. *Year of installation

In another study, rectification measures were carried out on 14 pumps owned by farmers in the *Tarai* region of Pant Nagar with respect to removal of nipple at the delivery side and replacement of short radius bends with long radius bends. These rectifications resulted in increase of discharge rate (on an average by 4.83%) of the pumps and saving in the fuel consumption of about 190 liter/year.

Apart from these fittings and installation, use of good quality foot valve is also an important factor for efficiency improvement. Results of rectification carried out on 241 pumps in 24 villages by GBPUAT, Pantnagar in *tarai* area, clearly indicated that improved foot valve saved about 11% energy (Table 2).

Table 2. Effect of foot valve and pipe fittings on discharge and power consumption

Fittings on Suction	Pipe fittings on delivery side							
	Elbow		Short radius bend		Standard bend		Total	
	Discharge (lps)	Power (watts/ lps)	Discharge (lps)	Power (watts/ lps)	Discharge (lps)	Power (watts/ lps)	Discharge (lps)	Power (watts/ lps)
With Local Foot Valve								
Elbow	26.80	181.45	28.88	173.71	25.39	162.47	27.02	172.54
Short radius bend	25.03	181.72	28.99	170.42	27.56	163.32	27.19	171.82
Standard bend	27.60	171.68	27.38	169.14	29.26	160.45	28.08	167.09
Average	26.48	178.28	28.42	171.09	27.40	162.08	27.43	170.48
With Pantnagar Foot Valve								
Elbow	40.28	156.38	40.37	156.82	41.41	149.70	40.69	154.30
Short radius bend	41.27	156.36	40.80	156.90	41.74	148.01	41.27	153.76
Standard bend	41.91	150.16	43.43	156.22	44.02	140.93	43.12	149.10
Average	41.15	154.30	41.53	156.65	42.39	146.21	41.69	152.39
Overall Average	*33.82*	*166.29*	*34.98*	*163.87*	*34.90*	*154.15*	*34.56*	*161.44*

Note: lps: liters per second

Based on the testing of 20,000 pumps owned and operated by farmers and rectification measures of one type or another carried out on 10,000 pumps, ICM, Ahemedabad prepared the recommendations for potential energy saving from different measures as given in Fig. 7.

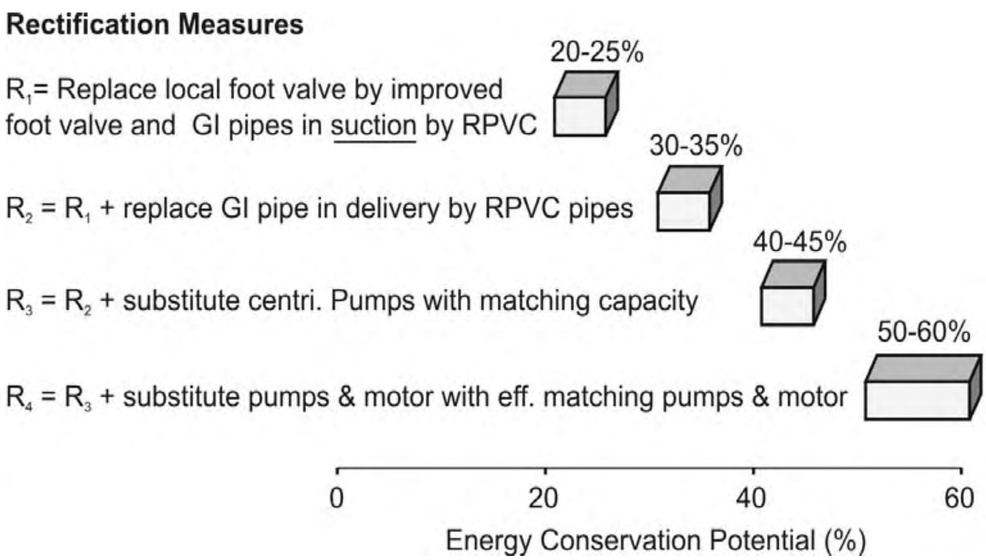

Figure 7. Effect of different rectification measures on energy conservation

The performance of pumps in the EIGP is also very poor, but detailed study in this respect is required to be carried out. There is a vast scope to adopt above such measures to improve pumping efficiency in eastern region.

