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Feasibility Evaluation of Pressurized Irrigation in Canal Commands

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Abstract India has one of the largest and most ambitious irrigation programme in the world with net irrigated area exceeding 47 million hectares. However, the overall project efficiency from the headwork to the farmer's field has been quite low which leads to not only poor utilization of irrigation potential created at huge cost, but also aggravates the degradation of soil and water resources and thereby endangers the sustainability of agricultural production system. As the cost of creating additional irrigation potential in terms of financial, human and environmental aspects has increased tremendously, need of the hour is to increase the irrigation efficiency of existing projects and use saved water for irrigating new areas or meeting the demand of non-agricultural sector. The contribution of application efficiency to poor irrigation efficiency is quite high and therefore increasing application efficiency by a shift in application method from surface to pressurized system has potential of vastly improving irrigation efficiency. To evaluate feasibility of this concept, a pilot study was initiated at Water Technology Centre for Eastern Region, Bhubaneswar, on one outlet of a minor irrigation command. The system has been designed in such a way that it provides pipe conveyance and surface irrigation for rice cultivation during monsoon season and pressurized irrigation during post monsoon period through a hybrid system of sprinkler and drip with four outlets for sprinkler irrigating 2.8 ha area and two outlets for drip irrigating 1.9 ha area. The system is also capable of providing irrigation through drip to part of a command during summer for third crop using water stored in service reservoir after the canal is closed in first week of April. To take care of sediment in the canal water, there are three stages of filtration: first by hydrocyclone filter which filters heavy suspended materials viz. sand, silt, etc., then by the sand filter and finally by the screen filter. The filtration at three stages reduces

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the turbidity to the desired level. It has been found that three-stage filtration reduced the turbidity to two NTU which is within permissible limit. Considering the cost of water saved, a benefit-cost ratio of the system was found out to be 1.126. This B: C ratio can be further increased by increasing the productivity of the fish and papaya in service reservoir area and better crop management during summer season.

Keywords Irrigation efficiency · Service reservoir · Turbidity · Filtration · Water saving · Pressurized irrigation · Canal command

1 Introduction

Irrigation has been a high priority area in economic development of India with more than 50% of all public expenditure on agriculture having been spent on irrigation alone. The land area under irrigation has expanded from 22.6 million hectares in 1950 to 90 million hectares in 2000, with 52% area being irrigated by surface water through canal network. Unfortunately, the overall efficiency of canal irrigation system worldwide is very low which leads to poor utilization of irrigation potential, created at huge cost. The average overall project efficiency of several canal irrigation projects in the rice growing areas in the world has been estimated to be 23% and that of non-paddy crops to be 40% (Walters and Bos 1989). Bos and Nugteren (1990) from International Institute for Reclamation and Improvement (ILRI), Netherlands reviewed the conveyance losses in irrigation supply schemes of different countries of the world and reported maximum conveyance loss of 60% in India and minimum in Philippines (13%). In other countries like Austria, USA, Spain, Columbia, Egypt, Greece and Italy, the conveyance losses ranges from 40% to 59% and in Japan, Australia, South Korea, Malaysia, Taiwan, France, the losses range from 16% to 37%. Sanmuganathan and Bolton (1988) reported that the canal irrigation efficiency in India is only 30–35%. In India, most of the irrigation networks are unlined and huge amount of the irrigation water is lost in main canal, distributory, minors and field channels. Navalwala (1991) found that about 71% of the irrigation water is lost in the whole process of its conveyance from head works and application in the field. The break up of the losses are main and branch canal (15%), distributaries (7%), water courses (22%) and field losses of 27%.

The situation is particularly bad in minor irrigation systems of plateau areas of eastern India, where the overall irrigation efficiency varies between 20% to 35%. These systems are located in coarse soil area and have rolling topography. Due to this, the conveyance losses are high and the system suffers from inadequate supply and poor water availability especially during lean season. Therefore the need of the hour is to increase irrigation efficiency of existing projects and use saved water for irrigating new areas or reducing the gap between potential and actual irrigated areas. Shifting to pressurized irrigation can be an option for increasing this irrigation efficiency. Walters and Bos (1989) have reported average application efficiency of 14 sprinkler-irrigated projects to be 70% and 15 basin and wild flooding projects to be 45%. Bucks et al. (1982) have reported that on-farm irrigation efficiency for trickle irrigation can theoretically approach 90% to 95%. Battikhi and Abu-Hammad (1994) reported that application efficiency was 82% and 64% for surface irrigation on citrus and vegetables respectively in Jordan valley project. The application efficiency was 88% for citrus under sprinkler irrigation and 91% for vegetable under drip irrigation. In north-eastern Spain, traditional surface irrigation systems often show application efficiencies close to 50% (Playan et al. 2000; Lecina et al. 2005), while properly designed and managed pressurized systems can attain 90% application efficiency (Dechmi et al. 2003a, b). As a consequence, changing the irrigation system from surface method to sprinkler method in field crops such as maize resulted in sharp reduction in irrigation water demand, roughly from 12,000 to 7,000 m^3/ha. Magar et al. (2007) reported that under Indian conditions, the application efficiency of drip irrigation and sprinkler irrigation are 95% and 80% respectively whereas irrigation efficiency of major and medium irrigation projects is only 30% to 35%.

