# Implications of Submersible Pumps in Declining Water Table Areas of Trans Indo-Gangetic Plains

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**Abstract:** Declining water table has emerged as the most serious challenge to sustainability of irrigated agriculture in many states of India. In the trans Indo-Gangetic plains comprising Punjab and Haryana, water table in few blocks is declining at the rate of 1 m per annum over the last one decade. As such farmers are replacing centrifugal units with submersible units particularly in the rice-wheat cropping areas. Already, upto 90% of total numbers of centrifugal units have been replaced. It is observed that such a large-scale replacements would disturb the groundwater balance of the region and would promote overexploitation of the groundwater. Besides it would impact the irrigation water quality, soil quality and the cropping patterns. It would have a greater impact on energy scenario. It is assessed that on an average at current level of electrical tariff, farmers have to pay around 2-2.5 times the cost of electricity over a normal centrifugal pump. It would accentuate the gap between the rich and poor farmers as well as would be a potential source of conflict in the rural areas. The paper highlights these observations through field surveys conducted in the trans Indo-Gangetic plains of India. Based on studies conducted at CSSRI, Karnal and other organizations in this region, a basketful of alternative strategies have been listed that would help to stabilize the water table at the current level of rice–wheat cropping in the region.

## INTRODUCTION

Groundwater has attained the distinction of being the main source of water for agriculture. Importance of groundwater resources in India could be realized by the fact that about 60% of total irrigated area is dependent upon groundwater (Statistical Abstract of Haryana, 2003-04) and a major fraction of the irrigated food production is realized through groundwater irrigation. It has been assessed that annual groundwater use as well as number of groundwater structures in India are the highest amongst few selected countries (Table 1). The volume of groundwater withdrawal in these countries varies from 30-100 $km^3$, being highest in India at 150 $km^3$ (Shah et al., 2000; Shah et al., 2003). As such, declining water table has emerged as the most serious challenge to sustainability of irrigated agriculture in many states of India. In the trans Indo-Gangetic plains comprising Punjab and Haryana, water table in few blocks is declining at an alarming rate exceeding 1 m per annum over the last one decade. It has serious implications for groundwater-irrigated agriculture. Therefore, efforts are being made to put in place resource conservation technologies to save the precious water. On the other hand, farmers are unwilling to heed the alarm and are adopting technologies that would rather worsen the already grim situation. Replacement of centrifugal units with submersible units is one such act that may jeopardize the efforts being made to conserve the water resource. This paper looks at this technology in the context of its impact on water balance, water quality and energy scenario and dwells upon adverse socio-economic implications. The paper highlights that research/extension efforts should be put in place to advise the farmers to go for most efficient pumping systems. Since it would be a long-term investment, there would be little scope to change the inefficient systems as has happened in the case of centrifugal units. Besides they should also resort to resource conservation technologies to sustain irrigated agriculture in this belt.

## CURRENT STATUS

Advent of green revolution in Indian states of Punjab and Haryana and consequent large-scale land reclamation activities undertaken by the farmers converted the erstwhile problematic low productive areas into intensively cultivated agricultural areas. It was made possible through introduction of rice-wheat cropping in waterlogged and waterlogged salt affected lands (Gupta et al., 2000). With the policy support of the government, the experience was replicated even on soils unsuitable for this cropping sequence. Since, irrigation requirements of rice and wheat crops were not completely met through rainfall and canal water supply, groundwater pumping became a common phenomenon resulting in installation of large number of shallow tube wells (Table 2). For example, number of tube wells in Haryana increased by twenty fold from a meager 28,000 in 1966-67 to about 6,00,000 in 2001. The situation is no different in the Punjab with 11.44 lakh tube wells in operation as on March 2004 (Table 2). In the Indian context, groundwater structures are increasing at an exponential rate (Fig. 1) such that area under irrigation with groundwater has surpassed the irrigated area with all other sources put together. Over-exploitation of groundwater for rice-wheat cropping is resulting in water table decline, reduction in well yield, and failures of wells/tube wells, increased pumping costs due to higher energy consumption.

