PERFORMANCE EVALUATION OF PATNA MAIN CANAL COMMAND

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ABSTRACT

Immense pressure on finite land and water resources of India can be gauged from the fact that it shares 2.45% geographical area and 4% water resources of the world but supports 16% population and 18% livestock of the world. Sustainable agricultural production from these limited resources in order to meet the food requirement of ever increasing population of India is a challenge to researchers, planners and policy makers. Though operation and maintenance of existing irrigation systems and development of new irrigation projects both are important but the former is being preferred over the later due to low budget requirement. Hence, to achieve sustainable agricultural production resource use efficiency needs to be enhanced alongwith bringing additional area under irrigation. Study to identify the constraints in water delivery from canal and develop performance indicators from the point of view of water users and canal managers in Patna Canal Command under Sone Canal System in India reflects that there are multi-dimensional problems like technical, socio-economic, hydraulic, managerial, institutional and financial related to water release, allocation, distribution and utilization in canal command and lack of frequent communication and dialogue among water users and canal managers. The major problem reported by the water users was mismatch/wide gap between water supply and demand leading to water stress conditions either due to excess or deficit availability and ultimately adversely affecting the crop.

Various indicators such as output per unit command, output per unit cropped area, output per unit water consumed and output per unit irrigation supply related to production with land and water, and designed and actual water duty, water delivery capacity, relative water supply and relative irrigation supply related to water supply from the system with crop water demand were applied to compare the performance of head, middle and tail reaches of the canal. In addition to this, the study also highlighted the attempt to evolve performance indicators based on water users’ perspective related to adequacy, equity, timeliness, reliability, regularity and dependability of need based water supply. Analysis of performance indicators reveal that there is plenty of scope for improvement in performance of Patna Canal as well as water productivity in the canal command provided works related to command area development, on-farm water management, timely operation and maintenance of canal, frequent dialogue and meetings among water users and canal managers, training and awareness campaign are initiated in participatory mode involving wider constituency of stake holders.

Key words: Performance indicators, water supply, water demand, water duty, command area, evapotranspiration

INTRODUCTION

Land and water are natural finite resources but due to indiscriminate and unscrupulous utilization, these resources are diminishing at an alarming rate. To feed the ever-increasing population of India, it is emphasized that agricultural production should be improved on sustainable basis by efficiently and

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judiciously utilizing the available resources. Review of prevailing constraints and existing status of land and water resources gives an idea about availability and utilization pattern of these resources, difference between actual and potential output, and scope for improvement in the performance of system, which is represented by its measured levels of achievement in terms of one or several parameters that are chosen as indicators of the system’s goals. The basic concept is that irrigation managers must modernize their operations with the appropriate technical and managerial components. There are many factors that influence the performance of irrigated agriculture. The system managers have to see how the irrigated agriculture is performing within various settings. Several workers have proposed indicators depending on the purpose of the performance assessment. Major purpose of the assessment is to assist irrigation managers to improve water delivery service to users. The purpose of this study is to apply a set of comparative performance indicators that will allow for comparative analysis of irrigation performance in the head, middle and tail reaches of Patna canal command. Some researchers have proposed indicators for performance evaluation of irrigation systems. A brief review of some of the important works related to performance assessment of irrigation systems are mentioned below.

Burt et al (1997) emphasized to standardize the definitions and approaches to quantify various irrigation performance measures. The ASCE Task committee on defining irrigation efficiency and uniformity provides a comprehensive examination of various performance indices such as irrigation efficiency, irrigation consumptive use coefficient, application efficiency, irrigation sagacity, distribution uniformity, adequacy and potential application efficiency. They proposed methods to assess the accuracy of numerical values of the performance indicators.

Clemmens and Burt (1997) suggested that evaluation of actual irrigation system performance should rely on an accurate hydrologic water balance over the area considered. They provided equations, procedures and examples for making these calculations and recommended that confidence intervals be included in all reporting of irrigation performance parameters.

