# Emerging Issues due to Adoption of Submersible Pump Technology in Marginal Quality Areas of Haryana

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## ABSTRACT

Declining water table, indicative of overall negative ground water balance, has emerged as the most serious challenge to sustainability of irrigated agriculture in many states of India. It is resulting in reduced discharge from shallow wells, and replacement of centrifugal with submersible pumps. It is more so in marginal ground water quality areas such as Assandh block of Karnal district of Haryana, where deep semi-confined aquifers are of relatively good quality as compared to shallow aquifers. Ground water balance of the Assandh block, a marginal water quality area, was assessed based on the net annual pumping from the groundwater and net annual replenishable recharge. Even under the existing set-up, net annual replenishable recharge was negative and would result in lowering of water table by 80-90 cm.annum$^{-1}$. Temporal changes in pumped water quality revealed some increase in EC of the water of deeper aquifer. Studies revealed that water productivity was low under submersible than under centrifugal pump systems, mainly due to higher water application under the former situation. Under both the situations, pump efficiencies for selected centrifugal and submersible pumps were low (< 40%), although relatively higher efficiencies were observed for submersible pumps. Inappropriate size of submersible pumps and its placement at inappropriate depth were few reasons of low efficiencies amongst others. Since rice-wheat crop rotation is being factored as the major cause of groundwater decline in several states, notably Haryana, Punjab and Western Uttar Pradesh, diversification to low water requiring crops would help halt the declining trend in the water table to some extent, and would reduce the replacement rate of centrifugal to submersible pumps.


*Key words: Centrifugal pump, ground water balance, rice-wheat rotation, submersible pump*

Green revolution in the states of Punjab, Haryana and Western Uttar Pradesh through introduction of rice-wheat cropping has resulted in a number of second generation problems. With policy support from the state governments, rice-wheat cultivation had also spread to areas/soils otherwise unsuitable for this cropping sequence (Gupta *et al.*, 2000). Since, irrigation requirement of rice-wheat cropping sequence cannot be met through rainfall and limited canal water supplies in the semi-arid regions, ground water development proliferated and resulted in installation of large numbers of shallow tube wells. As such, number of tube wells in Haryana increased by more than 25 times from a meager 27,957 in 1966-67 to more than 7 lakhs in 2009-10 (Anon, 2011). The situation is no different in Punjab with around 13.74 lakh tube wells in operation during 2009-10 (Anon, 2011). Even in the Indian context, groundwater structures are increasing at an exponential rate, currently accounting for 20 million modern water extraction structures. The area under irrigation with groundwater has surpassed the irrigated area from all other sources put together, being more than 60 per cent (Shah, 2009). In Haryana, area irrigated with groundwater in 2010-11 was also 1.63 Mha as compared to canal irrigation accounting for 1.4 Mha. It appears that due to inadequate and unreliable supplies of canal irrigation, agriculture during green revolution became groundwater dependent. Although over-exploitation of ground water table could be ascribed to all-round increase in the water requirement of various sectors of economy, notably the domestic and industrial sectors, but the major factor contributing to the situation is the large-scale cultivation of rice-wheat in agricultural sector. Water table in several blocks of these states declined at the rate of 1 m per annum over the last one decade. Spatial-temporal changes in number of over exploited blocks in states of Haryana and Punjab are indicative of overall negative tendency of groundwater balance (Table 1). It would not be out of place to mention that most of these blocks are located in districts with predominantly rice-wheat cropping.

In order to cope up with the problems associated with declining water table, farmers owning shallow tube wells run by centrifugal pumps adopted an indigenous technology