**Table 1.** Extent of groundwater development and average size of water extraction mechanisms in various countries

| *Country* | *Annual groundwater use (km$^3$)* | *No. of groundwater structure (million)* | *Extraction per structure (m$^3$/year)* | *Population dependent on groundwater (%)* |
|---|---|---|---|---|
| Pakistan Punjab | 45 | 0.5 | 90,000 | 60-65 |
| India | 150 | 19 | 7,900 | 55-60 |
| China | 75 | 3.5 | 21,500 | 22-25 |
| Iran | 29 | 0.5 | 58,000 | 12-18 |
| Mexico | 29 | 0.07 | 414,285 | 5-6 |
| USA | 100 | 0.2 | 500,000 | <1-2 |

*Source:* Scott et al., 2002

**Table 2.** Number of tube wells in Punjab and Haryana (Lakhs)

| | 1970-71 | | 2003-2004 | |
|---|---|---|---|---|
| | *Diesel* | *Electrical* | *Diesel* | *Electrical* |
| Punjab | 1.01 | 0.91 | 2.88 | 8.56 |
| Haryana | 0.17 | 0.86 | 2.43 | 3.64 |

*Sources:* Statistical Abstract of Haryana (2003-04), Statistical Abstract of Punjab (2004)

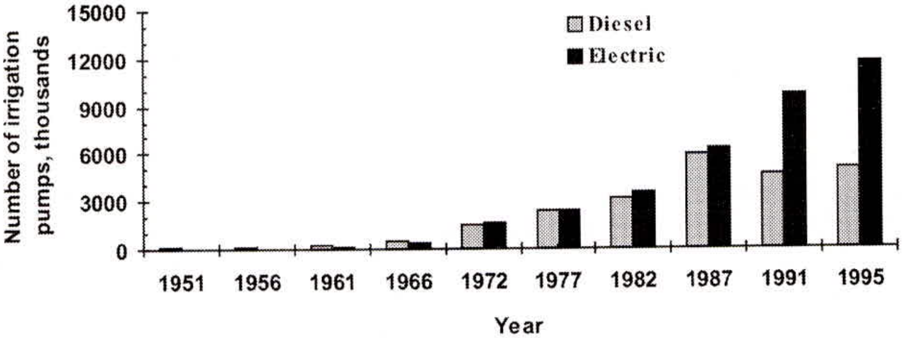



**Fig. 1.** Growth of irrigation pumps in India.

## MATERIALS AND METHODS

For this study, groundwater and related data for the trans Indo-Gangetic plain comprising the states of Punjab and Haryana were obtained from secondary sources. Qualitative assessment of the increasing water requirement of these states was carried out to have a fair view of the contribution of the rice-wheat cropping sequence to water deficit. Groundwater table data of few districts predominantly following rice-wheat cultivation were obtained to form a general view of the state of affairs in the trans Indo-Gangetic plain, while the real situation is illustrated through the example of four rice growing districts of Haryana for which fairly long-term data were obtained. Surveys were conducted in the Karnal and Fatehgarh Sahib districts of Haryana and Punjab to collect primary data and solicit information on the kinds of submersible units used, investments made and other relevant issues. A thorough review and compilation of various land and water management options was undertaken to list them for a brief reference. Although not a part of this paper, these interventions were discussed at various forums comprising farmers, officers of the State Department of Agriculture, scientists from various organizations and machinery manufacturers to arrive at specific recommendation for their implementation through technology transfer or policy interventions.