Molden et al (1998) compared performance of eighteen irrigation systems located in eleven different countries through various indicators. They presented nine indicators namely output per unit cropped area, output per unit command, output per unit irrigation supply, output per unit water consumed, relative water supply, relative irrigation supply, water delivery capacity, gross return on investment, and financial self-sufficiency. Results showed large differences in performance among the systems.

Singh (1998) highlighted the need for improvement in hydraulic performance of conveyance system, equity, adequacy and efficacy of water supply suitable to crop production system. He also presented some performance evaluation parameters in order to assess the functioning of (i) conveyance, distribution and application systems; (ii) command system; (iii) crop production system; and (iv) farmers organizational network and its linkage with the state departments.

Bastiaanssen and Bos (1999) after reviewing significant works suggested to use remote sensing determinants to evaluate irrigation performance indicators and suggested that it refines the spatial scale as compared to the classically collected flow measurements. Bastiaanssen et al.(1999) and Sakthivadivel et al.(1999) assessed performance of the Bhakra Irrigation System in Haryana using remote sensing data and presented spatial variation of productivity in terms of land (kg/ha) and water (kg/m$^3$). They found that differences in agricultural performance could be ascribed more to the hydrological setting rather than to the water delivery performance.
Droogers et al (1999) used four performance indicators: yield over transpiration, yield over evapotranspiration, yield over flow volume, and yield over depleted water and they concluded that if irrigation performance indicators are used only at a local scale, a misleading picture can be given on the regional scale. This paves a way for evaluating the management of all water resources in a river basin context.

Mishra et al (2001) applied the MIKE 11 hydraulic model to the Right Bank Main Canal system of the Kangsabati project, West Bengal, India and computed a performance ratio (a ratio of the observed flow rate to the scheduled flow rate), which was used as an indicator for assessing the degree of uniformity in flow deliveries along the length of the canal. A sharp decline was seen in the performance ratio along the length of the canal because most of the distributaries of the head and middle reaches have drawn more than their desired shares.

Droogers and Bastiaanssen (2002) reported that irrigation performance and water accounting are useful tools to assess water use and related productivity. Remote sensing and a hydrological model were applied to an irrigation project in Western Turkey to estimate the water balance to support water use and productivity analyses. Some common irrigation performance indicators such as the relative water supply, relative irrigation supply, depleted fraction and process fraction were quantified.

Ray et al (2002) computed multi-temporal remote sensing data based performance indices namely adequacy, equity and water use efficiency for the distributaries of the Mahi Right Bank Canal command in Gujarat, India. The analysis showed that performance indicators could identify the problem distributaries, an intensively managed and studied irrigation system. The integration of remote sensing data and GIS tools to regularly compute performance indices could provide irrigation managers with the means for efficiently managing the irrigation system.

Styles and Marino (2002) utilized and refined a set of evaluation indicators to describe the irrigation performance for sixteen international irrigation projects in less developed countries and found that performance of many projects was poor. The causes behind the poor performance of these projects were due to technical, financial, managerial, social, and/or institutional causes. They concluded that modernized irrigation delivery service index can be used as a determinant of an economic irrigation project performance indicator.

Bandara (2003) used NOAA satellite data to assess the performance of three large irrigation systems in Sri Lanka during the 1999 yala (dry season from April to July): Polonnaruwa, Kirindi Oya and Gal Oya. In Kirindi Oya, the relative water supply was higher than in the other two systems and irrigation efficiency was considerably lower. He evaluated evapotranspiration deficit (ETp− ETa), productivity of land, productivity of water inflow, and productivity per unit ET.