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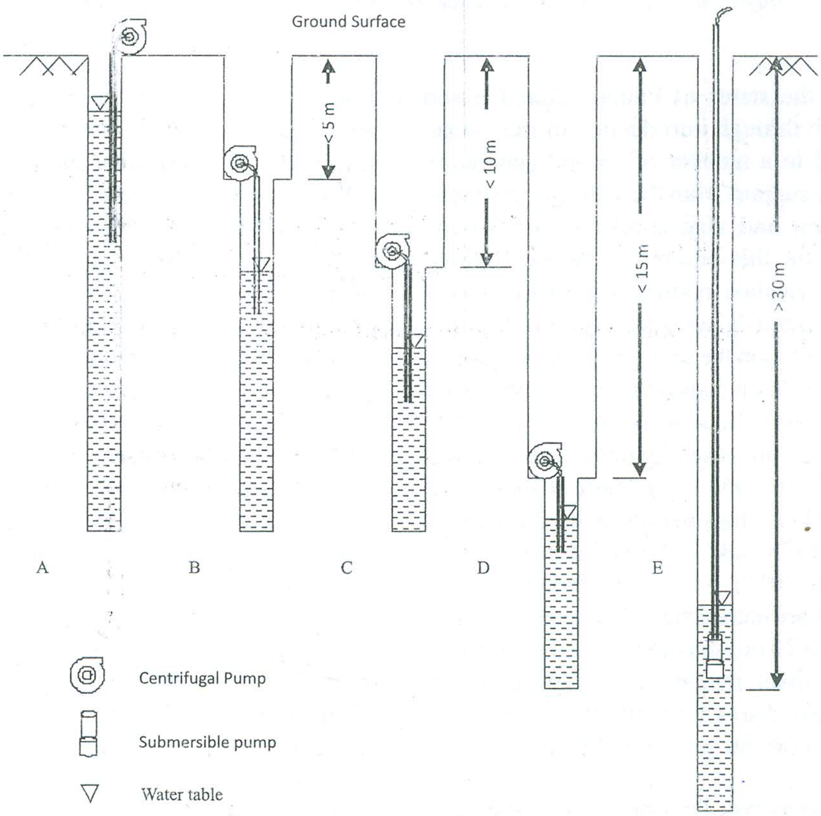
**Table 1. Temporal changes in status of over-exploited blocks and stage of groundwater development**

| State | Number of over-exploited block | | | | Stage of groundwater development in 2010 (%) |
|---|---|---|---|---|---|
| | 1984-85 | 1992-93 | 1997-98 | 2010-11 | |
| Haryana | 31 | 51 | 41 | 55 | 109 |
| Punjab | 64 | 70 | 83 | 103 | 145 |
| India | 253 | 383 | 445 | 839 | 58 |

*Source: Chadha (2002); MIB (2006); CGWB (2010)*

of making pits to minimize the suction lift within reach of a centrifugal pump. These pits were deepened every year, or in alternate years, as the water table continued to decline over the years. Temporal changes in depth to water table, changes in depth of these structures and finally the change in pumping technology are schematically shown in Fig. 1 (Kaledhonkar *et. al.*, 2006). The replacement rate is high in good, relatively low in marginal and the lowest in poor quality groundwater areas. Since use of marginal water quality is on the increase, replacement of centrifugal with submersible pumps is steadily increasing in these areas. Both the planners and water managers are uncertain about the implications of large-scale adoption of submersible pumps, although they are quite concerned about the future scenario. They fear that such a change would significantly alter the ground water withdrawal rates, groundwater balance and even have implications on water quality and water productivity. To address some of




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; E: Submersible pumps around 2000 onwards

**Fig.1: Chronological events in the development of ground water in Trans-Indo-gangetic plains**

these issues, water balance components of village Jai Singh Pura of the Assandh block of Karnal district were assessed. A survey was conducted to monitor the water quality and water productivity of submersible and centrifugal pumps covering both rice and wheat seasons. Possible impacts of submersible pumps on ground water balance, pumped water quality and water productivity of rice-wheat crops is highlighted to provide a comparative picture under centrifugal and submersible pump technologies.

## MATERIALS AND METHODS

To assess the dynamics of ground water table in northeast Haryana, depth-to-water table data were analyzed to know the status of decline/rise in water table and to categorize the water table under different depth categories (0-1.5 m, 1.5-3.0 m, 3-10.0 m, 10.0-20.0 m, 20.0-30.0 m, 30.0-40.0 m and above 40.0 m) for predominantly rice-wheat cropping districts of northeast Haryana namely, Kurukshetra, Kaithal, Karnal and Panipat (Khuller, 2006). The information was used to assess areas amenable to centrifugal and submersible pump technologies in these districts. It was assumed that farmers would use centrifugal pumps only until the water table depth is within 15 m such that they are able to restrict the suction lift by providing lined/unlined pits. Beyond this depth, they would prefer to have a submersible pump. The data were accordingly used to estimate the percent area where centrifugal pumps could still work.

