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Managing canal water through farm-pond fed pressurized irrigation system

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ABSTRACT

The hydraulic performance of Nagpur minor canal system under Puri main canal jurisdiction (Odisha) having adequacy, equity and relative water supply values of 0.3, 0.68 and 0.72, respectively revealed the reduced performance of the system. Thus, in order to increase its performance in the command in terms of yield enhancement of crops, less water use and increase in physical as well as economic water productivity, pipe based pressurized irrigation system connected with farm ponds were laid out in upper, middle and lower canal reaches. Crops like groundnut, sesamum and vegetables were promoted during post-monsoon season in the year 2017-18 and 2018-19. In head reach, the crop yield and physical water productivity of groundnut and sesamum crops increased in the range of 14.5-28.9% and 41-75.5%, respectively, using 18.2-24.2% less water under pipe conveyance system, when compared with channel conveyance system. In middle reach, for the same crops, the performance of the sprinkler irrigation system was compared with pipe conveyance based irrigation and channel irrigation. There was increase in yield by 18.9% and 35.3% in groundnut, and 19.8% and 35.9% in sesamum under sprinkler irrigation system in comparison with pipe conveyance and channel conveyance systems, respectively. Physical water productivity through sprinkler irrigation system resulted 0.88 kg m^{-3} and 1.18 kg m^{-3} for groundnut and sesamum, respectively. Similarly, in lower reach, while growing groundnut, pointed gourd and bitter gourd, the yield increased by 28.4% and 39.5%; 25.1% and 33.0%; and 23.4% and 30.3% under drip irrigation system when compared with pipe conveyance and channel conveyance systems, respectively. The physical water productivity was observed as 8.48 kg m^{-3} and 9.85 kg m^{-3} in case of bitter gourd and pointed gourd through drip irrigation system, respectively. Further, drip irrigation system resulted in net economic water productivity of 111.5 ₹ m^{-3}, whereas channel conveyance system reported 117.6% less net economic water productivity. Thus, the provision of pressurized irrigation system in canal command area promises an opportunity for enhancing physical as well as economic water productivity.

1. INTRODUCTION

As recorded in ancient Indian scriptures, the history of irrigation development in India dates back to prehistoric times. However, the modern method of irrigation development started in India during British rule. The water sources for irrigation in coastal areas of India presently include major, medium or minor canal irrigation systems, tanks, ponds, groundwater and lift irrigation systems. The relative importance of canals (now at 17 M ha) has come down from 40% in 1951 to 26% in 2010-11 (Dhawan, 2017). This is mainly due to low efficient functioning of the system. This low efficiency is attributed to earthen run canals causing loss of water in conveyance process; lack of volumetric distribution; field to field irrigation; and privileged head reach farmers. Explorative study to find the rampant misuse of canal water taken up in the command area of Jhansi minor of the Bargi observed that the farmers use pressurized irrigation using tube wells, which are recharged by canal water. It was interesting to note that farmers taking water from personal tube wells were using sprinklers and were found personally present in the field, while the farmers taking canal water were wild flooding the fields and were not present in the field (Nema and Shrivastava, 2018). It indicated that abundancy of water is the major culprit in its management. On the other hand, a poor maintained canal system increases enormous conveyance loss, leading to a low performing irrigation system. A study carried out in Hirakud canal command area by Panda *et al.* (2016) indicated that the average water conveyance loss in the lined canal section is 0.026 $ls^{-1}m^{-2}$, where as in the unlined canal section it is observed as 0.409 $ls^{-1}m^{-2}$ (*i.e.* 94% less conveyance loss in lined section). While studying the bench marking performance of Nagpur minor of Puri canal system, system performance revealed that seasonal irrigation water supply per unit command area is 73% less than the designed supply of 20970 $m^3 ha^{-1}$ (Panda *et al.,* 2018). In India about 71% of the irrigation water is lost in the whole process of its conveyance from head works to application in the field. The breakup of the losses is main and branch canal (17%), distributaries (8%), water courses (20%) and field losses of 27%. Due to this, the water productivity of rice has remained in the range between 0.2-0.3 kg m^{-3} only. Similarly, Basediya *et al.* (2018) while evaluating canal command area of Samrat Ashok Sagar Project, Vidisha district, Madhya Pradesh on the basis on Nelson's parameters revealed that amount water reaching to tail end is not satisfactory and requires proper planning.