## RESULTS AND DISCUSSIONS

### Causes of Water Table Decline

Water table decline could be subscribed to all-round increase in the water requirement of various sectors of economy particularly the domestic, industrial and agricultural sectors. Due to inadequate and unreliable supplies of the canal irrigation, agriculture during green revolution became groundwater dependent. Expansion of rice-wheat cropping further tilted the scales in favour of tube well irrigation (Fig. 2). As per the statistics available, total area under rice-wheat cropping is 33% of the gross cultivated area in Punjab and 17% in Haryana. Spatial-temporal changes in number of over exploited and dark blocks in states of Haryana and Punjab are indicative of overall negative tendency of groundwater balance (Table 3). It would not be out of place to mention that most of these blocks are located in districts with a predominantly rice-wheat cropping (Fig. 3 a, b). Groundwater table data for four districts namely Kurukshetra, Kaithal, Karnal and Panipat with predominantly rice-wheat cropping (70.8, 85.1, 76.1 and 62.1 % of net cultivated area under rice crop, respectively) for the period 1974-2004 revealed a steady decline in water table in all the four districts over the last 30 years (Table 4). Clearly, the fastest decline is in District Kurukshetra where water table declined at a rate of 37 cm per annum during this period. In our view, besides the rice-wheat cropping, two major aberrations in the cropping of rice that appeared during the last decade worsened the situation. These aberrations are (i) taking two crops of rice (summer rice crop known as *sathi* crop in local parlance) and the normal rice crop during the monsoon season, resulting in a cropping intensity of 300% and (ii) early sowing of rice in 2nd/3rd week of May instead of 3rd week of June or thereafter. It may be mentioned that at one time nearly 25% of the area under rice was put under the *sathi* crop in districts of Kurukshetra and Karnal. Similar situation or even worse was reported from Punjab. Reduction in well yields and failure of few structures forced the farmers to take remedial measures through deepening of tube well pits and replacement of centrifugal units with submersible units. Chronological events in groundwater pumping since early seventies could be described schematically as in Fig. 4. Later these pits proved to be death pits as a result of toxic accumulation of gases from the rice fields. Even today, the farmers are facing paradox of deepening or not deepening. If they don't deepen, the rice crop suffers and if they deepen, there is a fear of pits caving in resulting in deaths of the labourers employed and consequent litigation and compensation. Moreover, the water table in some regions is going down so fast that the farmers need to deepen the pits almost every alternate year. As a result, farmers prefer one time investment on installation of submersible units.