Vandersypen et al. (2009) studying the Office du Niger irrigation scheme in Mali found that the central management wants to increase irrigation efficiency through fully fledged collective action, whereas farmers value the latter only when it favors easy irrigation. They found that only collective action at the inlet of the tertiary canal, increases irrigation efficiency by 14%. It is evident from above that any irrigation efficiency improvement system should be easy to adopt and only social action can improve the system efficiency marginally. Rowshon et al. (2009) studied the Tanjung Karang Irrigation Scheme, one of the large rice granaries in Malaysia and found that tertiary canals located at upper reaches of the main canal normally get more water than in the downstream due to uncontrolled gate opening of the Constant Head Orifice (CHO) off take structures. Many downstream farmers often could not get irrigation water. To provide a reliable, equitable sharing and predictable irrigation supply to fields, they developed a GIS-integrated tool known as RIMIS for equitable irrigation supply to tertiary canals and the characterization of their irrigation delivery performance as the season advances. However this requires collection of a lot of data and very skilled manpower to operate the system, therefore its application is limited. Zardari and Cordery (2009) found that in *warabandi* irrigation system of Indus basin of Pakistan, almost half the irrigation water delivered from the reservoir does not give direct benefits to the farmers. Crop demand for irrigation water under *warabandi* principles did not match the amount of canal water allocated to farmers. Irrigation water availability ranged between 0.82 and 1.92 mm/day only in the watercourse where the study was carried out. There was wide variation in canal water allocations for head, middle, and tail end farmers. The actual amount of water received by tail end farmers was small as about 25% of the allocated water share was lost in unlined water courses. Hence, there is a need to improve irrigation efficiency of canal irrigation system for enhancing productivity as well as ensuring equity among farmers of different segments.

Modernization of the irrigation system is required for improving the overall project efficiency of irrigation projects and increasing the water productivity. Modernization and optimization of irrigation systems have often been promoted in public and private agendas as tools to improve irrigation efficiency and producing more agricultural goods with less water input. Playan and Maetos (2006) has discussed a number of irrigation modernization and optimization measures by giving particular attention to improvement in irrigation management. This showed much better economic return than the improvement of irrigation structures. Shifting from surface irrigation to pressurized irrigation system to increase water use efficiency is an important component of the modernization process. The modernization program of the canal irrigation systems in India is going on in different commands with help from international funding agencies as well as from national funds. In the state of Orissa in India, a massive modernization program at a cost of $ 24 million was taken up in 1998 with the funding from World Bank. However, the attention was mainly on large irrigation commands. Further the improvement was concentrated on renovating the canal network and not much emphasis was on below the outlet. Thus a need was felt for identifying the interventions to be done below outlet level which will provide a significant improvement in water use efficiency as well as productivity. This intervention not only improves water productivity but also increase the cropping intensity which is of prime importance in improving the conditions of farmers. With this in view the interventions were designed.

Shifting from surface irrigation to pressurized irrigation system requires changing the supply of water from on-off mode to continuous, reduction of turbidity to desirable level and modifying system to provide surface irrigation to rice crop in monsoon and different types of pressurized irrigation to suit different crops of the command in post monsoon season. The technical and economic feasibility of these interventions require studying the real field conditions. With this in view, a pilot study on one outlet of a minor irrigation system was conducted to convert a 5 ha area from surface irrigated to hybrid pressurized irrigated system and evaluate its technical and economic feasibility. This paper presents the results of this study.