As per estimates of the National Commission for Integrated Water Resources Development Plan, the irrigation sector will consume about 68% of the available water resources in 2050, when available water resources shall account to be 1180 BCM (MoWR, 2011). It is estimated by erstwhile Planning Commission, Government of India that with a 10% increase in the present level of water use efficiency (WUE) in irrigation projects, an additional 14 M ha area can be brought under irrigation from the existing irrigation capacities.

Functioning of the canal irrigation systems are evaluated through performance indicators, and now-a-days, emphasis is given to promote micro-irrigation in canal command areas for enhancing economic water productivity. In this regards, encouraging research results obtained from various canal command areas in the country are referenced herewith. Water harvesting through monsoon water and canal conveyed water and use of harvested water through efficient means is one of the options to increase WUE. Sivanappan (1994) found this result through shifting of surface irrigation to drip and sprinkler irrigation methods, which could save water up to 60% alongwith enhancing yield by 10-50% in different crops. While adopting pressurized irrigation system in canal command area, the problem of turbidity of canal water can be managed by making it to pass the adjunct reservoir, catch well and a three-stage filtration process (Basediya *et al.*, 2017). Thus, the canal based drip and sprinkler irrigation system with adjunct reservoir has the potential of becoming a feasible way of irrigation in canal commands. Nagpur minor canal directly off taking from Puri main canal system, in coastal Puri district of Odisha (India) is deficient in its functioning due to non-demand based water supply in the canal, as it mostly runs during monsoon season months. Thus, there was need of provision of auxiliary water storage structures for creating an assured irrigation source for the crop fields. Keeping this in view, the hydraulic performance of the irrigation system followed by a pilot study was strategized in Nagpur minor canal. The aim of the study was to create assured water resources, to increase crop yields and economic water productivity. The design procedure for the irrigation system was followed based on prescribed guidelines suggested by Michael (1978).

2. MATERIALS AND METHODS

Study Area

Nagpur minor canal system, which starts from Puri main canal at reduced distance (RD) of 35.620 km (L) in Khurda district of Odisha, India (20°13'27"N latitudes and 85°52'46"E longitudes) was selected for the study purposes (Fig. 1). The minor runs a length of 3.0 km with design discharge of 0.3 cumec and command area of 156 ha with canal scheduling between 15th July to 15th November. The study area experiences total annual average rainfall amount of 1428 mm with effective rainfall of 85 mm only during post monsoon season.

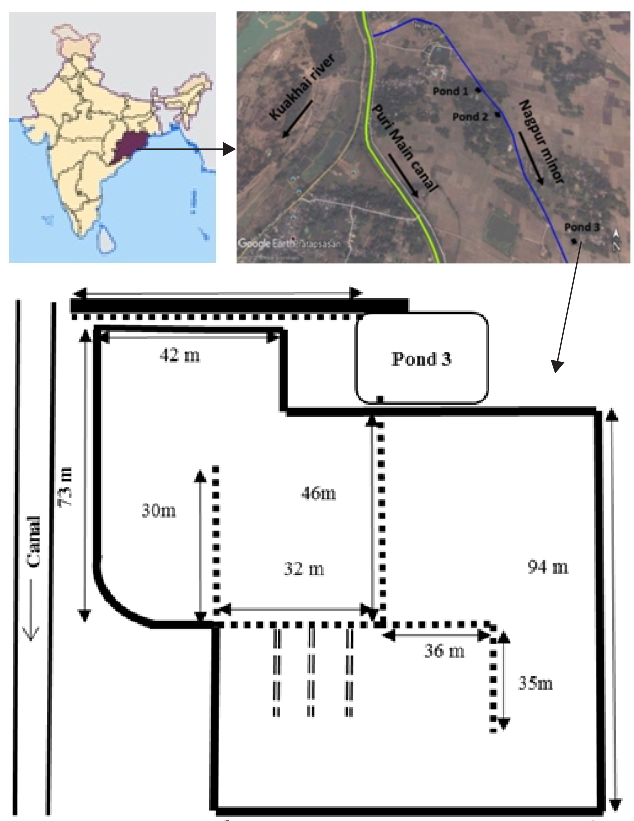

Fig. 1. Schematic diagram of the study area

Hydraulic Performance of the Minor Irrigation System

Hydraulic performance of the selected canal system was studied based on adequacy, equity and relative water supply (Molden and Gates, 1990). Adequacy of water delivery is dependent on water supply, specified delivery schedules and the capacity of hydraulic structures to deliver water according to the schedules and the operation and maintenance of hydraulic structures. A measure of performance relative to this objective for a region 'R' served by the system over the period T is given as follows:

$$P_A = \frac{1}{T}\sum_{T}\left(\frac{Q_{Dt}}{Q_{Rt}}\right)$$

Where, Q_{Dt} = the actual amount of water delivered by the system in t^{th} time period, Q_{Rt} = the amount of water required for the consumptive use, leaching requirement, land preparation and conveyance losses downstream of the delivery point in t^{th} time period and T is the sum of all these time periods.