To have an idea of groundwater balance, various groundwater balance components of the Assandh block were collected, assessed or assumed on the basis of available information. All relevant details such as rainfall, crop rotation, irrigation requirements of crops, crop areas, and depth to water table were collected from Groundwater Cell of Haryana, Karnal. With the help of these data sets and appropriate assumptions, water balance calculations were made. The groundwater balance was calculated and matched with the observed drawdown of the water table. Groundwater quality from centrifugal and submersible pumped installations was monitored to understand the possible effects of exploitation of different strata with centrifugal/submersible pumps. The water samples were analyzed for EC, SAR and RSC.

To assess the effect of centrifugal and submersible pump technology on seasonal groundwater withdrawal rate, data on pump discharge and pumping duration for rice and wheat crops were collected for 6 centrifugal pumps and 13 submersible pumps in the village Jai Singh Pura of Assandh block. Soil samples from respective fields were collected at time of sowing as well as harvest of the crops to assess soil quality in terms of pH (1:2), $EC_e$ and $SAR_e$. Crop cutting was conducted from randomly selected locations in the field at the time of harvest of rice and wheat crops covering an area of 1 $m^2$ in each selected field. Average yield on hectare basis was calculated using average of two locations in one set-up. Water productivity was calculated using average yield of crops (kg) divided by the total amount of irrigation water applied ($m^3$). Simultaneously, depth of water table, water power and rated power were used to determine pump efficiencies for centrifugal and submersible pumps. Farmers' opinions were sought on the selection of pumps to arrive at the plausible reasons of low efficiencies and to arrive at recommendations on ways and means to improve pump efficiencies.

## RESULTS AND DISCUSSION

### Ground water Table Behaviour

Ground water table data for the period 1974-2004 for 4 districts namely, Kurukshetra, Kaithal, Karnal and Panipat with predominantly rice-wheat cropping (72.94, 70.30, 64.10 and 55.75% of geographical area under rice crop, respectively, as per Anon (2000) revealed a steady decline in the water table in all the four districts over the last 30 years. The fastest decline was observed in District Kurukshetra where water table declined at the rate of 37 cm per annum during this period (Table 2). The data further revealed that the rate of decline increased substantially in the last decade (1995-2005), varying from 0.58 m to 1.00 m in various blocks of Kurukshetra district. In our view, besides the rice-wheat cropping, two major aberrations in the cropping

**Table 2. Rate of water table decline in four districts with rice-wheat as predominant cropping pattern**

| District | Average rainfall (m) | Depth to water table in June, 1974 (m) | Depth to water table in June, 2004 (m) | Average rate of water table decline per annum (cm) |
|---|---|---|---|---|
| Kurukshetra | 0.69 | 8.10 | 17.70 | 0.32 |
| Kaithal | 0.54 | 6.91 | 8.97 | 0.07 |
| Karnal | 0.68 | 5.38 | 8.25 | 0.10 |
| Panipat | 0.61 | 5.21 | 10.35 | 0.17 |

of rice that appeared during the last decade worsened the situation. These aberrations were (i) taking two crops of rice: summer rice crop known as *Sathi* rice (60 days rice crop) and the normal rice crop during the monsoon season, and (ii) early sowing of rice in 2nd/3rd week of May instead of $2^{nd}$/3rd week of June. The cultivation of *Sathi* rice resulted in a cropping intensity of 300%. It may be mentioned that at one time, nearly 25% of the area under rice was put under the *sathi rice* crop in the districts of Kurukshetra and Karnal. Similar situation, or even worse, was reported from Punjab. On the basis of work at Punjab Agricultural University, Ludhiana (Singh, 2009), it was observed that early sowing of rice also had a significant effect on relative water use in the rice crop, thus resulting in faster decline in the water table (Fig. 2).