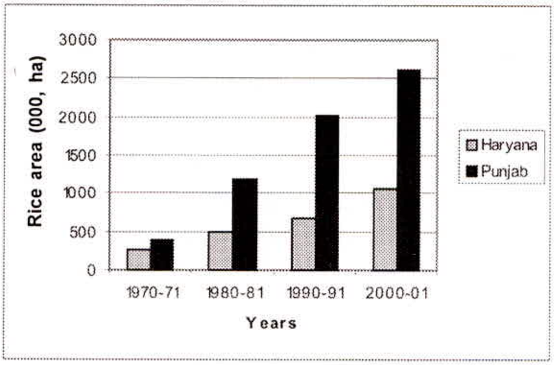



**Fig. 2.** Expansion of rice-wheat cultivation in trans Indo-Gangetic plains.

**Table 3.** Temporal changes in status of dark and over-exploited blocks

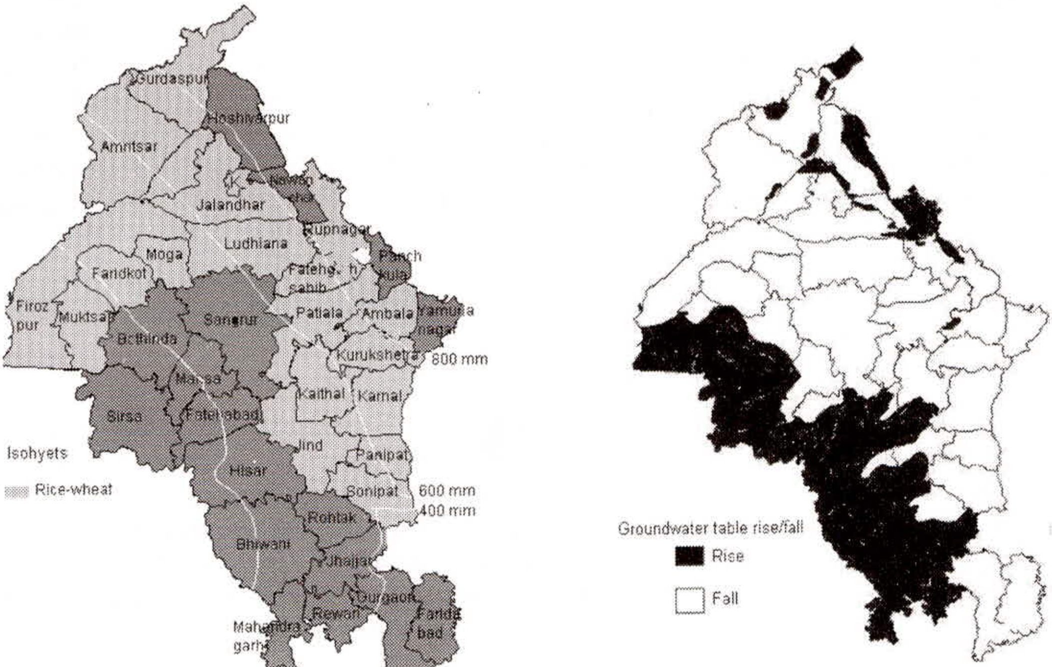
| *State* | *1984-85* | *1992-93* | *1997-98* | *2003-04** |
|---|---|---|---|---|
| Haryana | 31 | 51 | 41 | 67 |
| Punjab | 64 | 70 | 83 | 112 |
| India | 253 | 383 | 445 | 673 |

*Sources:* Chadha (2002), Gupta (2006), MIB (2006); *The change both due to increased over-exploitation as well as due to increased number of pumping units

**Table 4.** Rate of water table decline in four districts with rice-wheat as the predominant cropping pattern

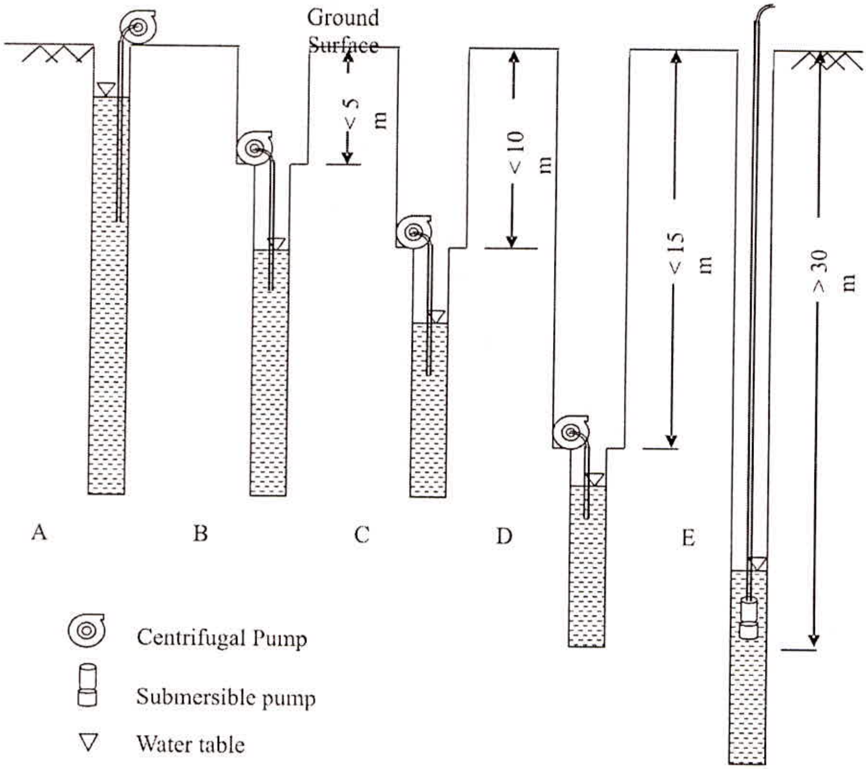
| *District* | *Rainfall (m)* | *Depth to water table in June, 1974 (m)* | *Depth to water table in June, 2004 (m)* | *Rate of water table decline per annum (cm)* |
|---|---|---|---|---|
| Kurukshetra | 0.69 | 8.10 | 17.70 | 0.37 |
| Kaithal | 0.54 | 6.91 | 8.97 | 0.10 |
| Karnal | 0.68 | 5.38 | 8.25 | 0.11 |
| Panipat | 0.61 | 5.21 | 10.35 | 0.20 |