Efficient Water Management for Enhancing Productivity of Pumped Water

Since most of the pumps in EIGP are operated by diesel, ground water becomes too costly for the farmers to irrigate their fields. Farmers are therefore interested in saving water along with maximizing its benefit, or in other words enhancing water productivity. Water management therefore becomes an important issue for ground water users. Agricultural water management is an important aspect influencing the overall groundwater draft and energy requirement. Broadly, the important water management measures for enhancing productivity of groundwater in EIGP would involve (a) proper irrigation scheduling, (b) improved agronomic practices, (c) conjunctive use of rain, canal and groundwater, (d) optimization of rice transplanting date, (e) acceleration of resource conserving technologies such as zero tillage, conservation tillage and raised bed, (f) use of water and energy efficient irrigation methods, for example micro-irrigation, and (g) multiple water use. Under the aegis of AICRP on Water Management, the optimum schedule of irrigation has been worked out for most of the important crops grown in different agro-climatic zones of the country. By adopting these recommendations, substantial amount of water can be saved and the yields can be increased. As it is perceived that rice needs continuous submergence, but studies undertaken all over the country revealed that the intermittent irrigation as impounding of 5±2 cm of water in the rice fields three days after disappearance of previously ponded water is the most optimum irrigation schedule. The results indicated that such treatment could save 23 to 65% of water as compared to traditionally rice growing under continuous submerged condition.

The methods of water application play an important role in controlling the water losses through deep percolation, surface runoff, and direct evaporation from soil surface. Among the gravity fed irrigation systems, border irrigation is mostly recommended for cereals except paddy for which check basin irrigation is traditionally used. Furrow irrigation with its different configurations saves appreciable water over the other methods. However, all the gravity methods need to be adopted with utmost care and recommended design parameters, so that the irrigation efficiency can be achieved to the maximum extent. Pressurized irrigation system (drip, sprinklers, and micro-sprinklers) are efficient irrigation methods. The water saving varies in the order of 20-30% with the sprinklers. Drip irrigation saves large amount of water (40-60%) as compared to gravity methods and makes appreciable improvement in quantity and quality of produce. Low cost star microtube drip irrigation method (newly developed and refined) has been tested and found beneficial for banana and vegetable crop in farmer’s field condition of south Bihar (Bhatnagar, 2005). Even without considering the benefits of water saving, the benefit cost ratio worked out for the system was 1.18 to 1.24 depending upon the variety and crop spacing used. The energy requirement for pumping water from varying groundwater depths (3, 7, 11 and 15m) for surface (gravity) and drip irrigation was analyzed at WTCER, Bhubaneswar (Srivastava and Upadhyaya, 1998). The results show that the energy requirement gets reduced substantially with drip irrigation as compared to gravity irrigation system (Fig.8).

Technological Push for Groundwater Utilization

Some of the reasons for underutilization of groundwater in realizing the potential are understood to be medium to high rainfall, canal water supplies, small and highly fragmented land holdings, poor economic condition, lack of access to capital and energy infrastructure, unavailability of smaller and portable diesel pumping units, and unreliable/ energy supplies.