## Feasibility of Centrifugal and Submersible Pumps in Districts of North East Haryana

The depth-to-water table data for the four districts revealed that except in the Kaithal district, nowhere the water table was within 3.0 m (Table 3). It could be attributed to the quality of ground water as ground water quality varied widely in the Kaithal district with some areas affected by sodic water (high residual sodium carbonate, RSC) where pumping is limited. As said before, Kurukshetra district is the worst affected, where 90% area of district requires only submersible pump technology to pump groundwater. In Kaithal, Karnal and Panipat districts 44, 37, 38% areas require submersible pump technology (Table 4).

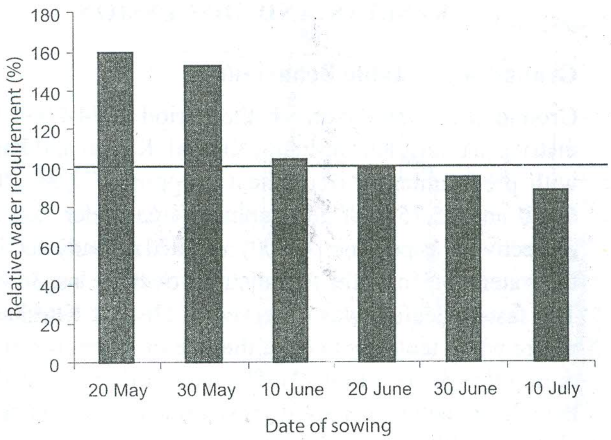



**Fig. 2: Relative water use at different transplanting date of rice crop**

## Groundwater Balance of Assandh Block of Karnal District

The ground water balance analysis based on different components (rainfall, canal water supply, ground water withdrawal, irrigation requirements of crops, groundwater recharge, etc.) for a period of 7 years (1999-2005) revealed that the annual rainfall varied from 120 mm to 512 mm. Canal water supplies were quite limited, and never exceeded 10 cm during the two cropping seasons. The rice-wheat cropping in an average year required about 130 cm of water, resulting in a water deficit varying from 89 cm to about 112.8 cm assuming effective rainfall as 60 per cent. In years of low rainfall, effective rainfall could be high as most of it could be stored in bunded rice fields. The total monsoon rainfall and the onset of monsoon both influenced the cropped area under rice, which varied from 65 to 80% of the total cropped area. The area under the rice crop was lowest in 2002 due to abnormal nature of the rainfall. Since all the deficit of water was met through ground water, any reduction in area under rice to some extent reduced the load on ground water.

Actual depth of water pumped from the aquifer was determined considering irrigation water deficit and cropped area. The actual depth of pumping from the aquifer in the study block was always less than the calculated water deficit for all the years which was assessed as 89 cm to about 112.8 cm (Table 5). Assuming 50% of applied irrigation water

**Table 3. Area under different depth-to-water table category for declining water table region of northeast Haryana in June 2005**

| District | Total Area (ha) | Area under particular depth-to-water table category (ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0-1.5 | 1.5-3.0 | 3.0 to10 | 10 to 20 (m) | 20 to30 | 30 to 40 | Above 40 |
| Kurukshetra | 168253 | 0 | 0 | 985 | 31645 | 134273 | 1350 | 0 |
| Kaithal | 228406 | 0 | 1780 | 79024 | 92459 | 38809 | 16334 | 0 |
| Karnal | 247112 | 0 | 0 | 65123 | 177703 | 4286 | 0 | 0 |
| Panipat | 125618 | 0 | 0 | 52708 | 50504 | 20511 | 1895 | 0 |

*(Source: Khuller, 2006)*

**Table 4. Percent area suitable for centrifugal and submersible pump technology in declining water table region of northeast Haryana**

| District | Total Area (ha) | Percent area under particular depth to water table category | |
|---|---|---|---|
| | | 0 to 15 m (suitable for centrifugal pump) | 15 to 40 m (suitable for submersible pump) |
| Kurukshetra | 168253 | 9.99 | 90.01 |
| Kaithal | 228406 | 55.62 | 44.38 |
| Karnal | 247112 | 62.31 | 37.69 |
| Panipat | 125618 | 62.10 | 37.90 |