2 Materials and Methods

The plateau areas of eastern India are characterized by high rainfall ranging between 1,100 to 1,600 mm. The mean monthly distribution of rainfall and their standard deviation of the region are shown in Fig. 1. Bulk of the rainfall occurs during the monsoon period of June to October (88% of total rainfall). Maximum average rainfall occurs in the month of July (392.26 mm) followed by August (333.7 mm) and September (324.41 mm) respectively. The standard deviation values varies form

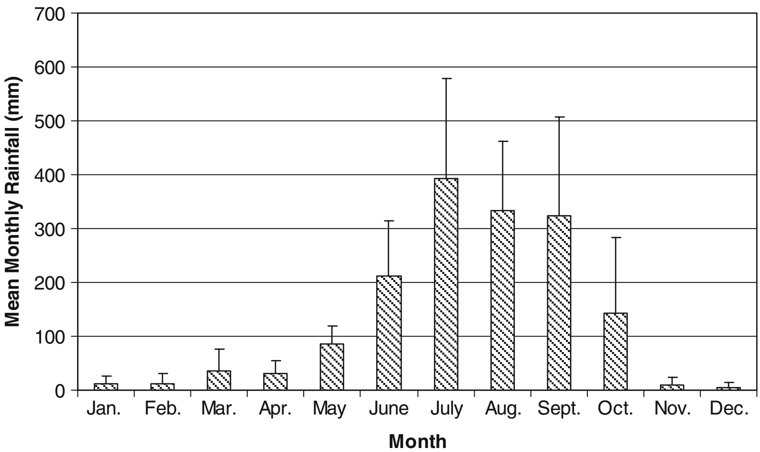

Fig. 1 Mean monthly rainfall of the study area with standard deviation bars

102.36 mm to 186.98 mm during the monsoon period of June to October and 9.99 mm to 33.50 mm during the non-monsoon period of November to May. But the coefficient of variation values varies from 3.86% to 9.93% during the monsoon months and 7.27% to 27.92% in non-monsoon months. So, even though standard deviations are higher in the monsoon months, the deviations with respect to mean in the above months are lower.

As significant rainfall occurs during monsoon season (June-October), only rice crop can be grown in medium and low lands, which form major chunk of canal command area. The canal water carries a heavy silt load especially during monsoon, which has to be taken care of before this water is used for pressurized irrigation. The land holdings in the command of an outlet are small with large number of owners of varied socio economic background and therefore the command area has diversified cropping pattern especially during post monsoon season, each requiring different irrigation method. Further the area has potential of aquaculture, which can be beneficially exploited while changing the supply from on-off to continuous. Based on these constraints and potential, a canal-based pressurized irrigation system should satisfy following conditions:

1. It should have an adjunct service reservoir to maintain continuous supply of water.
2. It should provide surface irrigation to rice in monsoon season and pressurized irrigation to non-rice crops during dry season.
3. The system should be integrated to operate different types of systems, viz., sprinkler, drip and micro-sprinkler to suit various crops under one outlet.
4. It should have provision for removal of silt deposited in the pipe network during operation for surface irrigation.
5. It should have provision of aquaculture for increasing production by non-consumptive utilization of water body.

The study was carried out at research farm of Water Technology Center for Eastern Region (WTCER), which lies in the command of Deras Minor Irrigation Project in Khurda district of Orissa (India). In this system, the water is released from reservoir in July and closed in mid November. After a gap of 2 to 3 weeks, the canal runs again and is closed in first week of April. During monsoon, the canal runs continuously but during post monsoon season it is on-off schedules at weekly interval. A system was designed to maintain continuous supply of water and use it more efficiently by using drip and sprinkler irrigation systems. To maintain continuous supply of water, one adjunct reservoir of 2,500 m^3 capacity was constructed to store the diverted water from canal. A filtration unit was installed along with the pump so that sediments in the water can be removed which is required for drip irrigation system to prevent emitter clogging. The filtration unit was a three-stage filtration process involving a hydrocyclone filter, followed by a sand filter and then a screen filter. A catch well was constructed between the adjunct reservoir and the pumping-cum-filtration unit to facilitate the pumping of water. Provision was made with on/off valve so that the system can be run as gravity fed irrigation for paddy crops in the monsoon season and pumping based drip and sprinkler irrigation for vegetable crops in the post-monsoon season. With an available overland slope of 0.9%, the mainline diameter was kept 110 mm instead of normal 75–90 mm so that the friction loss in pipeline is less than the gravity head available to facilitate gravity flow during monsoon (Srivastava and

Ahmed 1998). The schematic diagram of the water supply system and pressurized irrigation system is shown in Fig. 2.

The system was designed in such a way that both sprinkler and drip irrigation sets can be operated simultaneously. Four outlets were taken out from the mainline to irrigate 2.8 ha area by sprinkler irrigation system and two outlets were taken out to irrigate 1.9 ha by drip irrigation system. As the sprinkler system requires more head than the drip system, the first four outlets were used for sprinkler irrigation and next two outlets were used for drip irrigation system. Crops like pea, potato, french bean, cowpea and sunflower were taken under sprinkler irrigation system and crops like tomato, maize, okra, marigold and capsicum were taken under drip irrigation system. Maize, Okra and tomato were irrigated by 4 lph drippers whereas marigold and capsicum were irrigated by 2 lph drippers. The drip system was designed in such a way to fit crop geometry of different crops. The service reservoir was designed with two outlets at different elevations in such a way that the water flow from upper outlet by gravity during monsoon for surface irrigation and it flows through the other outlet to a catch well for pumping during post monsoon season.