*Source:* Gupta et al. (2006)




(a) (b)

**Fig. 3.** Trans Indo-Gangetic plain (a) rice-wheat cropping area and (b) area showing rise and fall in the water table.




A: Tube wells during early seventies; B: Tube wells during early eighties; C: Tube wells during late eighties and early nineties with gas problem in pit; D: Tube wells during late nineties having problem of deaths due to caving of pits; and E: Tube wells with still deeper pits, more deaths due to caving of pits or submersible pumps around 2000 onwards.

**Fig. 4.** Chronological events in the development of groundwater in trans Indo-Gangetic Plains.

## Submersible Pumps: Extent of Conversion

The centrifugal units are placed and operated above the water body and lifts water due to suction lift developed at the eye of impeller. It could be run both with diesel engine or electric motor. On the other hand the submersible pump is a compact unit made up of a submersible pump and motor with shafts connected to sleeve and operates beneath the surface of water. To run the submersible pump with a diesel engine, a generator to generate electricity would be required. The technical details of centrifugal and submersible units are compared in Table 5. Conversion from shallow centrifugal to deep submersible units is in its infancy although some pockets of fast replacement were observed. Sample surveys in some parts of Haryana and Punjab compiled in Table 6 revealed that the minimum replacement was in village Panjoli while maximum was in Patarsi Kala and Patarsi Khurd in Punjab. The replacement is intermediate upto 80% in Haryana.

**Table 5.** Comparison of centrifugal and submersible units

| *Sr. No.* | *Item* | *Centrifugal pump* | *Submersible pump* |
|---|---|---|---|
| 1. | Power range (HP) | 1-15 | 3-25 |
| 2. | Total Head (m) | 8-90 | 4-95 |
| 3. | Discharge ($l\ m^{-1}$) | 120-1700 | 80-2500 |
| 4. | RPM | 1440-2880 | 2900 |
| 5. | Frequency (Hz) | 50 | 50 |

*Source:* Pamphlets of submersible pumps of different companies.

**Table 6.** Adoption percentage for submersible pumps in parts of Punjab and Haryana based on field visits

| *Places* | *Centrifugal pumps (%)* | *Submersible pumps (%)* |
|---|---|---|
| *Haryana* | | |
| Dadupur (Karnal Block) | 62 | 38 |
| Darar (Karnal Block) | 20 | 80 |
| Aungadh (Jundla Block) | 65-70 | 30-35 |
| Assandh Block | 60-95 | 5-40 |
| Nissang Block | 50-70 | 30-50 |
| *Punjab* | | |
| Panjoli (Fatehgarh Sahib) | 95 | 5 |
| Patarsi Kala (Fatehgarh Sahib) | 10 | 90 |
| Patarsi Khurd (Fatehgarh Sahib) | 10 | 90 |

Because of the high investment of Rs. 1.0 to 1.5 lakhs, farming community is not very enthusiastic about the technology but is grudgingly accepting it to live with the rice-wheat cropping which the farmers still consider the best. This change must be considered in the light of the following issues that would help to generate guidelines on the potential of an area to support the extent of conversion.

- The likely disturbance in the hydrological balance due to higher discharge of submersible pumps as compared to shallow wells.
- Change in water quality (shallow and deep wells tap altogether different aquifers) and its impact on productivity and land resource.
- Increased energy requirement.
- Socio-economic impact on farmers still having shallow wells in the vicinity of deep submersible pumps.

