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# Command Area Development and Management Strategies in a Coastal Region

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**Command area development and management strategies were attempted in Nagpur minor canal in a coastal district of Puri, Odisha (India) under Puri canal system. Benchmarking of the irrigation system was carried out considering domains of system performance, agricultural productivity and financial aspects. Under system performance, the results revealed that seasonal irrigation water supply per unit command area is 73% less than the designed supply of 20970 m$^3$ ha$^{-1}$. Under agricultural productivity for paddy crop as expressed in market based output versus supplied water was computed as 18% less, when it is computed as Rs. 9.9 m$^{-3}$ (considering MSP of paddy Rs. 1410 q$^{-1}$ during 2015-16; average crop yield of 3.9 t ha$^{-1}$ and actual water supply of 5565 m$^3$ ha$^{-1}$). Similarly, under financial performance expressed as cost - recovery ratio was obtained as 0.1 only. The irrigation efficiency under surface irrigation methods (check basin, furrow and raised bed furrow) in different crops was observed to the tune of 35-60% which could be improved up to 80–90% using pressurized irrigation (pipe conveyance, drip irrigation and sprinkler irrigation) in upper, middle and tail reach of the minor. The results of the study reveal that the use of pressurized irrigation, which could increase the irrigation efficiency and water productivity is one of the potential options for sustainable crop production in water scarce canal command area of coastal Odisha.**

*(**Key words:** Command area in coastal area; irrigation benchmarking; conveyance system; water management)*

Out of about 140 million ha of cultivable land in India, the canal irrigated area inclusive of coastal region was 8.3 million ha during 1950-1951, which is now 17 million ha. Despite that, the relative importance of canals has come down from 40% in 1951 to 26% in 2010-11 (Dhawan, 2017). To name a few prominent limitations in canal systems, earthen run canals cause enormous loss in conveyance process; lack of proper irrigation infrastructures with no volumetric distribution provision; field to field irrigation; and head reach farmers privilege in fetching lion's share of canal water cause the system an inefficient proposition. However, due to lack of conservation of water in rainy season, the supply of water becomes a constraint for sustaining crop production in command areas during post monsoon season.

Presently, the water use efficiency (WUE) in medium and major canal commands of India is only 38%, which can be substantially improved. 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 (http://planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_major.pdf). It is estimated that a 10% increase in the present level of water use efficiency in irrigation projects, an additional 14 million ha area can be brought under irrigation from the existing irrigation capacities, which would involve a very moderate investment as compared to the investment that would be required for creating equivalent potential through new schemes (http://planningcommission.nic.in/plans/planrel/fiveyr/9th/vol2/v2c4-2.htm).

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 in coastal regions. Improvement in the present form of surface irrigation methods and way of scheduling irrigation is one of the ways to increase WUE. Further, shifting of surface irrigation to drip and sprinkler

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irrigation methods which could save water up to 60% with enhancing yield by 10-50% in different crops is another option (Sivanappan, 1994). In water scarce scenarios, the pilot scale studies of micro irrigation implemented through drip and sprinkler is required in different crops in various agro climates. Benchmarking has to be restored to measure and compare the performance of a project and the practices in the commands.

Eastern India is one of the water rich regions of the country. However, due to inefficient use of water, the water productivity (WP) in crop production in the region is lowest in the country. Rice is the dominating crop in the region, in which the WP is too low (0.2-0.3 kg $m^{-3}$). There is an urgent need to improve WUE or WP through enhanced irrigation efficiency and crop yield. Alternate wetting and drying (AWD) is one of the ways to enhance WP in rice (Motea *et al*., 2017). Keeping this in view, the benchmarking of the irrigation system followed by a pilot study was strategized in one of the minor canal directly off taking from Puri main canal system, in coastal Puri district of Odisha. Under the study, provision of auxiliary water storage structures on either side of the minor canal with PVC conveyance system along with pressurized irrigation facility and AWD was tried in its head, middle and tail reaches with the aim to create assured water resources, to increase the crop yields and the economic water productivity.