The evaluation of the system was done in four parts: (i) Hydraulic evaluation of sprinkler and drip system; (ii) Crop production; (iii) Horticultural plants on embankment of the service reservoir; and (iv) Pisciculture in the service reservoir. With the information on water saving and productivity available, the economic analysis of the system was done.

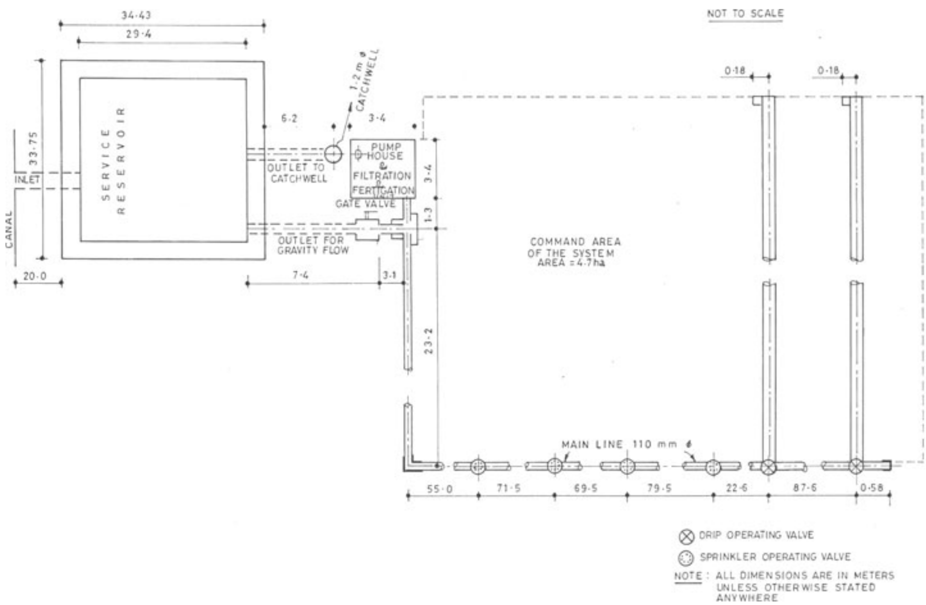

Fig. 2 Schematic diagram of canal based pressurized irrigation system

2.1 Hydraulic Evaluation

The Hydraulic evaluation consisted of evaluation in terms of (i) reduction in turbidity of canal water; (ii) efficacy of the reservoir in providing continuous supply of water; (iii) conveyance and application efficiency; and (iv) pressure, discharge and uniformity coefficient of the pressurized irrigation systems.

For assessment of reduction in turbidity, water samples were taken from canal, reservoir, and catch well and then from dripper. Although attempts were made to collect sample after each filter, it could not be done during running of the system. Turbidity levels at different stages were compared to determine the reduction in turbidity level. The efficacy of the reservoir in providing continuous supply of water was studied by regular monitoring of water level in the reservoir.

For conveyance efficiency studies under surface irrigated conditions, two flumes were installed in the channel feeding the surface irrigated area. One flume was installed at about 100 m from channel outlet and another just before opening to the field. The water levels in these flumes were monitored at regular interval and conveyance efficiency was estimated. The application efficiency in dry season crops was estimated by moisture monitoring in different soil layers by gravimetric method and using standard formula (Michael 1978). The conveyance efficiency (Ec) and application efficiency (Ea) are described by following relations.

$$Ec = \frac{W_f}{W_d} \times 100 \tag{1}$$

Where W_f = water delivered to the irrigation plot, and Wd = water diverted from the source.

$$Ea = \frac{W_s}{W_f} \times 100 \tag{2}$$

Where Ws = Water stored in the rootzone of the plants, and W_f = Water delivered to the irrigation plot.

The available pressure at the filters and drip and sprinkler irrigation systems were monitored through pressure gauges. The discharge of the drippers was measured by manual monitoring. The uniformity coefficient (Cu) of sprinkler irrigation method and Emission uniformity (EU) of drip irrigation methods were measured by following relations.

$$C_u = \left(1 - \frac{\sum X}{mn}\right) \times 100 \tag{3}$$

Where, m = average value of all discharge observations, n = total number of discharge observation points, X = numerical deviation of individual observations from the average application rate

$$EU = \left(1 - \frac{m}{D}\right) \times 100 \tag{4}$$

Where, d = average discharge of the emitter and m = mean deviation of the discharge from the average.