The National Water Policy (MOWR, 2002) recognized the need to regulate groundwater withdrawals in such a manner that it does not exceed the groundwater recharge. It also emphasized that the central and state governments should effectively prevent the detrimental environmental effects of over-exploitation of groundwater. To answer the above mentioned issues and to achieve the goals as enshrined in the NWP, it is right time to study the technology when it is still in its infancy, for promoting right inputs to minimize its adverse impacts and sensitize the farming community for its balanced and justified use.

## IMPACTS OF SUBMERSIBLE PUMP TECHNOLOGY

The possible impacts of submersible pump technology on groundwater balance, pumped water quality vis-à-vis land quality, energy requirement and socio-economic aspects are discussed in the following subsections.

### Groundwater Balance

The pumping units in shallow cavity wells in Punjab and Haryana have driving units with an HP rating in the range of 7.5-10 HP which earlier used to be in the range of 5-7.5 HP. The discharge of these pumps ranged from 600 to 900 lpm. With the increase in the suction head, the discharge of the cavity wells has decreased considerably. The deepening of the pits usually follows when the discharge of the cavity wells is reduced by 30-50% of the original discharge. Information gathered during the surveys revealed that farmers in trans Indo-Gangetic plains go for submersible units with a motor rating in the range of 10-25 HP with a preference for the 15 HP rating motor. These units are generally installed at 30 to 35 m depth. Their discharge ranges from 1000 to 1500 lpm. Since the compact units remain underneath water, there is little possibility of reduction in the discharge from these units. Clearly, a switchover from a cavity well to a submersible pump would effectively mean increased abstraction by about 1.5 to 2.5 times. In other words, a cavity well replaced with a submersible well would effectively mean an additional shallow cavity well. Such a change would significantly affect the groundwater balance and would encourage the farmers to enhance cropping intensity. Even the aberrations in rice cropping discussed in previous section would accentuate, worsening the situation in overexploited and dark blocks (Table 3).

### Groundwater Quality

Groundwater quality problem has not been realized so far but could be a real threat that might endanger the human and animal health as well as affect crop productivity. We take the case of Haryana to illustrate this issue. Groundwater quality in the state is usually better in shallow than deeper aquifers (Table 7). It is clear that there is substantial increase in saline water area having EC > 6 $dSm^{-1}$ in case of deep groundwater except three districts of Ambala, Kurukshetra and Karnal. Naturally when deeper aquifers would be exploited, it might be possible that one would end up in a poor quality water resource compared to the shallow aquifer. Thus, it would not only affect the crop productivity but would adversely affect the soil health also. In some areas, sodicity of water increases with depth and that might lead to formation of alkali lands. These soils may demand additional investment on application of gypsum every year. In case of saline waters, leaching of the root zone by fresh water would be essential.

Besides the above paradigm in water quality, two other issues could crop up that might be even more critical. Our studies have shown that so far there is a gradient of groundwater from northeast to southwest Haryana. Fortunately the groundwater quality is also good in the northeast than the southwest. Since the overexploitation is more in the northeast than the southwest, reversal of groundwater gradients cannot be ruled out. Once it happens, there would be inflow from poor to good quality aquifers endangering the groundwater-irrigated agriculture of this belt.

Declining water table has proved to be catastrophic in parts of West Bengal due to increased dissolution rate of arsenic to contaminate the groundwater aquifers with arsenic. Although, more