**Study Area - Patna Main Canal**

Sone Canal Project is one of the oldest irrigation systems in the country, which was completed in 1873-74 at a cost of Rs. 26.8 million with an anicut at Dehri and Western and Eastern Canal systems mainly to serve rabi winter irrigation. In 1960, Sone Barrage Project was conceptualized, which consisted mainly of a barrage at Indrapuri 8 km upstream of Dehri anicut, two link canals on either flank to connect old Sone Canal system with the new barrage and two high level canals from two link canals to cover upper areas outside the command. The Barrage was actually commissioned in 1968. An
index map showing Indrapuri barrage, Sone river, canal and distributaries, and command area is given in Fig 1. Eastern Link canal originates from Indrapuri barrage at Sone river and Patna Main Canal (PMC) emanates from Eastern Link Canal at Barun (Fig. 1). The total length of PMC is 78 mile. It has 12 reaches namely (i) Barun, (ii) Dehra, (iii) Tejpura, (iv) Sipaha, (v) Agnoor, (vi) Belsar, (vii) Balidad, (viii) Arwal, (ix) Mahablipur, (x) Ranitalab, (xi) Bikram, and (xii) Naubatpur. Schematic diagram of Patna Main Canal and distribution system (from 0 to 36 Miles and from 36 to 78 Miles) are shown in Figs. 2 and 3.

Schematic diagrams of Patna Main Canal show that in all there are 33 distributaries offtaking from it and 12 sub-distributaries offtaking from its distributaries. The length of distributaries varies in the range of 0.57 mile to 26 miles and sub-distributaries in the range of 2.75 miles to 10 miles. The designed discharge of distributaries and sub-distributaries varies in the range of 0.283 cumec to 11.327 cumec and 0.283 cumec to 2.265 cumec, respectively. The Culturable Command Area (CCA) of distributaries is as low as 180 ha to as high as 19904 ha. As per records of Irrigation/ Water resources Department the total CCA of PMC is 117 thousand ha. All the outlets at the distributaries or sub-distributaries are pipe outlets and their size varies from 3” to 12” with maximum numbers of outlets of 6” size. There are 109 direct outlets from Patna canal in which 92 are pipe outlets (55 on the left side and 37 on the right side) and 17 rectangular outlets (11 on the left side and 6 on the right side). Pipe outlets vary in size from 6” to 2’ with maximum number of direct outlets of 9” diameter.

As per the information received from Water Resources Department, Government of Bihar, during Kharif (monsoon) season, the Patna Main Canal opens on 25th May and closes on 25th October, whereas during Rabi (winter) season it opens on 10th December and closes on 10th April. Due to shortage of water, 10 days on and 5 days off cycle is followed during Kharif season, whereas during Rabi season no such on and off cycle exists and canal runs daily.

Problems related to water release, allocation, distribution and utilization in Patna Main Canal

The problems related to water release, allocation, distribution and utilization in Patna Canal Command as obtained after survey and close interaction with water users and canal managers can be broadly categorized as (i) Technical, (ii) Social, (iii) Managerial and Hydraulic, (iv) Institutional & Financial, and (v) Administrative, which lead to wide gap in canal water availability and crop water requirement.

Technical Problem

- Lack of awareness about recent water management technologies and advanced agricultural practices among water users.

Social Problem

- Dominance of rich over poor
- Small and fragmented land holdings
- Superstitions
- Low interaction level

Managerial and Hydraulics

- Un-timely release of adequate water from canal.
- Lack of communication
- Lack of timely O&M
Fig 2 & 3: Schematic Diagram of Patna Main Canal and It’s Distribution System
• Unauthorized, ungated outlets not proportional to command
• Obstructions in canal flow causing breaches

**Institutional and Financial**
• Un-timely availability, release and utilization of funds for O &M.
• Lack of efficient and trained manpower.
• Lack of linkage among stakeholders and financial institutions.

**Administrative**
• Poor law and order.
• Insecurity
• No crop insurance
• No reward or punishment policy
• Poor communication, transport and infrastructural facilities.

Due to these problems, there is inadequacy, irregularity, non-dependability and unreliability in canal water supply. Non-availability of adequate quantity of water at appropriate time leads to wide gap between supply and demand ultimately affecting the crop yield adversely.