2.2 Crop Production

A rice-based crop rotation was grown to evaluate its performance in terms of the productivity and water use efficiency under surface irrigated condition and pressurized irrigation system. For comparison, another area was put under same crop rotation with open channel conveyance. During monsoon the only difference between these two was that inside project area it was pipe conveyance and surface application while outside project area it was open channel conveyance and surface application. During dry season, the comparison was between surface irrigation with open channel conveyance and pressurized irrigation. While in monsoon and winter season, the crops were put up under both types of application methods, no crop was planted with surface irrigation during summer as the canal is closed by first week of April. During summer (March end–mid June) a part of drip-irrigated command was put under crop, which was irrigated by water stored in the reservoir. During monsoon season, the water regime was monitored in terms of depth of ponded water, while during winter and summer; the moisture at different depths was monitored.

2.3 Horticultural Crops

Papaya was planted on the top and creeping type cucurbits on outward slope of the reservoir embankment. The data on crop growth was monitored every month and the fruits were harvested whenever it was ready.

2.4 Pisciculture

In the service reservoir, fry of Indian major carps were stocked @ 10,000/ha along with advanced fingerlings @ 2,000/ha for a period of 8 months. The growth of the fish and water quality parameters were monitored for the whole growth period. However, to avoid loss on account of poaching the production process was leased for an annual fee of US $ 113/-.

2.5 Economic Analysis

Economic analysis of the system was done by calculating the cost of saving the unit amount of the water by the system. For this, the benefits due to increased production of the crops in the command during monsoon and winter season, additional production from summer crops, horticultural crops on embankment of the adjunct reservoir and pisciculture in the reservoir were estimated. The cost was taken as the annual cost of the system inclusive of reservoir (which include depreciation, interest on investment, maintenance and energy cost for operating the pump), cost of cultivation of summer crops, horticultural crops on embankment and pisciculture. The amount of the water saved was estimated by calculating water saved during monsoon and winter season, water available for the summer cultivation and then deducting the water lost from the adjunct reservoir due to seepage and evaporation. The total income from summer crops has been accounted as benefit as no crop can be grown during summer with existing system because the canal is closed in first week of April. Cost of manpower for operating the pumping system has not been accounted assuming that it will be almost same for both types of systems. The water saved will either irrigate additional area or meet the demand of other sector. In absence of this saving, new water resource will have to be created to meet this demand. In view of it, the cost of saved water has been added to the overall return from the system. Planning Commission of India has estimated that the cost of creating irrigation potential for 1 ha, i.e., 0.75 ha m at head works will be US $ 3,000/-. Assuming 20% loss from head works to outlet, the capital cost of providing 0.6 ha m (considering 20% loss from 0.75 ha m) of water at outlet level is US $ 3,000/- . Hence capital cost of providing 1 ha m of water at the outlet is US $ 5,000/-. Based on this, the annual cost of creating 1 ha m of water at outlet level has been estimated as US $ 525/- considering life as 50 years, interest @ 9%, maintenance and operating cost @ 2%.

3 Results and Discussion

3.1 Hydraulic Evaluation of the System

The integrated system has four submains for sprinkler and two submains for drip system. As reported earlier, the system was designed to ensure gravity flow during monsoon season for irrigating rice crop. The discharge from the pipe at outlet level in gravity flow during monsoon season ranged from 6.5 to 8.5 lps depending upon level of water in the reservoir. The water reservoir remained at full supply level (FSL) for monsoon period ensuring gravity flow to the rice fields. During post monsoon season, the water level fluctuated between FSL and lower levels up to March, after which the pond level declined as the water supply to the canal system was stopped in the first week of April (Fig. 3). Thus the reservoir fulfilled the condition of providing water through gravity flow during monsoon season and converting on-off supply to continuous supply during post monsoon season.