Equity of irrigation water supply is the supply of irrigation water in equitable manner over the reach.

$$P_E = \frac{1}{T}\sum_{T} CV_R\left(\frac{Q_{Dt}}{Q_{Rt}}\right)$$

Where, P_E is equity, $CV_R\ \frac{Q_{Dt}}{Q_{Rt}}$ is the spatial coefficient of variation of the ratio $\frac{Q_{Dt}}{Q_{Rt}}$ over the region R. This measure describes the degree of variability in relative water delivery from point to point over the region. The closer value of P_E to zero, the greater the degree of equity.

Similarly, relative water supply (RWS) relates the irrigation water available for crops from surface and rain water to the amount of water the crop needs.

$$\text{RWS} = \frac{\text{Total water supply}}{\text{Crop demand}} = \frac{\text{Irrigation supply + Rainfall}}{\text{Crop ET + Seepage + Percolation}}$$

Irrigation Infrastructure

Irrigation provision having PVC pipe conveyance system, PVC pipe conveyance alongwith sprinkler irrigation system, and PVC pipe conveyance along with drip irrigation system were laid out in head, middle and tail reaches of the selected canal command area during 2017-18. The created conveyance facilities were connected to the existing farm ponds. The hydraulic performance of the drip (Coefficient of variation, CV; emission uniformity, EU and water distribution efficiency, WDE) and sprinkler irrigation (distribution uniformity, DU) systems were determined following the procedures suggested by Karmeli and Keller (1975) and Michael (1978).

The cost of irrigation infrastructures on annuity basis was included alongwith the cost of cultivation of the crops while computing the economics of the system in head, middle and tail reaches.

3. RESULTS AND DISCUSSION

The canal schedule remained seasonal (15th July-15th Nov) with designed command area, actual irrigated command area and total length of 156 ha, 132.6 ha and 3.0 km, respectively. Similarly, design and actual average discharge rate of 0.31 m^3s^{-1} and 0.10 m^3s^{-1} were documented, respectively. There are 15 no. of outlets in Nagpur minor canal serving a command area of 156 ha that includes 580 beneficiary farmers of the village of Hirapur and Nagpur of Balianta block.

Assessing Hydraulic Performance of the Minor Canal System

Performance measures of Nagpur minor irrigation system were studied during 2016-17 in terms of adequacy, equity and relative water supply indicators, and are presented in Table 1.

Four major crops were grown in *rabi* season 2018 in the command, *viz.,* groundnut, sesamum, pointed gourd, and bitter gourd. Total volume of canal water supply to Nagpur minor (based on Water Resources Department, Government of Odisha data) was computed as 184032 m^3 (15th July-15th Nov, 2018). Adequacy value of 0.3 indicated the ill performance of the Nagpur minor irrigation system. The low value of adequacy is mainly due to poor water supply of canal system in this season. The delivery of canal irrigation water is considered adequate when irrigation water supply (Q_D) is equal to the required irrigation water (Q_R). It means a canal can be adequate, when its value is unity *i.e.* 1. Also, the value of equity of 0.68 showed the poor equity of the canal water. The closer the value of equity to zero, the more equitable the distribution of water is in the system. Similarly, the relative water supply was calculated as 0.72. From the results obtained, it is clear that there is less quantity of water available at the canal reach. The value of

Table: 1
Hydraulic performance based on Molden and Gates (1990)

Crops grown	Area under different crops (ha)	Crop water requirement (m)	Adequacy	Equity	Relative water supply
Groundnut	79.8	0.47	0.302	0.687	0.726
Sesamum	21.5	0.3			
Pointed gourd	17.5	0.7			
Bitter gourd	7.8	0.6			

RWS greater than or equal to 1 indicates good performance of water distribution system. Thus, based on the canal performance indicators, it revealed that there is need of improvement in the canal performance. As most of the canal length is unlined; there is enormous seepage from the canal resulting in poor performance.