**METHODOLOGY**
The performance indicators are computed for head, middle, tail reaches as well as for the whole Patna Main canal. The main output considered is crop production and the major inputs are water and land. Eight basic comparative performance indicators namely designed and actual water duty, output per unit command, output per unit cropped land, output per unit water consumed, output per unit irrigation supply, water delivery capacity, relative water supply, and relative irrigation supply were computed. Computation of these indicators required data on cropped area, command area, evapotranspiration, peak demand, water diverted by the canal, rainfall and production value. Data on cropped area, command area, water diverted by the different reaches of canal were collected from different divisional offices of Irrigation department, Govt. of Bihar. Rainfall data in the canal command was collected from Department of Statistics and Evaluation, Govt. of Bihar at three raingauge stations (Daudnagar, Pauliganj and Naubatpur located in head, middle and tail reaches of Patna Canal, respectively). Evapotranspiration was computed using FAO-56 Penman-Monteith equation, for which required meteorological data were collected from ICAR-RCER meteorological observatory.

**RESULTS AND DISCUSSION**

Seven indicators were applied for head, middle, and tail reaches of Patna main canal command and the results obtained are discussed in the following section.

**Performance Indicators**

**Designed water duty in the command of Patna Main Canal**

Designed water duty was computed for all the distributaries, reaches and PMC as presented in Table 1.
Table 1: Designed Water duty variation in Patna Main Canal and its reaches

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of distributary</th>
<th>CCA (ha)</th>
<th>Design discharge (Cumec)</th>
<th>Water duty (ha/cumec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Eastern</td>
<td>4695</td>
<td>5.097</td>
<td>921.13</td>
</tr>
<tr>
<td>2</td>
<td>Teldiha</td>
<td>2029</td>
<td>0.708</td>
<td>2865.82</td>
</tr>
<tr>
<td>3</td>
<td>RPC-A</td>
<td>1700</td>
<td>0.566</td>
<td>3003.53</td>
</tr>
<tr>
<td>4</td>
<td>Tejpura Feeder</td>
<td>575</td>
<td>0.425</td>
<td>1352.94</td>
</tr>
<tr>
<td>5</td>
<td>Chanda</td>
<td>6465</td>
<td>4.248</td>
<td>1521.89</td>
</tr>
<tr>
<td>6</td>
<td>Tuturkhi</td>
<td>3838</td>
<td>2.265</td>
<td>1694.48</td>
</tr>
<tr>
<td>7</td>
<td>Anchha</td>
<td>1265</td>
<td>1.274</td>
<td>992.94</td>
</tr>
<tr>
<td>8</td>
<td>Mali</td>
<td>13118</td>
<td>9.203</td>
<td>1425.40</td>
</tr>
<tr>
<td>9</td>
<td>Kochasa</td>
<td>19904</td>
<td>8.495</td>
<td>2343.03</td>
</tr>
<tr>
<td>10</td>
<td>RPC-C</td>
<td>505</td>
<td>1.274</td>
<td>396.39</td>
</tr>
<tr>
<td>11</td>
<td>Amra</td>
<td>7106</td>
<td>3.097</td>
<td>1394.15</td>
</tr>
<tr>
<td>12</td>
<td>Imamganj</td>
<td>5671</td>
<td>5.663</td>
<td>1001.41</td>
</tr>
<tr>
<td>13</td>
<td>RPC-D</td>
<td>180</td>
<td>0.991</td>
<td>181.63</td>
</tr>
<tr>
<td>14</td>
<td>RPC-E</td>
<td>286</td>
<td>0.991</td>
<td>288.60</td>
</tr>
<tr>
<td>15</td>
<td>LPC</td>
<td>260</td>
<td>0.991</td>
<td>262.36</td>
</tr>
<tr>
<td>16</td>
<td>RPC-I</td>
<td>1800</td>
<td>1.699</td>
<td>1059.45</td>
</tr>
<tr>
<td>17</td>
<td>Aiyara</td>
<td>1500</td>
<td>2.124</td>
<td>706.21</td>
</tr>
<tr>
<td>18</td>
<td>Murka</td>
<td>4300</td>
<td>4.531</td>
<td>949.02</td>
</tr>
<tr>
<td>19</td>
<td>RPC-II</td>
<td>1100</td>
<td>1.699</td>
<td>647.44</td>
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<tr>
<td>20</td>
<td>Paliganj</td>
<td>5600</td>
<td>5.097</td>
<td>1098.69</td>
</tr>
<tr>
<td>21</td>
<td>RPC-III</td>
<td>1600</td>
<td>1.699</td>
<td>941.73</td>
</tr>
<tr>
<td>22</td>
<td>Dorwa</td>
<td>1400</td>
<td>1.756</td>
<td>797.27</td>
</tr>
<tr>
<td>23</td>
<td>RPC-IV</td>
<td>2800</td>
<td>1.926</td>
<td>1453.79</td>
</tr>
<tr>
<td>24</td>
<td>Dhana</td>
<td>200</td>
<td>0.283</td>
<td>706.71</td>
</tr>
<tr>
<td>25</td>
<td>Maner</td>
<td>6800</td>
<td>11.327</td>
<td>600.34</td>
</tr>
<tr>
<td>26</td>
<td>Rewa</td>
<td>2800</td>
<td>2.407</td>
<td>1163.27</td>
</tr>
<tr>
<td>27</td>
<td>Adampur</td>
<td>1600</td>
<td>1.699</td>
<td>941.73</td>
</tr>
<tr>
<td>28</td>
<td>RPC-V</td>
<td>1400</td>
<td>1.416</td>
<td>988.70</td>
</tr>
<tr>
<td>29</td>
<td>Khajuri</td>
<td>1000</td>
<td>1.133</td>
<td>882.61</td>
</tr>
<tr>
<td>30</td>
<td>Manjhauli</td>
<td>2200</td>
<td>2.265</td>
<td>971.30</td>
</tr>
<tr>
<td>31</td>
<td>Fatehpur</td>
<td>4200</td>
<td>5.663</td>
<td>741.66</td>
</tr>
<tr>
<td>32</td>
<td>Danapur</td>
<td>1000</td>
<td>1.557</td>
<td>642.26</td>
</tr>
<tr>
<td>33</td>
<td>Patna</td>
<td>1000</td>
<td>1.133</td>
<td>882.61</td>
</tr>
<tr>
<td>34</td>
<td>RPC-VI</td>
<td>200</td>
<td>0.425</td>
<td>470.59</td>
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</table>