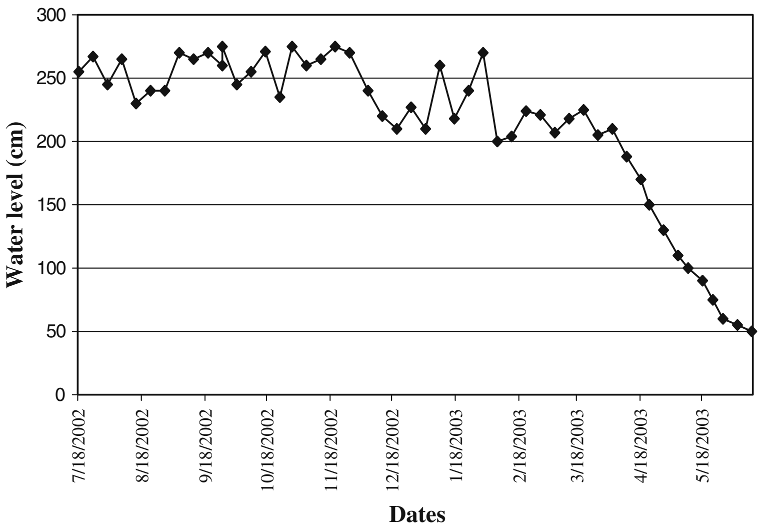

Fig. 3 Fluctuation of water level in the auxiliary reservoir

Turbidity levels were measured at the canal, pond, catch well and drippers on three different days in each year. In between catch well and drippers, three filters i.e. hydrocyclone filter, sand filter and screen filter were present. But the turbidity of water after each filter could not be measured, as it was not possible to collect the water samples from filter points when the pump was running. Figure 4 shows the turbidity levels at the canal, pond, catchwell and drippers on three different dates of 2004. It indicates that the service reservoir reduces the turbidity by two to five NTU, the catch well reduces the turbidity by two to four NTU and the filtration system reduces the turbidity by three to six NTU with final turbidity being within tolerable limit of four NTU. The tolerance limit of four NTU has been taken on the basis of experimentation to assess the reduction in discharge of the drippers with time running with different turbidity levels (Biswal 2004). The research results were similar in earlier years. Thus, the service reservoir not only ensured a continuous supply of water but also reduced the turbidity. If the turbidity had not been reduced significantly before the water enters the pumping system, there would have been more pressure on the pumping as well as the filtration system.

The conveyance efficiency of earthen conveyance channel (200 m length) was estimated by installing flumes on both ends. The discharge was measured at the source and at the delivery point to the field and the average conveyance efficiency over 3 years was found to be 75.1%. This indicates the extent of loss from the channel in a coarse soil area in undulating topography. The available pressure in the sprinkler irrigation system varied from 2 to 2.5 kg/cm^2 and in the drip irrigation system, it varied from 1.5 to 2 kg/cm^2. The discharge of 4 lph drippers varied form 3.5 l/min to 3.9 l/min, whereas the discharge of 2 lph drippers varied from 1.7 l/min to 1.9 l/min. The uniformity coefficient of the sprinkler irrigation system along the periphery and along the radius was found to be 82.6% and 80.2% respectively. Emission uniformity of drip irrigation system was evaluated for individual laterals and the whole system. The mean value of emission uniformity for individual laterals and whole system were

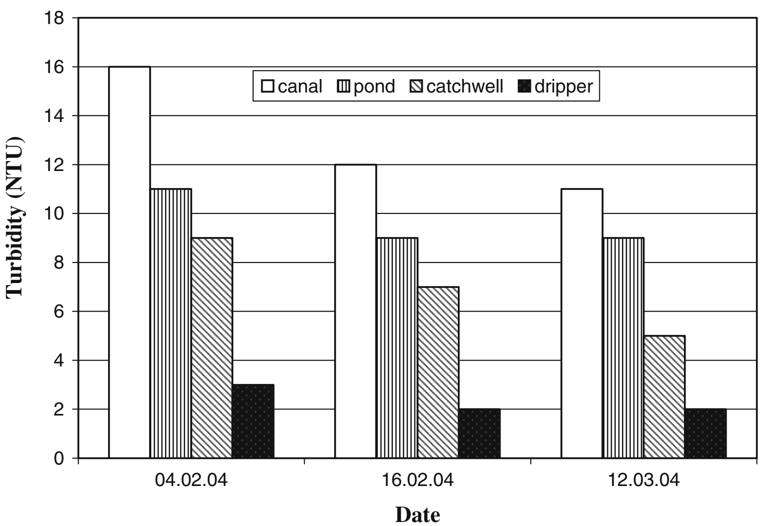

Fig. 4 Variation of turbidity at different stages of the system

found to be 97.1% and 94.2% respectively, which are well within the satisfactory level.

The application efficiency of surface, drip and sprinkler irrigation system was estimated on different dates. In surface irrigation system and drip irrigation system, it was evaluated in tomato crop and in sprinkler irrigation system, it was evaluated in cowpea. The mean application efficiency of surface irrigation system, sprinkler irrigation system and drip irrigation system were estimated as 61.5%, 77.2%, and 90.2% respectively (Srivastava et al. 2006). Studying this along with conveyance efficiency, it can be said that the irrigation efficiency below the outlet for surface irrigation system was 46.1%, against that of 77.2% for sprinkler and 90.2% for drip (assuming 100% conveyance efficiency). This indicates that the irrigation efficiency increases by 67.3% in case of sprinkler system and 95.5% in case of drip system.