There are examples and evidences to suggest that even with these limitations, awareness regarding the benefits of appropriate agricultural technologies and institutional arrangements have prompted farmers to go for groundwater irrigation and/or conjunctive use of groundwater. Such innovative and cost-effective technologies aimed at value addition and increasing water productivity may provide "technological push" for increased adoption of pumps for groundwater utilization. Such agricultural and water use management technologies when demonstrated in a participatory mode may encourage this push. For example, ICAR-RCER under ICAR-DfID Project demonstrated that accelerating adoption of optimization of rice transplanting through various means of communication not only improved rice-wheat productivity but also encouraged groundwater utilization in the commands of RP Channel-V of Sone Command in Patna. This involved advancing the date of rice transplanting by 15-20 days by raising nursery in the last week of May to first week of June using pumped water and transplanting it in the last week of June to middle of July. Seeing benefit of this techniques, the farmers not only employed use of pumped ground water to raise nursery but also enhanced rainwater utilization, saved irrigation to rice crop, encouraged ground water utilization, timely sowing of wheat and enhanced rice and wheat yields. Timely raising of rice nursery using tube well water, registered 2.5 times increase in groundwater market. Additionally the economics and risks of failure of monsoon/ or canal water supplies which encourage (or discourage) use of groundwater in canal commands and helps in determining the options of purchasing water, renting pumps or having own tube wells. Routing of pumped water for irrigation through a reservoir or tank to enhance water productivity through multiple use and integrating with horticulture, fishery and livestock is another example of

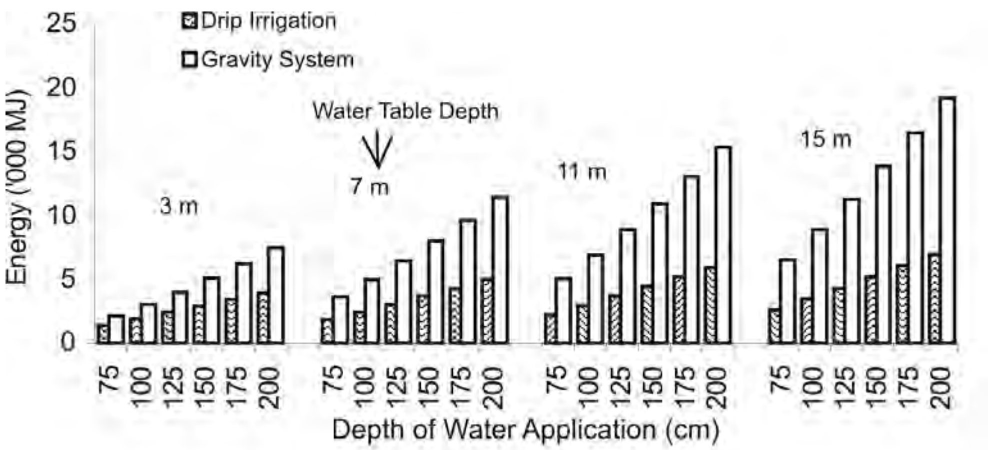

Figure 8. Energy requirement in drip and gravity irrigation

technological push to encourage groundwater utilization for improving water productivity in the eastern region.

In a study, at ICAR-RCER, Patna routing of tube well water from secondary reservoir gave additional benefit in terms of fish harvest of 11.0 tonnes/ha when weekly water exchange was done (Bhatnagar et al., 2004b). There is a need to develop and demonstrate such technologies to provide a technological push and convince farmers in the eastern region for increased adoption of pumps to enhance agricultural productivity.

Group Tubewells – A Cooperative Movement for Enhancing Productivity

There are evidences to support the concept and functioning of group tubewells owned and operated by small and marginal farmers in regions of eastern UP (Deoria) and north Bihar (Vaishali). Group tubewells were installed initially with the initiatives and support of People's Action for Development India (PADI)[1].

Vaishali Area Small Farmers' Association (VASFA), a registered NGO established in 1979, facilitated group borings and tubewells in Vaishali district. They installed 35 group tubewells with 6″ or 4″ delivery (7.5 – 10 hp pump) with command area of 20 to 40 acres. Each group tubewell has Small Farmers' Association (SFA) with 20 to 40 farmers having nominal membership fee (Rs. 3/month) as service charge, each consisting of a sub-committee of three (a President, Secretary and Treasurer). Each SFA is represented by their President in the Executive Body of VASFA. Water distribution, operation and maintenance are managed by SFA with the help of VASFA. Cost of water includes - operating charges and service charges - as decided by the committee. At present the committee charges Rs. 40/hour from the members and Rs. 50-60/hour from the non-members. Each group tubewell sells around 20% of water to non-members. Conflicts, if any, are being resolved amicably in the meetings. Farmers of tube well commands reported rice and wheat yields of 5-6 ton/ha. Associations also helped the small farmers in meeting their requirements of quality inputs, technology and sale of output at reasonable price besides managing valuable water resource. It demonstrates a good example of PIM in groundwater management, even in "socially disturbed" area.