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Reach</th>
<th>CCA (ha)</th>
<th>Design Discharge (Cumec)</th>
<th>Water duty (ha/cumec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Head</td>
<td>72500</td>
<td>37.095</td>
<td>1954.44</td>
</tr>
<tr>
<td>2</td>
<td>Middle</td>
<td>28596</td>
<td>27.043</td>
<td>1057.43</td>
</tr>
<tr>
<td>3</td>
<td>Tail</td>
<td>16625</td>
<td>19.680</td>
<td>844.77</td>
</tr>
<tr>
<td></td>
<td>PMC</td>
<td>117721</td>
<td>83.818</td>
<td>1404.48</td>
</tr>
</tbody>
</table>
It is revealed from Table 1 that CCA and design discharge of distributaries are not proportional and designed water duty of distributaries is varying in the range of as low as 181.63 ha/cumec for RPC-D to as high as 3003.53 ha/cumec for RPC-A. Water duty is decreasing from head to tail reach as in head reach one cumec water is provided to irrigate 1954.44 ha whereas in the middle and tail reach one cumec water is provided to irrigate 1057.43 ha and 844.77 ha, respectively. The water duty of PMC is computed as 1404.48 ha/cumec.

**Actual water duty in the command of PMC**

Actual water duty was computed for PMC and its reaches for eight years (1996 to 2003) of Kharif and Rabi season (Fig. 4 and 5). For computation of water duty, area irrigated and discharge from the reaches were collected from irrigation department, Government of Bihar.