3.2 Crop Production

A summary of the yield, irrigation water use and irrigation water productivity of crops grown with pressurized irrigation system compared to open channel conveyance and surface irrigation (Table 1) shows that in monsoon season also, there is saving of water, although there is no significant difference in the yield under both irrigation systems. For post monsoon crops, there is significant jump in yield, water saving and irrigation water productivity for all the crops. As different crops were grown under the system, the flexibility of individual farmer to grow crops as per his preference remains. The average total annual saving of water in a command area of 4.7 ha is 12,614 m^3. Thus shift to the pressurized system increases the irrigation efficiency as well as the productivity.

3.3 Horticultural Plants on Embankment of the Service Reservoir

The monthly crop growth data and yield were recorded in all the 3 years. It was found that 1,025, 1,010 and 1,645 kg of fruits were obtained from the plants in 2002–2003, 2003–2004 and 2004–2005 respectively. The yield was lower in earlier years, as the soil was excavated earth from the pond and therefore was poor in fertility. Bottle gourd (*Lagenaria vulgaris*) was grown on the outer embankment of the pond and the average annual production was 211 kg.

3.4 Pisciculture

Growth performance of C. mrigala was higher than that of L. rohita probably due to the fact that being bottom dweller; C. mrigal is more tolerant to oxygen depletion. Overall growth performance was good. After 8 months of rearing, the mean body weights were 885, 460, and 520 gm, respectively for *C. Catla, L. rohita* and *C. mrigala* respectively. Faster growth rate was however, recorded for C. *catla* (3.68 gm ADG) followed by *C. mrigala* (2.16 gm ADG) and *L. rohita* (1.91 gm ADG). The critical water quality variables remained within the optimal range. The average yield was 2.34 t/ha. However for economic calculation, the lease fee paid by the contractor has been accounted.

Table 1 Summary of effect of pressurized irrigation on water use and water productivity for crop year 2002–2003, 2003–2004, and 2004–2005

Crop (1)	Crop period (2)	Method of irrigation (3)	Area, ha (4)	Average yield, t/ha (5)	Increase in yield over channel conveyance and surface irrig., % (6)	Av. depth of irrig. with pressurized system, mm (7)	Av. gross depth of irrigation with open channel conveyance and surface irrig., mm (8) $\eta_c = 75\%$	Gross water saving over channel conveyance and surface irrig., mm (9 = 8–7)	Increase in irrig. water productivity over channel conveyance and surface irrig., % (10)
Rice	July–October	Pipe conveyance and surface irrigation	4.50	4.75 (4.56)[a]	5.72	152	240	88	64.47
Pea	November–February	Sprinkler	0.28	0.95 (0.89)	6.74	40	99	59	164.18
Potato	December–March	–do–	1.70	14.37 (11.29)	27.40	265	520	255	149.75
Cowpea	December–March	–do–	0.18	1.05 (0.81)	30.35	184	345	161	143.05
Sunflower	December–March	–do–	0.52	0.65 (0.41)	59.26	188	354	166	198.52
Frenchbean	December–March	–do–	0.20	1.21 (0.93)	30.11	180	335	155	142.14
Tomato	December–March	Drip	0.55	18.02 (13.47)	33.80	193	305	112	191.41
Capsicum	November–February	–do–	0.10	5.00 (3.10)	61.30	90	237	147	324.73
Okra[b]	March end–June	–do–	0.40	4.33 (3.93)	10.02	152	260	152[a]	88.46
Maize[b]	March end–June	–do–	0.25	3.00 (2.50)	20.00	218	397	218[a]	118.53
Marigold	November–April	–do–	0.50	7.00 (6.50)	7.69	220	375	155	83.56
Average annual gross saving of water								1,261.42 ha mm = 12,614.2 m^3	

η_c average conveyance efficiency

[a]Data in parenthesis indicate yield with open channel conveyance and surface irrigation

[b]These crops can not be grown with surface irrigation as there is no water in canal. Were grown with ground water, and therefore total water used has been taken as water saving

Table 2 Water balance of the system (average of three crop years)

Sl no.	Item	Average amount, (m^3)
1.	Water saved in monsoon	3,960
2.	Water saved in winter by sprinkler	5,960
3.	Water saved in rabi by drip	1,540
4.	Water saved during summer	1,150
5.	Total gross water saved	12,610
6.	Water lost from tank through evaporation from October to May	680
7.	Water lost by seepage loss @ 2 mm per day from October to May	140
8.	Net water saving through the system (4-5-6)	11,790