## MATERIAL AND METHODS

The study area is located in two villages namely; Nagpur and Hirapur under Umadei Brahmapur Gram Panchayata, Balipatna Tahasil, disctrict Khurda of Odisha, India (20° 13′ 27″ N latitude and 85° 52′ 46″ E longitude). Nagpur minor canal offtakes from Puri main canal at Reduced distance (RD) 35.620 km (L) and passes through Nagpur and Hirapur villages (Fig. 1).

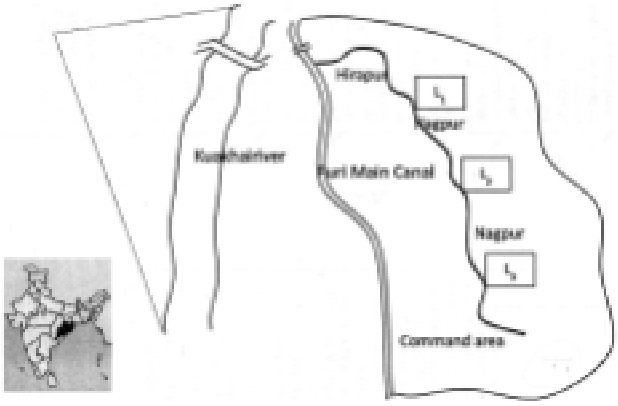


***Fig. 1.*** *Schematic diagram of the Study area*

This minor comes under Puri main canal of Nimapara Irrigation Division. Puri Irrigation Division comes under the jurisdiction to command irrigation of Daya-Bhargovi-Doab, (No. VII), which is a part of Mahanadi Delta Stage-II, major irrigation project having command area of 49828 ha. The minor runs a length of 3.0 km with design discharge of 0.3 cumec and command area of 156 ha. The pH of the soil was 6.6-7.3, whereas the organic carbon, available N, available P, available K and water holding capacity were 2.77-4.45 g $kg^{-1}$, 178-209 kg $ha^{-1}$, 25.3-31.0 kg $ha^{-1}$, 126-161 kg $ha^{-1}$ and 47.2-61.2%, respectively. The study area experiences total annual average rainfall amount of 1428 mm, out of which monsoon period (June-October) experiences 1239 mm (87%).The details of weekly mean rainfall and pan evaporation for last twenty years at the study site is presented in Fig. 2. The average annual maximum and minimum temperature remains within 29.1°C and 22.5°C, respectively.

### Irrigation benchmarking

Irrigation canal performance considering three domains of system performance, agricultural productivity and financial aspects was studied based on the guidelines prescribed by INCID (2002). The performance indicators like Annual irrigation water supply per unit command area under system performance ($m^3$ $ha^{-1}$); output per unit irrigated area (Rs. $ha^{-1}$), and output per unit crop water demand (Rs. $m^{-3}$) under agricultural productivity; and cost recovery ratio under financial indicators were considered for hydraulic performance of the canal system.

The data pertaining to annual irrigation water supply in the canal was collected from the Department of Water Resources, Govt. of Odisha and measured in the canal also. Similarly, the crop yield data was collected from the farmers farm produce and converted to monetary term based on the minimum support price of a particular crop. Cost recovery ratio was obtained based on the gross revenue collected to the cost involved in running the canal system including maintenance cost.

### Irrigation efficiency and conveyance systems

Irrigation efficiency (application efficiency and distribution efficiency) and water use efficiency (yield per water use) in the crops (groundnut and vegetables) grown during *rabi* season under surface irrigation in the command were determined. The irrigation water applied to different crops was measured using parshall flume in the field channels of the command area. Irrigation provision of PVC pipe conveyance system, PVC pipe conveyance along with sprinkler irrigation system and PVC pipe conveyance along with drip irrigation system were laid out in head, middle and tail reaches. In each reach, around one hectare of crop area was selected and pressurized irrigation systems were installed in that land for the study. The design of the irrigation systems were done following the steps suggested by Michael (1978). The created conveyance facilities were connected to the existing auxiliary water storage structures. 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 Michael (1978) and Karmeli and Keller (1975).