Fig. 4: Variation in actual water duty in PMC and its reaches during Kharif season

Fig. 5: Variation in actual water duty in PMC and its reaches during Rabi season
Actual water duty in Kharif season during different years was found to vary between 1186.8 and 1418.3 ha per cumec in the head reach, 643.8 and 978.8 ha/cumec in the middle reach and 511.4 and 687.4 ha/cumec in the tail reach and for entire Patna Main Canal it varied from 882.6 to 1063.5 ha/cumec. Average actual water duty in Kharif season was found to be 1256.9, 862.8 and 598.0 ha/cumec for head, middle and tail reach, respectively and for entire Patna Main Canal it was 975.0 ha/cumec. During Kharif season average actual water duty decreased from head to tail.

During Rabi season its value in different years varied from 107.7 to 383.2 ha/cumec for head, 269.1 to 385.9 ha/cumec in middle and 73.5 to 300.8 ha/cumec in tail reach and for entire Patna Main Canal its value was found in the range of 156.0 to 341.4 ha/cumec whereas average water duty was found to be 235.1, 291.2 and 173.4 ha/cumec in head, middle and tail, respectively and for entire Patna Main Canal it was 238.7 ha/cumec. During Rabi season actual water duty was highest in middle reach followed by head and tail reach.

(i) **Output per unit command**

This indicator specifies production value per unit command area and defined as:

\[
\text{Output per unit command} = \frac{\text{Production value}}{\text{Command area}}
\]

The output per unit command ($/ha) in head, middle and tail reach of Patna Main Canal was computed considering yield of rice and wheat as 2.8 t/ha and 2.5 t/ha, and price as $ 121.43/t and $ 145.24/t, respectively. The value of this indicator was found as 278.10, 418.80, 386.96, respectively, whereas for Patna Main Canal it was found as $ 327.65/ha. The reason for such variation is due to the difference in command area and cropped area. In the head, middle and tail reaches cropped area (sum of area under different crops in a year) is 80.64, 120.84, and 111.34 percent of the command area. This indicates that there is an urgent need to develop command area and increase cropped area in head and tail reaches as compared to middle reach.

(ii) **Output per unit cropped area**

This indicator specifies production value per unit of irrigated cropped area and defined as:

\[
\text{Output per unit cropped area} = \frac{\text{Production value}}{\text{Irrigated cropped area}}
\]

Output per unit cropped area for Patna Main Canal command was computed considering yield of rice and wheat as 2.8 t/ha and 2.5 t/ha, and price as $ 121.43/t and $ 145.24/t, respectively. The value was found as $703.10/ha. This value is very low and indicates that output per unit cropped area needs improvement through increase in production, reduction in cost of cultivation and inputs and providing proper support price for the produce.
(iii) **Output per unit water consumed**

This indicator specifies production value per unit volume of water consumed and defined as:

\[
\text{Output per unit water consumed} = \frac{\text{Production value}}{\text{Volume of water consumed by ET}}
\]

The output per unit water consumed was computed considering ET for rice and wheat as 748 mm and 197 mm, respectively. The value of this indicator in ($/m^3$) in head, middle and tail reach was found to be 0.0545, 0.0586 and 0.0612 respectively, whereas for whole Patna Main Canal the value was found to be 0.0569. This reveals that production value per unit of water consumed in tail reach is little better than middle and head reach.

(iv) **Output per unit irrigation supply**

This indicator specifies production value per unit irrigation supply and defined as:

\[
\text{Output per unit irrigation supply} = \frac{\text{Production value}}{\text{Diverted irrigation supply}}
\]

The value of this indicator during kharif season (in $/m^3$) in head, middle and tail reach of the canal was found as 0.0490, 0.045 and 0.0298, respectively, whereas for whole Patna Main Canal the value was found as 0.0438. This indicates that production value per unit irrigation supply in head reach is better than middle and tail reach. Higher value of this indicator in the head reach indicates lower irrigation supply.