Irrigation infrastructures were laid out as described in the afore-mentioned section in upper, middle and lower reaches. Prior to taking up the experiment, the application efficiency and distribution efficiency were measured under surface irrigation method and were observed to vary between 55% to 75%, and 65% to 80%, respectively. The hydraulic performance of sprinkler and drip irrigation systems were found satisfactory with CV of 7%, EU of 95% and DE of 96% under drip irrigation, and DU of 87% under sprinkler irrigation. Overall, the study indicated that the irrigation efficiency can be raised to 90% under drip and 80% under sprinkler from present 35-60% in different crops (Panda *et al.,* 2018).

Yield, Physical and Economic Water Productivity under Pressurized Irrigation Systems

Upper reach

Irrigation provision of PVC pipe conveyance system was laid out in head reach in the proposed minor irrigation system. The created conveyance facility was connected to the existing auxiliary water storage structure. During *rabi* and summer seasons of 2017-18 and 2018-19, groundnut and sesamum were grown in upper reach and it was observed that the yield and physical water productivity of the crops increased by 14.5-28.9% and 41.0-75.5%, respectively, using 18.2-24.2% less water under pipe conveyance system in comparison with channel conveyance system. Crop yield, water use and physical water productivity under channel conveyance system varied between 0.76-1.31 t ha^{-1}, 165-330 mm, and 0.39-0.45 kg m^{-3} in case of groundnut and sesamum crops (Table 2). Even if, B:C ratio for both the methods of irrigation was reported to be 1.1, the pipe based irrigation system resulted in net economic water productivity of 2.60 ₹ m^{-3}, whereas channel conveyance resulted 106% less net economic water productivity (Table 3).

Middle reach

Existing auxiliary water storage structure was linked with the PVC pipe conveyance facility alongwith sprinkler irrigation system in the middle reach in the canal. Similar to upper reach, during *rabi* and summer seasons of 2017-18 and 2018-19, groundnut and sesamum were grown. The performance of the sprinkler irrigation system was compared with pipe conveyance based irrigation and channel irrigation. The results revealed that yield of groundnut increased by 18.9% and 35.3%, and of sesamum by 19.8% and 35.9% under sprinkler irrigation system in comparison with pipe conveyance and channel conveyance systems, respectively. Water use was less by 12.7% and 26.6% under sprinkler irrigation system compared to pipe conveyance and channel conveyance systems, respectively. Highest physical water productivity of 0.88 kg m^{-3} and 1.18 kg m^{-3} from groundnut and sesamum, respectively, were recorded with the sprinkler irrigation system (Table 2). Similarly, sprinkler irrigation system resulted in highest net economic water productivity of 11.40 ₹ m^{-3}. Channel conveyance

Table: 2
Average yield and physical water productivity under pressurized irrigation systems (2017-19)

Location	Crops	Irrigation methods	Yield (t ha^{-1})	Water applied (mm)	Physical water productivity (kg m^{-3})
Upper reach	Groundnut	Pipe conveyance	1.5	270	0.55
		Channel conveyance	1.31	330	0.39
	Sesamum	Pipe conveyance	0.98	125	0.79
		Channel conveyance	0.76	165	0.45
Middle reach	Groundnut	Pipe conveyance	1.74	270	0.64
		Sprinkler	2.07	240	0.88
		Channel conveyance	1.53	320	0.48
	Sesamum	Pipe conveyance	1.01	125	0.81
		Sprinkler	1.21	105	1.18
		Channel conveyance	0.89	150	0.59
Lower reach	Groundnut	Pipe conveyance	1.76	270	0.66
		Drip	2.26	210	1.08
		Channel conveyance	1.62	330	0.49
	Pointed gourd	Pipe conveyance	15.15	270	5.57
		Drip	18.96	195	9.85
		Channel conveyance	14.25	325	4.36
	Bitter gourd	Pipe conveyance	12.4	225	5.47
		Drip	15.31	180	8.48
		Channel conveyance	11.75	270	4.32

Table: 3
Economics of crop production and water productivity

Crops	Conveyance Method	Gross returns (₹ ha^{-1})	Gross Expenditure (₹ ha^{-1})	Net Returns (₹ ha^{-1})	B:C ratio	Gross economic water productivity (₹ m^{-3})	Net economic water productivity (₹ m^{-3})
Upper reach							
Groundnut and	Pipe	67295	62229	5066	1.1	34.1	2.6
sesamum	Channel	55776	52700	3076	1.1	22.5	1.2
Middle reach							
Groundnut and	Pipe	74100	62229	11871	1.2	37.5	6.0
sesamum	Sprinkler	88418	68750	19668	1.3	51.3	11.4
	Channel	65217	53000	12217	1.2	27.8	5.2
Lower reach							
Groundnut and	Pipe	258271	94046	164226	2.7	101.3	64.4
vegetables	Drip	322421	104934.60	217486.70	3.1	165.3	111.5
	Channel	243073	85033	158039	2.9	78.8	51.3

system reported the lowest physical and net economic water productivity.