**Water saving irrigation with alternate wetting and drying (AWD) method in transplanted rice**

Prior to taking up the pipe conveyance based irrigation in the command area during post monsoon season, an experiment was conducted to ascertain the best time to irrigate the rice crop. Water saving method of AWD was adopted during monsoon season following the procedures suggested by Bouman *et al.,* (2007). This method was developed by International Rice Research Institute, Philippines through a field water tube for use as the tool to monitor the water level below the soil surface.After an irrigation application, the field water depth will gradually decrease in time. When the water level (as measured in the tube) is 15 cm below the surface of the soil, it is time to irrigate and flood the soil with a depth of around 5 cm. However, this critical depth of 15 cm below the soil surface varies with soil, weather and water table conditions. To determine this critical depth, a field experiment was conducted during wet season of 2016 in a split plot design with three replications. Continuous submergence was compared with the AWD in main plots. Three levels of safe AWD *viz*., water level at 5 cm, 10 cm and 15 cm below the soil surface before re-flooding were the subplot treatments.

In the present experiment, nine PVC pipes of 20 cm in diameter and 40 cm in length were used. In the bottom 25 cm of the pipe, holes of 5 mm diameter were done. The holes were spaced at 2 cm gap. The top 15 cm of the PVC pipe was above the soil surface level and bottom 25 cm was below the soil surface in the experimental field with transplanted rice. A standing water level of 5 cm was provided through surface irrigation, when water level inside the PVC pipe reached the critical level.

The transplanted rice seedlings were allowed to establish by maintaining shallow submergence (2-5 cm) for the initial 18 days. This helped in easy establishment of seedlings and also in managing weed problems. After seedling establishment, the field water depth was managed under AWD method. In this method, field water depth was allowed to fall to the pre-determined threshold depth (below the soil surface) before the next irrigation is applied. Three threshold depths tried in this experiment were 5 cm, 10 cm and 15 cm below the soil surface.

Due to the under performance of the canal system, pipe conveyance based pressurized irrigation provision has been created in upper, middle and tail reaches in the command area for improving the system performance (Fig. 3 and Photo 1). It was planned that water can be fetched from adjunct field tanks adjacent to the minor during post monsoon season.

## RESULTS AND DISCUSSIONS

The details of the outlets versus command area in Nagpur minor is given in Table 1. The canal schedule remained seasonal (15th July-15th November) 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 rates of 0.31 $m^3s^{-1}$ and 0.10 $m^3s^{-1}$ were measured, respectively.

Benchmarking of the minor in terms of system performance, agricultural productivity and financial performance was studied. Under system performance, the results revealed that presently seasonal irrigation water supply per unit command area is 73% less than the designed supply of 20970 $m^3$ $ha^{-1}$. Under agricultural productivity for paddy crop as expressed in market based output versus supplied water was computed as 18% less, when it is computed as Rs. 9.9 $m^{-3}$ considering MSP of paddy Rs. 1410 $q^{-1}$ during 2015-16; average crop yield of 3.9 t $ha^{-1}$; and actual water supply of 5565 $m^3$ $ha^{-1}$. Similarly, under financial performance expressed as cost - recovery ratio was obtained as 0.1 only (Table 2), when water charges and cost of providing the water in the command are calculated as Rs. 0.39 lakh considering water charge for kharif season as Rs. 250.00 $ha^{-1}$ (Source: Gazette No. 494 Dt. 05.04.2002) and Rs. 4.0 lakh (Source: Department of Water Resources, Govt. of Odisha).

The application efficiency and distribution efficiency measured under different surface irrigation methods used by farmers in different crops during *kharif* season in the command varied from 55 to 75% and from