(v) **Water delivery capacity**

The water delivery capacity ratio gives an indication of the degree to which irrigation infrastructure is in any way constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands and is defined as:

\[
\text{Water delivery capacity} = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}}
\]

The value of this indicator during kharif season in head, middle and tail reach of the canal was found as 1.17, 1.27 and 1.92 respectively, whereas for whole Patna Main Canal the value was found as 1.31. This indicates that water delivery capacity in tail reach is better than head and middle reach. Higher value of this indicator in the tail reach indicates that its capacity has lesser constraint to meet crop water demands. Since water delivery capacity values in head, middle and tail reaches are greater than unity there may not be difficulties in meeting short-term peak demands.
(vi) **Relative water supply**

Relative water supply ratio relates water supply to demand and indicates the condition of water abundance or scarcity and how tightly supply and demand is matched. It can be defined as:

\[
\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop demand}}
\]

The value of this indicator during kharif season in head, middle and tail reach of the canal was found as 0.93, 0.84 and 1.14 respectively, whereas for whole Patna Main Canal the value was found as 0.97. The value more than 1.0 indicates that total water supply is enough to meet the crop demand. In tail reach, farmers get sufficient water supply to meet crop demand, whereas in head and middle reach relative water supply needs improvement to meet the crop demand.

(vii) **Relative irrigation supply**

Relative irrigation supply ratio relates irrigation supply to demand, which can be defined as:

\[
\text{Relative irrigation supply} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}}
\]

The value of this indicator during kharif season in head, middle and tail reach of the canal was found as 0.88, 0.77 and 1.22 respectively, whereas for whole Patna Main Canal the value was found as 0.96. The value more than 1.0 indicates that irrigation supply by the canal is enough to meet the crop demand. In tail reach, farmers get sufficient irrigation water supply to meet crop demand, whereas in head and middle reach relative irrigation supply needs improvement to meet the crop demand.

**Output of OPTALL model as a performance indicator**

The main problem in the canal water allocation is unequal distribution. Due to this, on one hand some farmers misuse precious water and on the other hand few farmers are deprived of this precious water. The output of OPTALL model, which is based on quadratic programming approach and has capability to study the scenario, when water is allocated optimally and equitably in various offtakes of Patna Main Canal keeping in view the requirement and system constraints can be used as performance indicator.

**Actual and optimal canal water supply and comparison with irrigation requirement**

Actual and optimal water releases in various distributaries of Patna Main Canal were studied and compared with irrigation requirement considering average rainfall during Kharif (Monsoon season) in Patna Main Canal (Fig. 6).
It may be observed from the figure that in case of actual water supply there is a wide gap between supply and irrigation requirement. In some weeks supply is excessively higher than requirement, whereas in other weeks it is excessively lower than demand. Optimal releases as obtained after employing OPTALL model never show excess supply than requirement and gap between supply and irrigation requirement is minimum. Since releases computed by OPTALL model are optimum and equitable, requirements are met out either fully if water is available or partially and equitably if limited water is available. Studies show that OPTALL model is capable of suggesting the optimal and equitable water release schedule of canal, which can meet the demand in canal command without any wastage in the form of excess release. The optimal releases as computed from OPTALL model can also be used as one of the performance indicators because it helps in analyzing the gap between actual supply and irrigation requirement and suggests how this gap can be minimized by optimal release of water. This model can be used in real time also and can suggest the canal managers about the gate opening and corresponding water release, which can meet the irrigation requirement in the command optimally and equitatively.

**Performance Indicators from water users’ perspective**

Five performance indicators namely (i) reliability of roaster, (ii) rate of water delivered, (iii) rate of water loss in conveyance, (iv) drought proofing, and (v) rate of water table rise were selected and water users were asked to arrange them in the order of importance/priority. Majority of water users ranked the indicators as mentioned below.
Rank | Performance Indicators
---|---
1. | Drought Proofing,
2. | Reliability of the Roaster (operation schedule),
3. | Rate of water delivered,
4. | Rate of water loss in conveyance, and
5. | Rate of water table rise.