**Table 7.** District wise percent areas under shallow and deep groundwater quality zones

| Sr. No. | District | Area | Shallow (5-50 m) | | | Deep (50-150 m) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Fresh | Marginal | Saline | Fresh | Marginal | Saline |
| | | | < 2 | 2-6 | > 6 | <2 | 2-6 | >6 |
| | | (km$^2$) | dSm$^{-1}$ | | | | | |
| 1. | Ambala | 3822 | 96 | 4 | 0 | 97 | 3 | 0 |
| 2. | Kurukshetra | 3740 | 58 | 37 | 5 | 90 | 9 | 1 |
| 3. | Karnal | 3721 | 86 | 14 | 0 | 82 | 16 | 2 |
| 4. | Sonepat | 2206 | 19 | 73 | 8 | 27 | 5 | 68 |
| 5. | Faridabad | 2150 | 34 | 61 | 5 | 38 | 31 | 31 |
| 6. | Jind | 3306 | 28 | 60 | 12 | 18 | 21 | 61 |
| 7. | Rohtak | 3841 | 9 | 65 | 26 | 20 | 3 | 77 |
| 8. | Gurgaon | 2716 | 45 | 51 | 4 | 19 | 4 | 76 |
| 9. | Sirsa | 4276 | 30 | 64 | 6 | 19 | 12 | 69 |
| 10. | Hisar | 6315 | 30 | 56 | 14 | 9 | 3 | 88 |
| 11. | Bhiwani | 5099 | 38 | 51 | 11 | 4 | 20 | 76 |
| 12. | Mahendragarh | 3010 | 40 | 57 | 3 | 51 | 45 | 4 |

*Source:* Gupta and Gupta, 2003

elaborate scientific investigations would be required, it is believed that with increasing disturbance of the lower strata, dissolution rates of some specific ions such as fluoride might increase. If it happens, it would have severe negative impacts on human and animal health.

## Cropping Pattern and Cropping Intensity

Assured and adequate supply of irrigation water might lure the farmers to bring more areas under rice cultivation. There is a strong possibility that farmers might switchover to more water demanding cropping sequences so much so that in large areas cropping intensity could increase to 300%. Rice-rice-wheat (*Sathi* rice), Rice-sunflower, rice-potato-wheat, rice-raya-wheat, rice-wheat-green gram are few sequences that could find favour with the farmers to get quick returns from the investments. Switching over to wheat-sugarcane is yet another possibility. Even without a change in the cropping pattern, early sowing of rice (20$^{th}$ May to 20$^{th}$ June) that gives more yields but consumes 1.5 times the water might turn the table on water demand. Without doubt, such changes would allow the farmer to recover investment yet it would significantly impact the already overexploited water resource.

## Energy Scenario

Energy consumption is directly linked to the rating of the driving unit, which in turn is selected on the basis of discharge of the pump, the total head against which water is lifted and the efficiency of the pumping unit. When a pit is deepened, besides additional investments on deepening of the tube well pit, power requirement is also increased in proportion to the total head. As such, it might require a change in the rating of the motor used. The average rating of motors for centrifugal pumps in this belt has increased by about 5 HP when compared with the past. Surveys in parts of Karnal district of Haryana state, revealed that depth of bore for submersible pump is around 100 m and pump is generally placed at a depth of 30 m. Horsepower range of submersible units is in the range of 10-25, most preferable being 15 HP. It is observed that replacement of centrifugal by submersible units would almost double the power requirement per unit water pumped as a result of high HP, high discharge and increased head against which water is pumped. The only redeeming feature would be that deep submersible units would be more efficient than the centrifugal units provided adequate precautions are taken in proper selection of pumps and fittings (Tyagi et al., 1979). The pump should match the discharge requirement and the total head against which water is lifted.

### Social and Economic Aspects

A desk study conducted by the authors revealed that the cost of a submersible pump would be around Rs. 0.70 to 1.5 lakh. Since, such a high investment is beyond the reach of small/marginal farmers, they have no choice but resort to deepen the existing pits to maintain suction lift within the optimum range. But they are likely to face problems on account of increasing number of submersible pumps in two ways. One, when a submersible pump in the vicinity would be operated, there would be huge drawdown. In that case, the cavity well may either function at a reduced discharge or might even fail to operate. This might lead to conflicts that have so far been seen only on the distribution of canal water. Moreover, increased rate of lowering of the water table would require frequent deepening of the pits. Even this exercise of deepening is fraught with problems of litigation/compensations that might deter the farmers to go beyond a particular depth, such that after sometime it would turn into a non-functional unit. As such, small and marginal farmers would suffer huge economic losses, as they would be unable to maintain even the current cropping intensity. The situation will lead to increased gap between the haves and have nots, loss of employment and complications in the rural social fabric.