**Table 5. Estimation of pumping and water table change for Assandh Block**

| Year | Actual pumping (cm) | Net pumping (cm) | Estimated WT change (cm) | Observed WT change (cm) |
|---|---|---|---|---|
| 1999 | 85.39 | 20.39 | 156.9 | - |
| 2000 | 82.70 | 17.70 | 136.2 | 135 |
| 2001 | 77.62 | 12.62 | 97.0 | 85 |
| 2002 | 73.32 | 8.32 | 64.0 | 75 |
| 2003 | 79.97 | 14.97 | 115.2 | 101 |
| 2004 | 74.50 | 9.50 | 73.0 | 86 |
| 2005 | 71.37 | 6.37 | 49.0 | 41 |
| Average | | 12.84 | 90.6 | 87.2 |

for rice and wheat crops as return flow (CSSRI, 1990), the net pumping (pumping minus groundwater recharge) varied from 8.32 to 20.39 cm with an average of 12.84 cm. Since the specific yield on an average in the area was assessed at 0.13, the estimated drawdowns for each year are shown in Table 5. A good match between the observed and estimated values supported various assumptions made in the calculations as well as led to the conclusion that on an average such a situation would prevail in the area. It suggested that if farmers continued with rice-wheat crop rotation, the water table in the block might decline at the rate of 85-90 cm per year.

## Monitoring of Temporal Changes in Pumped Ground Water Quality

With the reported deterioration in groundwater quality in village Jai Singh Pura, the ground water quality survey revealed that initially the quality of groundwater from deeper strata were relatively good as EC ($dS.m^{-1}$) was 1.62 against 4.0 of the shallow aquifer; SAR $(mmol.l^{-1})^{0.5}$ 12 against 21; pH 8.5 against 8.9 and RSC ($meq.l^{-1}$) 3.0 against 10.5. Further monitoring over the years revealed that the pumped water quality from deeper strata (submersible pump) was better after few showers of rainfall during monsoon season, but EC remained high or even increased in July 2008 (Fig. 3 and Fig. 4). Soil samples analysis also revealed increased soil salinity due to overall deterioration in pumped water quality. It supported the observation that ground water quality has declined over the years (Fig. 5). Since the groundwater is being overexploited, it might