3.5 Economics of the System

Table 2 indicates that there is net annual saving of 11,790 m^3 of the water by shifting from surface irrigation to pressurized irrigation. Table 3 shows that annual additional benefit from crops and allied components is US $ 1,100/-. Table 4 estimates the annual cost of the system by calculating the cost of the adjunct reservoir and drip system separately which comes out to be US $ 1,526/-. Hence the additional annual receipt from the crops is less than the annual cost of the system. But there is significant water saving in the system. Hence by adding the cost of the saved water with the annual receipt from the crops, annual benefit from the system is obtained which is higher than the annual cost of the system. The benefit-cost ratio of the system has been found out as 1.126. This B-C ratio will improve further if the cultivation during summer season is enlarged and pisciculture in pond is better managed. However, the initial cost of the system is high and can not be funded by individual farmers. It has to be done either by government who has social obligation

Table 3 Net additional incomes from different activities

Sl. no.	Crop (1)	Area, ha (2)	Av. yield gain, t/ha (3)	Net additional production, Kg (4 = 2*3*1,000)	Net additional income, US$
1.	Rice	4.50	0.19	855.0	85.5
2.	Pea	0.28	0.06	16.8	5.4
3.	Potato	1.70	3.08	5,238.0	261.9
4.	Cowpea	0.18	0.24	43.2	9.0
5.	Sunflower	0.52	0.24	124.8	37.8
6.	Frenchbean	0.20	0.28	56.0	17.1
7.	Tomato	0.55	4.55	2,502.5	100.0
8.	Capsicum	0.10	1.90	190.0	18.9
9.	Okra*	0.40	0.40	160.0	18.9
10.	Maize*	0.25	0.50	125.0	12.6
11.	Marigold	0.50	0.50	250.0	300.0
	Total additional return from crops				867.1
	Fish				107.1
	Papaya and bitter gourd			1,297.0 + 211.0	125.1
	Total additional return				1,100.0

Table 4 Annual cost of the system and benefit–cost analysis

Sl no.	Item	Cost in US$
1.	Investment on pond and pump house	4,000
2.	Investment on drip and sprinkler system including pumping system	6,000
Sub total		10,000
Annual cost of pond and pump house		
1.	Depreciation on pond and pump house (assuming 25 years life and 50% junk value)	80
2.	Maintenance @ 1%	40
3.	Interest on investment @ 9%	180
Subtotal		300
Annual cost of drip and sprinkler system		
1.	Depreciation on drip and sprinkler system assuming 10 years life and 10% junk value	540
2.	Maintenance of the system @ 2%	120
3.	Interest on investment @ 9%	270
4.	Electricity charges @ 5 cents per KWH for 500 h of 10 hp pump	166
Subtotal		1,096
Additional cost of cultivation		
1.	Annual cost of fish cultivation and papaya cultivation	30[a]
2.	Annual cost of cultivation of Okra and Maize	100
Subtotal		130
Total annual cost of the system		1,526
Total additional receipt from crops		1,100
Water saved per annum		11,790 m^3
Annual cost of providing 1 ha m (10,000 m^3) of water at outlet		525
Equivalent cost of water saved		619
Annual benefit from the system		1,719
Benefit cost ratio of the system dividing annual benefit by annual cost		1.126

[a]Cost of fingerlings, papaya saplings, cost of planting (divided over 3 years) and annual cost of irrigation to papaya

to enlarge irrigated area for maintaining food security or an outside agency, which will utilize the saved water. Government machineries in India are slowly handing over a part of the network of the canal irrigation systems to ‘pani panchayats’ (water user’s association) for its operation and maintenance. Hence, once the canal based pressurized irrigation system is in place, the ‘pani panchayats’ can maintain the system with the collection of water tax from the farmer beneficiaries. The construction of auxiliary reservoirs can be fitted into the government program of rehabilitation of canal irrigations systems which is followed by transfer of irrigation management to ‘pani panchayats’.

Presently, the plateau areas of eastern region of India are witnessing a boom in metallurgy-based industrialization and it is estimated that additional annual demand of water for industrial sector will be about 1,500 M m^3. There is concern in irrigation circles that the demand from industry may reduce the water availability for agriculture. Already there is an agitation in command area of a multipurpose dam (Hirakud in Orissa state) to stop supply of water from dam to nearby metallurgical industries. If properly planned, the industry may pay for financing the infrastructure to improve the efficiency of the irrigation system and saved water can be diverted to meet the demand of industry.

4 Conclusion

It can be concluded from the study that shifting to pressurized irrigation in commands of flow based minor irrigation systems in plateau areas is feasible both from technical and financial point of view. The system reduced the turbidity of the water and provided continuous supply of water so that pressurized irrigation systems can be used with the canal irrigation system. The benefit-cost ratio of the system was found to be 1.126. The system has good potential of adoption in areas where the demand of water for non-agricultural sectors is going to rise sharply. Since the initial capital cost is higher, the funding mechanism needs to be developed in view of social, ecological and economic benefits.

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