Considering the ranking pattern of water user’s the first three indicators clearly indicate that users are highly concerned regarding on-farm water management needs while last two indicators indicate water congestion problems.

Dialogues on these aspects were initiated with users to know their perceptions as to how these problems can be minimized. The dialogues reflected that there is over dependency of users on canal water because it is much cheaper compared to ground water. So they are reluctant to own tube wells or purchase and use tubewell water.

**Possible Measures and Strategies to be adopted to improve performance of canal command**

- Old canal system along with distributaries, sub-distributaries and outlets should be inspected by Irrigation department and whole canal system should be repaired and maintained at least twice in a year during closure periods before Kharif and Rabi season.
- If canal is opened on 25th May and flow is available in the canal but crop water requirement is limited during nursery or lean period, some storage structures can be planned by the side of canal and options for fish growing as well as supplemental irrigation through these auxiliary or secondary storages during drought period or crop stress period may help in utilizing canal water more efficiently.
- Formation of outlet committees at outlet level, Water Users’ Associations at distributary level and Federation of Water Users at canal level should be encouraged.
- Efforts should be made to establish coordination and frequent meetings and discussions about problems among various committees and their linkage and dialogue with Irrigation/Water resources department and agricultural department.
- Staggering of paddy transplantation period, crop diversification, crop planning from head to tail reach and conjunctive use possibilities should be explored and suitable measures should be adopted in the canal command depending upon availability of water in the canal.
- Irrigation/Water Resources Department should devise a canal water delivery schedule in consultation with Water Users’ Association according to crop water requirement in the canal command.
- Communication facilities in the canal command should be improved so that water users get information from Irrigation/Water Resources Department about water availability and release pattern in advance and water distribution rules should be in accordance with predetermined water delivery pattern.
- Training to the farmers through communication material and field trials about recent agronomic, soil and water management practices should be imparted more frequently in the beginning of Kharif and Rabi seasons. Awareness campaign among water users about conveyance, distribution and application of canal water more efficiently and judiciously
and adoption of complete package of agricultural practices in their fields should be accelerated.

Engineers of Irrigation / Water Resources Department and CADA should be imparted training about improved agricultural and on farm water management practices so that they can revise their estimates of crop water requirement from time to time and deliver and distribute water more efficiently as per the requirement of water users.

CONCLUSIONS

Some indicators, which are related to the irrigated agriculture for Patna main canal command, are demonstrated. In the present study seven performance indicators were worked out to evaluate the performance of canal in head, middle, tail reaches and entire canal. The indicators are output per unit command, output per unit cropped area, output per unit water consumed and output per unit irrigation supply relate production with land and water, whereas rest three indicators i.e. water delivery capacity, relative water supply and relative irrigation supply relate water supply from the system with crop demand. Water duty was found to be decreasing from head to tail reach from 1954.44 ha/cumec to 844.77 ha/cumec. The water duty of PMC was computed as 1404.48 ha/cumec.

Studies indicated that there is a large gap between actual water released from canal and irrigation requirement in canal command. This gap can be minimized if water is released optimally and equitably as computed by OPTALL model. The optimal releases as computed from OPTALL model can be used as one of the performance indicators because it helps in analyzing the gap between actual supply and irrigation requirement and suggests how this gap can be minimized by optimal release of water. In real time operation canal managers can prepare gate operation schedule to release water optimally and equitably to meet the irrigation requirement.

Performance indicators indicate that there is significant difference in production, water supply and water use in head, middle and tail reaches and there is scope for improvement if command area development works for efficient on-farm water management are accelerated in participatory mode. Training and awareness campaign and frequent dialogue to establish linkage between canal managers and water users is very essential to improve the performance of canal system.

REFERENCES