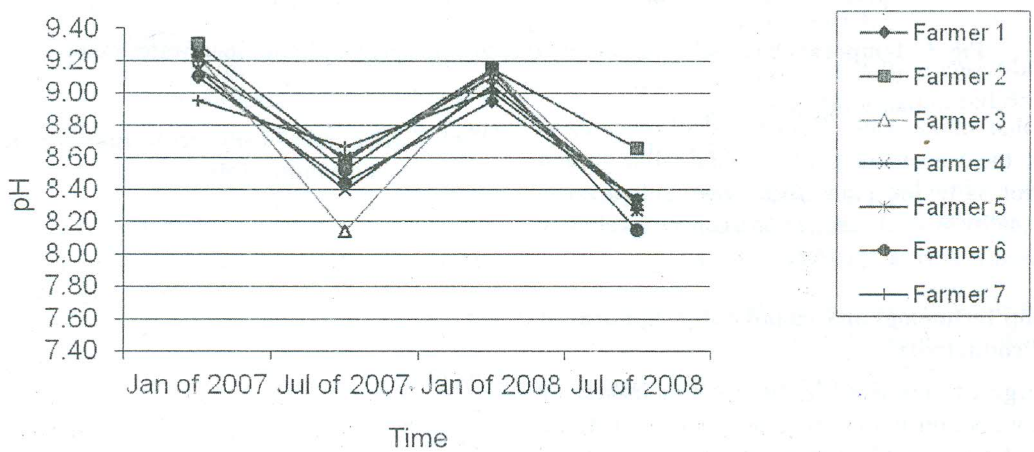



**Fig. 3: Temporal changes in pH of pumped water for submersible pumps**

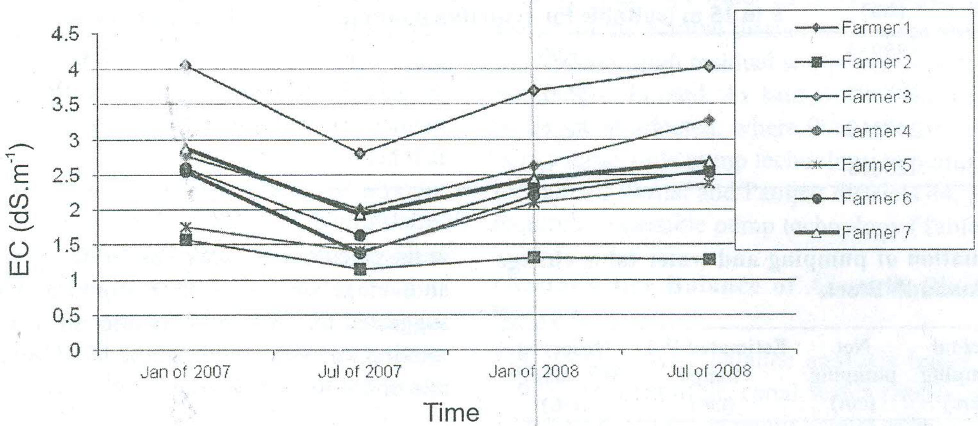



**Fig. 4: Temporal changes in EC of pumped water for submersible pumps**

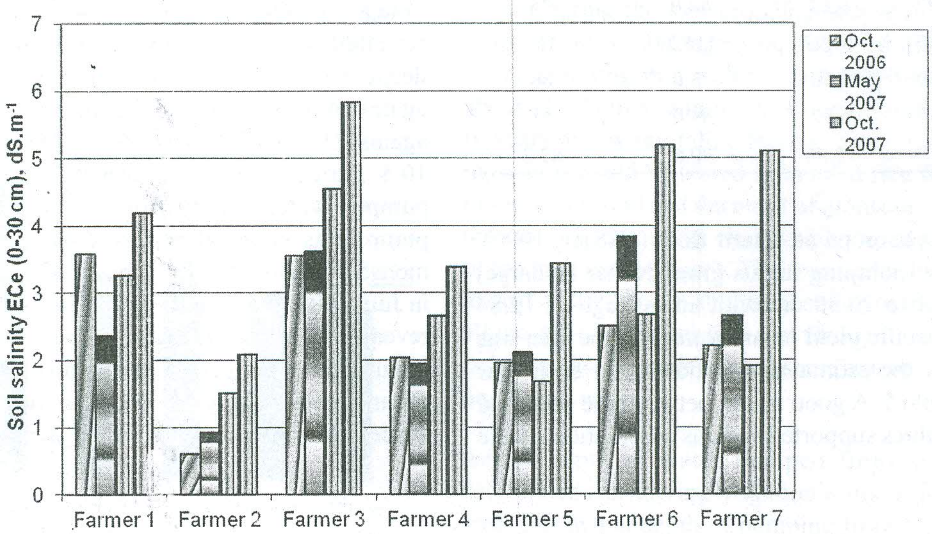



**Fig. 5: Temporal changes in soil salinity due to deterioration in pumped water quality**

be possible that saline water from the shallow strata is percolating to the deeper strata or horizontal saline ground water intrusion is taking place from surrounding areas having poor quality ground water. Such a concern is already being expressed in several quarters.

**Effect of Pump Technology on Ground water Withdrawal and Water Productivity**

High discharge of submersible pumps was indirectly responsible for poor on-farm water management practices. For example, farmers with submersible pumps preferred early rice varieties that are transplanted in early June. The tendency to apply more water as a safeguard against power cuts was also observed. The water productivity values for 3 different rice varieties given in Table 6 reveal higher

**Table 6. Rice and wheat water productivity for centrifugal and submersible pump**

| Crop | No. | Water productivity | | |
|---|---|---|---|---|
| | | Centrifugal ( $kg.m^{-3}$) | Submersible ( $kg.m^{-3}$) | Average ( $kg.m^{-3}$) |
| Rice non basmati | 22 | NA | 0.53 | 0.53 |
| Rice Pusa 1121 | 15 | 0.62 | 0.53 | 0.55 |
| Rice CSR-30 | 10 | 0.49 | 0.41 | 0.43 |
| Wheat | 15 | 1.57 | 1.22 | 1.40 |

water use efficiencies under centrifugal than submersible pumps. Results of wheat crop are also given in the Table 6. Farmers with centrifugal pumps used 33 cm of irrigation water to grow wheat compared to 41 cm by the farmers owning submersible pumps. Average water productivity was, therefore, less for submersible (1.22 $kg.m^{-3}$) compared to 1.57 $kg.m^{-3}$ for centrifugal pumps. On the whole, submersible pumps owners used more water and had low water productivity. Clearly, with use of submersible pump technology, ground water withdrawal would be higher resulting in faster decline of the water table than calculated.