***Table 1.*** *Outlets versus command area in Nagpur minor*

| Sl. No. | Outlet Nos./Reduced Distance (km) | Command area (ha) | Total beneficiary farmers |
|---|---|---|---|
| 1 | 1R/0.196 | 11.50 | 118 |
| 2 | 2R/0.179 | 4.94 | 52 |
| 3 | 3R/0.971 | 9.94 | 112 |
| 4 | 4R/1.461 | 4.29 | 38 |
| 5 | 5R/1.803 | 5.19 | 18 |
| 6 | 6R/2.142 | 5.046 | 18 |
| 7 | 7R/2.645 | 13.58 | 26 |
| 8 | 8L/0.072 | 1.45 | 12 |
| 9 | 9L/0.434 | 6.47 | 28 |
| 10 | 10L/0.575 | 6.42 | 26 |
| 11 | 11L/0.663 | 3.66 | 24 |
| 12 | 12L/1.680 | 14.310 | 44 |
| 13 | 13L/2.084 | 20.370 | 49 |
| 14 | 14L/2.486 | 17.34 | 36 |
| 15 | Tail/0.041 | 31.5 | 19 |
| Total | | 156.0 | 580 |

***Table 2.*** *Benchmarking through computation of performance indicators*

<table>
<tr><td rowspan="2">System Performance</td><td colspan="2">Total water supplied (cum)</td><td>Irrigated area (ha)</td><td>Total water supplied per unit irrigated area, ($m^3 ha^{-1}$)</td><td>Potential Area utilized / Potential Area created (ha)</td></tr>
<tr><td>Designed<br>Actual</td><td>3271267.3 $m^3$/122 days<br>737856 $m^3$/122 days</td><td>156<br>132.6</td><td>20969.7<br>5564.5</td><td>0.85</td></tr>
<tr><td rowspan="2">Agricultural Productivity</td><td></td><td>Agricultural production from irrigated area (Rs.)</td><td colspan="2">Output/actual irrigated area (Rs. $ha^{-1}$)</td><td>Output / unit irrigated water supply (Rs. $m^{-3}$)</td></tr>
<tr><td>Based on MSP<br>Based on market price</td><td>72,917,00<br>59,471,10</td><td colspan="2">54,990<br>44,850</td><td>9.88<br>8.06</td></tr>
<tr><td rowspan="2">Financial Performance</td><td>Water charges (Rs.)</td><td>Cost of providing the service (Rs.)</td><td colspan="2">Cost recovery ratio</td><td>Total O & M cost / actual area irrigated (Rs.$ha^{-1}$)</td></tr>
<tr><td>39,000</td><td>4,00,000</td><td colspan="2">0.1</td><td>235.3</td></tr>
</table>

Note: Average paddy selling rate based on local market = Rs. 1150 $q^{-1}$ and O& M cost = Rs. 200 $ha^{-1}$

65 to 80%, respectively (Table 3). Moreover, the low yield and water loss under surface irrigation resulted in low water use efficiency (0.31–6.35 kg $m^{-3}$) in different crops.

The hydraulic performance of the system was found satisfactory with CV of 7%, EU of 95% and WDE of 96% under drip irrigation and DU of 87% under sprinkler irrigation. Overall, the initial study indicated that the irrigation efficiency can be raised to 90% under drip and 80% under sprinkler from present 35–60% in different crops.

**Water saving irrigation with alternate wetting and drying (AWD) method in transplanted rice during monsoon season**

The results revealed that rice grain yield was similar to continuous submergence with AWD if the water level

***Table 3.*** *Irrigation efficiency and water use efficiency in different crops under surface irrigation during kharif season in the command*

| Irrigation method | Crop | Irrigation efficiency | | Water use efficiency(kg $m^{-3}$) |
|---|---|---|---|---|
| | | Application efficiency (%) | Distribution efficiency (%) | |
| Check basin | Groundnut | 60 | 70 | 0.35 |
| Check basin | Green gram | 55 | 65 | 0.31 |
| Furrow | Okra | 65 | 75 | 5.57 |
| Bed and Furrow | Bottle gourd | 70-75 | 75-80 | 3.72 |
| Bed and Furrow | Bitter gourd | | | 1.63 |
| Bed and Furrow | Watermelon | | | 6.35 |
| Bed and Furrow | Cucumber | | | 1.77 |

