Evaluation and Analysis of Water Management Strategies on the Punjab Irrigation Canals System

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Abstract: In this paper, we made a comprehensive analysis of water management strategies implemented within irrigation canal systems across three distinct zones in Punjab, Pakistan: Bahawalpur, Dera Ghazi Khan (DG Khan), and Faisalabad. The evaluation focused on two primary indicators: 1. The effectiveness of civil works, capacity building & institutional reforms. The effectiveness of civil works is assessed through a multi-dimensional approach, incorporating visual inspection (evaluating the quality of civil works and operations & maintenance practices in selected regions) and the assessment of hydraulic efficiency. The pertinent Data on civil works are collected in collaboration with the respective Punjab Irrigation Departments. Information on capacity building and institutional reforms is collected via a structured questionnaire survey. While the study partially achieved its overall objectives across the selected zones, the civil work component demonstrated comparatively satisfactory performance in terms of quality and hydraulic efficiency for the selected reaches of distributary and minor canals. The obtained Terminal Distributary Improvement (TDI) success index for civil works obtained at selected zones is 69% for Bahawalpur, 62% for DG Khan, and 67% for Faisalabad. Overall, the civil work component seems partly successful.

Keywords: Operational Strategies, Institutional Reforms, DPR, PMIU, FOS.

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1. Introduction

Integrated water management strategies are recognized globally as crucial for irrigation purposes. Proper planning and the adoption of optimal water management practices for irrigation systems, along with the application of these tools for improved water supply operations, can enhance productivity and water efficiency. Conveyance channels (irrigated canals) significantly contribute to economic growth in many countries, including Pakistan. In that research document, the water issues in Pakistan are discussed. For investigating those problems, he chose only one district, Sargodha, from Punjab. The main intention of this study is to foreground those points that are the main cause of ineffective management of the Punjab irrigation network system [1]. The research work is carried out in Sub-Saharan America and concluded that supplementary food production can be achieved with proper water management practices, so in this context, the researcher gives various expectations about water management issues to enhance the food productivity in the irrigation network sector [2]. Another researcher conducted research in NWFP, Pakistan, on the Surezai Minor of Warsak Gravity Canal Irrigation network system, to evaluate hydraulic efficiency in that

particular sector. The obtained results showed that the head is receiving 26% more discharge than the sanctioned amount, whereas average calculated discharge at the head, middle, and tail outlet of conveyance channels observed 36%, 42% & 16% more discharge than the sanctioned discharge. The average calculated weekly discharge varies from 0 to 25% [3]. The research aims to evaluate the capacity of local farmers in managing segments of irrigation systems, particularly at the distributary and minor canal levels. The objective is to facilitate a more equitable and efficient allocation of irrigation water. Furthermore, this study seeks to generate recommendations for future scaling and implementation based on the outcomes derived from pilot project evaluations [4]. A meaningful literature is presented by the researcher with reference to water management strategies and remediation abilities for the improvement of the irrigation system [5]. Ghumman et al. observed different methodologies to save the water of different hydraulic channels in the irrigation network of canals in Khyber Pakhtunkhwa of Pakistan [6]. The hydraulic efficiency was assessed by A.M. Liaqat et al. The canal network with particular water management strategies that supported the classical irrigated and neoclassical irrigated hydraulic efficiency performance [7].The hydraulic productivity of the irrigation network, the utilization of hydrological parameters for optimizing the water delivery performance ratio of the canal network in both (Intake & off-take) sections of the canal, and their optimum water provision in the required irrigation network system [8].Latif et al. Standoff: the comparative analysis of the delivery irrigation service in the Punjab irrigation network through the support of the Punjab Government of Punjab, Pakistan, which is introduced as capacity building and institutional reforms [9].

The efficient assessment of the irrigation network of a smallholder irrigation users scheme (Zanyokwe irrigation scheme) is one of the irrigation schemes of the Cape Province, South Africa. He summarized the various parameters of the economic process and made substantive suggestions for the transformation strategies of the irrigation network in South Africa. This research work is related only to the smallholder irrigation network by Elliot Ntsonto et al. [10]. The water management activity becomes more tangled when it is in transaction with sediment transport in irrigation canal networks. The sediment problem becomes more complex in the irrigation canal network system when these types of convenience channels face a cohesive sediment transport pattern [11]. By using suitable modelling tools for saving water losses and managing best practices for the available water for end users [12]. The misunderstanding aspects and lack of communication between institutions and farmer associations result in major drawbacks in water management techniques [13]. Tafte et al concluded that both parameters, like hydraulic efficiency and economic growth, are closely

related to the performance of irrigation networks, which could be increased with improved operations of the water supply, optimal management of irrigation systems, and capacity building reforms of farmers [14]. He studied the resources, methodologies, institutional reforms, and water management techniques that play a vital role in the conjunctive use of water management techniques of the multiple sources in the Rechna Doab [15].

2. Methodology

The three main factors of water management strategies are discussed above. The flow chart of the research methodology is shown in Figure 01.

a) Site visits to the selected Irrigation hydraulic channels, then discharge measurements and visual inspection at selected Irrigation canals.
b) Interviews with Farmers and Community, filling Questionnaire surveys, and detailed survey analysis of adopted water management practices in the chosen study area.