### Pump Efficiency and Causes of Low Efficiencies

The rating of submersible pumps was generally 11.19 kW and higher as compared to centrifugal pumps of 3.73 to 7.46 kW. The average pump efficiency for centrifugal and submersible pump was estimated as 35 and 39%, respectively. The use of centrifugal pumps for high suction and high-total head and use of submersible pumps for comparatively low head situations were observed to be responsible in overall low pump efficiencies. Farmer's viewpoint had been that they purchase a pump which works at a higher range of voltage fluctuations. A pump that runs even at low voltage is preferred as voltage fluctuation in the region is high. Inappropriate size of submersible pumps and its placement at inappropriate depth were also responsible for poor efficiency. As the water table is declining, the efficiency of centrifugal pump is likely to decrease further due to increase in suction lift. Since the pits now are around 15 m deep, further deepening of the pits might result in caving of the lined/unlined pit walls.

## CONCLUSIONS

Average water productivity of rice-wheat crops was lower for submersible than for centrifugal pumps. It emerged that large-scale adoption of submersible pump technology in rice-wheat area would promote overexploitation of groundwater and further disturb the groundwater balance of the region. Low efficiencies of submersible pumps is a concern requiring concerted efforts in terms of sensitization and training to save energy in a region which is already reeling under short supplies.

## REFERENCES

**Anon.** 2000. Statistical abstracts of Haryana. Economic and Statistical Organization, Government of Haryana, Chandigarh.

**Anon.** 2011. Statistical abstracts of Punjab. Economic and Statistical Organization, Government of Punjab, Chandigarh.

**Anon.** 2011. Statistical abstracts of Haryana. Economic and Statistical Organization, Government of Haryana, Chandigarh.

**CGWB.** 2010. Ground water scenario of India 2009-10. Central Ground Water Board, Ministry of Water Resources, Government of India, Faridabad, June, pp:12.

**Chadha D K.** 2002. State of art of artificial groundwater recharge applied on village level scheme in India. In: Proc. Seminar on Management of Aquifer Recharge and Subsurface Storage Making Better Use of Our Largest Reservoir, (Eds. Tuinhof, A and Heederik, J P), Wageningen, The Netherlands, 18-19.

**CSSRI.** 1990. Annual Report 1989-90. Central Soil Salinity Research Institute, Karnal.

**Gupta S K; Minhas P S; Sondhi S K; Tyagi N K; Yadav J S P.** 2000. Water Resources Management. In: Natural Resource Management for Agriculture Production in India. (Eds. Yadav, J S P, Singh, G B), Proc. International Conference on Managing Natural Resources for Sustainable Agricultural Production in 21st Century, New Delhi, 138-244.

**Khuller R K.** 2006. Groundwater management in Haryana and emerging issues. In: Groundwater Governance, 12th National Symposium on Hydrology, New Delhi, organized by NIH, Roorkee and CGWB, New Delhi, Nov. 14-15, New Delhi, 231-236.

**Kaledhonkar M J; Gupta SK; Saxena C K; Sharma D P.** 2006. Implications of submersible pumps in declining water table areas of trans Indo-gangetic Plains. In: Proc. 12th National Symposium on Hydrology, New Delhi, organized by NIH, Roorkee and CGWB, New Delhi, Nov. 14-15, New Delhi, 93-104.

**MIB.** 2006. India: 2005, A Reference Manual. Publication Division, Ministry of Information and Broadcasting, Govt. of India, New Delhi.

**Shah T.** 2009. India's ground water irrigation economy: the challenge of balancing livelihoods and environment. Bhujal, 24 (4), 21-37.

**Singh K.** 2009. Act to save groundwater in Punjab: its impact on water table, electricity subsidy and environment. Agric. Econ. Res. Rev., 22, 365–386.