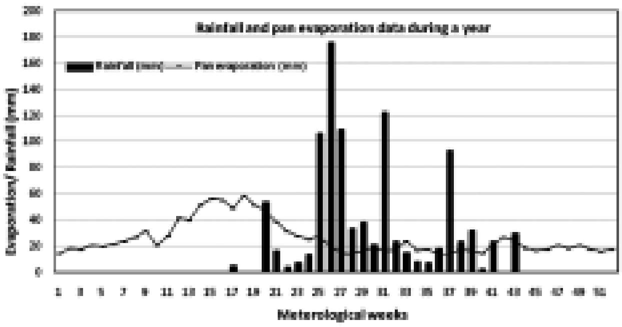


***Fig. 2.*** *Rainfall and pan evaporation data in different meteorological weeks during a year*

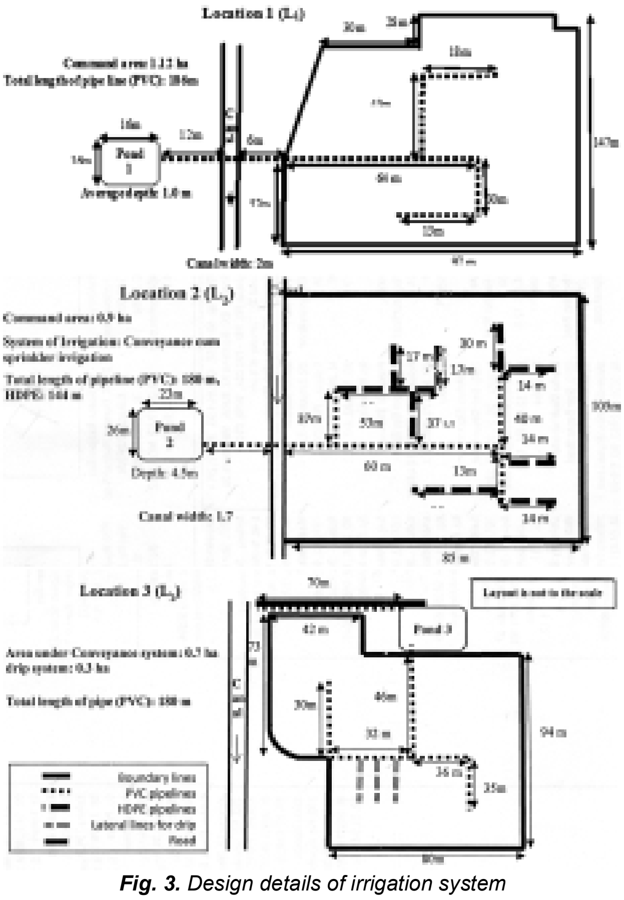


***Fig. 3.*** *Design details of irrigation system*

***Photo 1.*** *Pipe conveyance system in the canal command*

*Table 4. Rice grain yield as influenced by the depth of water level below the soil surface*

| Water level below the soil surface (cm) | Rice grain yield (t ha$^{-1}$) | |
|---|---|---|
| | AWD | Continuous Submerge |
| 5 cm | 4.33 | 4.50 |
| 10 cm | 4.10 | 4.43 |
| 15 cm | 3.97 | 4.47 |
| CD (5%) | 0.19 | 0.13 |

inside the perforated PVC pipe was 5 cm below the soil surface (Table 4). When the water level inside the PVC pipe was allowed to fall to 10 or 15 cm, there was decrease in grain yield as compared to continuous submergence. Thus, the safe level of AWD was 5 cm below the soil surface to economize in water use at similar yield.

Irrigation benchmarking is an essential tool to bring the improvement in irrigation performance in canal commands. The irrigated commands in coastal ecosystems with sub-optimum performance indicators should be treated with improved irrigation techniques. Water harvesting and use of harvested water through pressurized irrigation such as pipe conveyance, drip and sprinkler irrigation and alternate wetting drying are the potential options to increase irrigation efficiency and water productivity in rice-based canal commands. The water save may be used for other purposes or irrigating more areas under the crops. The study reveals that the alternate wetting drying technique in paddy and pressurized irrigation (pipe conveyance, drip and sprinkler) in different post-paddy crops could be used for obtaining higher water use efficiency with increased farm production in water scarce canal commands of coastal Odisha. These may be implemented in large scale in command areas to enhance yield and profitability in farming with less water.

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