Lower reach

Similarly, irrigation provision of PVC pipe conveyance along with drip irrigation system was laid out in tail reach (Photo 1). It was observed that the yield of groundnut, pointed gourd and bitter gourd increased by 28.4% and 39.5%, 25.1% under drip irrigation system, respectively when compared with pipe conveyance. While comparing with the channel conveyance systems, yield increases under drip irrigation system were 33.0%, 23.4%, and 30.3% for the respective crops. The water use by the above three crops were 180-210 mm, 225-270 mm, and 270-330 mm, respectively. Physical water productivity through drip irrigation system was 8.48 kg m^{-3} and 9.85 kg m^{-3} in case of bitter gourd and pointed gourd, respectively. Like previous cases, as expected, drip irrigation system along with introduction of vegetable crops resulted in highest net economic water productivity of 111.5 ₹ m^{-3}. Lowest net economic water productivity was recorded with the channel conveyance system and it was less by 117.6% than the drip irrigation system.

4. CONCLUSIONS

Shifting from field-to-field surface irrigation method to canal linked auxiliary water harvesting device using pressurized irrigation methods can be a viable proposition for increasing physical water productivity in canal command; as for instance in ground nut crops, sprinkler and drip irrigation system increased the physical water productivity in the tune of 83% and 120%, respectively in comparison to channel irrigation. Thus, this approach, as demonstrated successfully in various canal command areas in the country, can also be suited to under performing canal commands located in coastal areas during post monsoon season. However, in order to enhance the net economic water productivity, instead of adopting only PVC pipeline based irrigation facility, drip irrigation system alongwith economically viable vegetable crops may be considered in the canal commands.

REFERENCES

Basediya, S.S., Pyasi, S.K. and Shrivastava, R.N. 2018. Evaluation of performance indicators for canal command area of Samrat Ashok Sagar Project Vidisha district M.P. *Int. J. Agric. Eng.*, 11(1): 244-248, doi: 10.15740/HAS/IJAE/11.1/244-248.

Photo 1 (a) Irrigation setup in lower reach canal, (b) Canal water fed through drip irrigation

Basediya, S.S., Pyasi, S.K., Shrivastava, R.N. and Sharma, S.K. 2017. A review on feasibility of pressurized irrigation, in canal command area. *Int. J. Agric. Sci. and Res.* (IJASR). 7(6): 259-264.

Dhawan, V. 2017. Water and agriculture in India. Background paper for the South Asia experts panel during the Global Forum for Food and Agriculture (GFFA), German Asia-Pacific Business Association, pp 1-27.

MoWR, 2011. www.planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_major.pdf.

Karmeli, D. and Keller, J. 1975. Trickle irrigation design. Rain Bird Sprinkler Manufacturing Corporation, California, USA.

Michael, M. 1978. Irrigation Theory and Practice. Vikash Publishing House Pvt. Ltd., New Delhi, 801 p.

Molden, D.J. and Gates, T.K. 1990. Performance measures for evaluation of irrigation-water-delivery systems. *J. Irrig. Drain Eng.,* 116: 804-823.

Nema, R.K. and Shrivastava, R.N. 2018. Pressurized Irrigation in Canal Command Area. *Int. J. Agric. Sci.,* 10(8): 5849-5851.

Panda, R.K., Mohanty, S., Brahmanand, P.S., Kumar, A., Raju, P.V. and Rao, V.V. 2016. Appraisal of canal hydraulics and field water balance components at distributary level in Hirakud canal command. *Indian J. of Soil Cons.*, 44(1): 19-24.

Panda, R.K., Rautaray, S.K., Panigrahi, P., Ambast, S.K., Verma, O.P., Raychaudhuri, S., Thakur, A.K., Mohanty, R.K. and Sinha, M.K. 2018. Command area development and management strategies in a coastal region. *J. Indian Soc. Coastal Agric. Res.,* 36(1): 34-39.

Sivanappan, R.K. 1994. Prospects of Micro Irrigation in India. *Irrig. Drain. Syst.*, 8 (1): 49-58.