Even the relatively big farmer who would invest in the technology from borrowed money would find the cost too high to be absorbed in the already non-lucrative business of rice-wheat cropping. Thus, they are likely to face economic problems due to adoption of submersible pump technology. They are likely to be caught further into the web of taking loan to repay the loan. A single natural calamity during rice or wheat cropping could take a tragic turn that is being highlighted in the mass media.

## SUBMERSIBLE PUMPS: LOCAL VERSUS STANDARD MAKE

In the late sixties and middle of seventies, when the installation of shallow tube wells was in progress, research and development organizations made studies to assess the performance of pumps and motors and concluded that the efficiencies of most of the systems were below expectations of 50% or more. For example, Mittal (1976) found that the efficiency in some cases was as low as 16%. Campaigns to sensitize the farmers to install energy efficient pumps/motors and other accessories were undertaken. An interaction with farmers from Dadupur, Darad, Assandh and Nissang in Karnal district of Haryana, and Fatehgarh Sahib in Punjab revealed that the farmers go for less efficient local made units over the more efficient standard submersible units. Few of the reasons advanced by the farmers to adopt local made units are as follows:

- The discharge of the local made pump is more although energy consumption per unit water pumped is more (Fatehgarh Sahib).
- The local made motors start at a low voltage compared to standard motors/pumps. Since voltage fluctuations are high, non-standard equipments are preferred (Haryana).

- Being cheaper, investment is less (all sites).
- Farmers follow the advise of the dealer or copy their neighbours and use the unit used by them (all sites).
- Maintenance is easy since local firms are easily accessible (all sites).
- Old generators (highly inefficient) are used to minimize investments (Fatehgarh Sahib).

There are a number of other issues that have local relevance. Therefore, we believe that the situation is no different today as was prevalent during late sixties and middle of seventies. Since we have learnt our lessons from our past experience, it is high time that technology transfer guidelines are developed and popularized at this stage itself when the technology is in its infancy. Tomorrow might be too late.

## SUBMERSIBLE PUMPS AND SUSTAINABILITY OF IRRIGATED AGRICULTURE

From the foregoing discussions, it could be realized that submersible pump is not a long-term solution to the problem of declining water table being experienced throughout the length and breadth of the nation especially in the trans Indo-Gangetic alluvial plains. Submersible pumps would deplete the aquifers at a much faster rate than a shallow tubewell and as such aquifers would dry up sooner. Besides the engineering measure through the artificial groundwater recharge (Sharma and Kaushik, 1998), suitable water management strategy based on water and energy budgeting and supported by optimal crop planning could be the long lasting solution. Our calculations reveal that a saving of 15 cm water in rice-wheat cropping could stabilize the water table at the current level. Water management strategies for rice-wheat cropping that would save more than 15 cm of water are in place. Some of the technologies are rainwater management in rice fields, irrigation after hair cracks appear in rice fields, timing of last irrigation to rice, popularization of basmati rice, transplanting of rice towards the third week of June, zero tillage, laser land leveling, diversification to other crops in a part of the area and direct sowing of rice (Gupta, 2006). If appropriate knowledge based extension and policy initiatives are implemented, the farmers would not hesitate to adopt one or more of these strategies.

## CONCLUSIONS

The farming community out of compulsion to make both ends meet is adopting the submersible pump technology. They realize the negative impacts of the technology on groundwater balance, energy use and increased cost of cultivation. Since the farmers are making long-term investments, it is high time that guidelines on selection of efficient systems are popularized through the extension machinery. Simultaneously, water saving techniques in rice-wheat cropping should also be popularized to save the precious resource as well as to help the small and marginal farmers who are unable to invest on submersible units.

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