It has demonstrated a good example of participatory groundwater management through efficient use of tubewell and pump technology to enhance productivity of their fields. When integrated and supplemented with improved resource conservation technology and on-farm water management practices, this could further realize the potential of pump revolution for enhancing water productivity.

Pumps and Groundwater Markets

Advent of low cost pump technology and tubewell technology has led to spontaneous growth of groundwater markets for irrigation in many parts of IG Plains in India and Bangladesh. It involves localized informal sale and purchase of

[1]PADI was the predecessor of Council for Advancement of People's Action and Rural Technology (CAPART).

pumped water mostly through private owned shallow tubewells and low lift pumps. With the expansion of water markets in the private sector, the pricing system has also been undergoing changes to suit the needs of farmers. Groundwater markets have helped small and marginal farmers with small and scattered land holdings in providing access to groundwater for irrigation and enhancing productivity in the eastern region of UP, North Bihar, West Bengal and Bangladesh. Even today, the ownership of mechanical water extraction devices remains out of reach of the marginal farmers in parts of EIGP. In such a scenario, study has shown that the small farmers with land holdings up to 0.4 ha in eastern UP are the biggest beneficiaries of the groundwater market assumes an immense significance (Pant 2004). Our experience with the DfID Project in the commands of RP Channel V in Sone Command at Patna also confirms that small and marginal farmers are greatly benefited through these groundwater markets to access groundwater for irrigating their fields.

Field level institutions for water feel that water markets can help improve water allocation and its use and produce substantial gains for the sellers and buyers. At the same time, there is concern expressed by many others that water markets aggravate equities in rural areas, as it leads to monopoly of rich farmers and their control over the market. Simultaneously, this may also result in excessive exploitation and depletion of scarce resource. Houssain (1996) reports that in real terms, irrigation water has become substantially cheaper after liberalization of the water markets in Bangladesh. At the same time, the ability to sell provides an incentive for conserving water and using it more rationally. Informal water markets in South Asia operating without government interventions are able to increase access to water for some of the poorest farmers (Meinzen-Dick and Sullens, 1994). In Bangladesh, hourly charges have provided incentives to adopt supplementary irrigation in time of drought and have encouraged cultivation of modern varieties in the wet season. However, there are no clear policy statements or legal measures regarding water markets in India. There are arguments for and against water markets, but there can be no difference of opinion on the question of their sustainability. This is a serious issue in water scarce areas since, as depletion proceeds fast, the ecology of area deteriorates and the poor and marginal farmers suffer most. The basic issue, therefore, is that of evaluating a legally and institutionally enforceable system, which will ensure sustainability and provide the parameters within which water markets could operate in the IGB.

Conclusions

- Adoption of low cost pump technology has been rather uneven in EIGP, it is now picking up in different parts of the region such as Bihar.
- It is demonstrated that low cost pump technology has increased the access of marginal and poor and disadvantaged people to groundwater for irrigation either through owing the one, or renting the pumps or purchasing water through groundwater markets in EIGP.
- Low cost pump technology is increasing water productivity and livelihood not only in poor regions but also among poor farmers of EIGP-a pro-poor policy.

- Need to evolve and demonstrate innovative and cost effective technologies aimed at value addition through multiple uses and increasing water productivity to provide "Technological Push" for accelerating adoption and efficient utilization of pumps for groundwater utilization.
- Challenges for the research and development include development of energy efficient pumping units, low cost small capacity diesel pump sets, promoting participatory on-farm water management practices, multiple water use interventions, cooperative movement in groundwater utilization and management, and research on institutional, legal and policy issues relating to groundwater development and water markets.

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