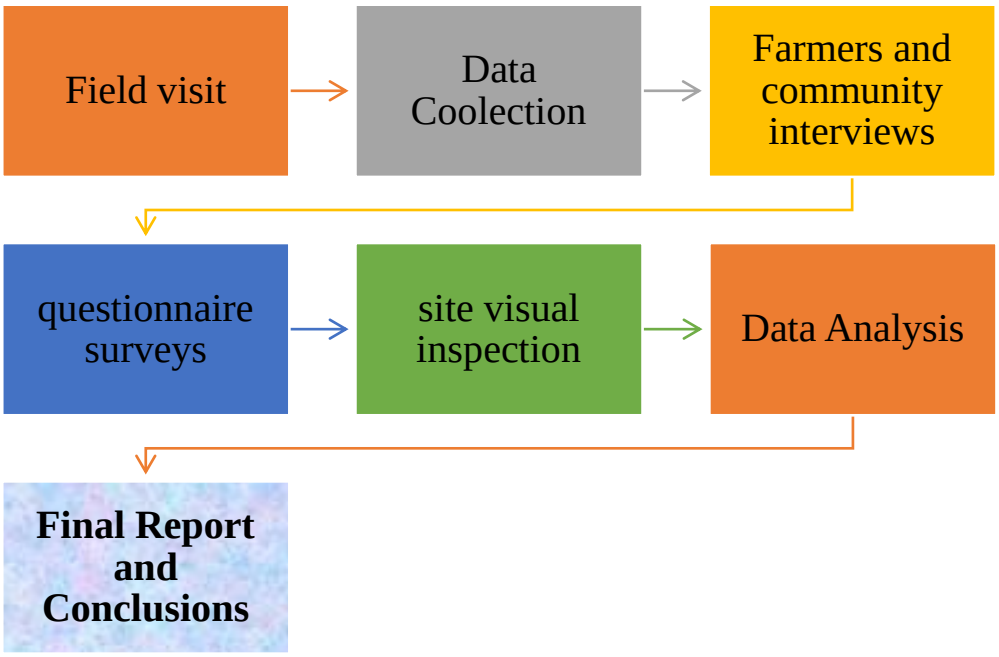


Fig. 1 Methodology adopted **for Research Work**

2.1. Identification & Evaluation of Performance Indicators

The brief explanation of these three groups of primary indicators is given as follows;

- Quality check of civil works (Primary Indicator group 1),
- Hardened concrete strength
- RD Marks
- Earthwork
- Concrete crack condition in channels

- Data Boards

✓ Operation and Maintenance level (Primary Indicator group 2),

- DE-siltation
- Removal of vegetation
- Crack repairing
- Berm protection
- Work as per design

✓ Hydraulic Efficiency Parameters (Primary Indicator group 3)

- Discharge measurement at the tail sections
- Reduction in seepage loss
- Crop production increment

2.2. Site Visits and Data Collections

Comprehensive field visits are carried out in order to collect data against the formulated indicators. During visits, a data sheet containing all the indicators is filled out. Examine the districts of Bahawalpur, D.G. Khan, and Faisalabad for each of the three irrigation zones.

2.3. Hydraulic Data Collection

Hydrographs of distributary and minor canals in the selected regions are obtained from the irrigation department (PMIU). These are the daily measured discharge data before and after the canal lining from 2020 to 2022. The obtained data is then analysed to calculate the delivery performance ratio (DPR) from the hydrographs before & after lining of selected minors and distributaries in different zones separately.

2.4. Evaluation Methodology

In this section, the data is collected through field surveys, interviews, and discussions with the staff and local farmers. The obtained data is then interpreted and analysed using statistical tools & techniques for the desired objectives. The monitoring plan and corresponding evaluation for this component are shown in Fig. 2.

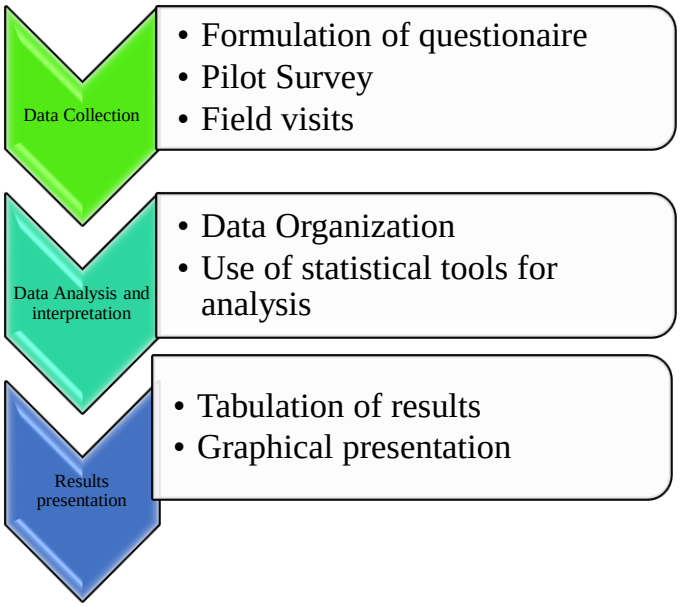


Fig. 2 Result layout sketch

3. Results & Discussions

3.1. Hydraulic Efficiency (DPR)

The discharge measurement (DPR) of outlets is the ratio between the observed discharge (actual discharge) and the target discharge (design discharge). The DPR value indicates the efficiency of an outlet.

3.2. Bahawalpur Irrigation Zone

The combined DPRs from 2020 to 2022, at the cross sections of selected distributary and minor canals in the Bahawalpur Irrigation zone, are given in Figure 3.

Figure 4 presents that the average discharge value after lining of the selected Bahawalpur irrigation zone hydraulic efficiency is calculated by taking the ratio of actual discharge & design discharge. Monthly discharge trends show that overall actual discharge is almost equal to design discharge at tail sections for every selected distributary due to minimizing water losses through lining of canals.

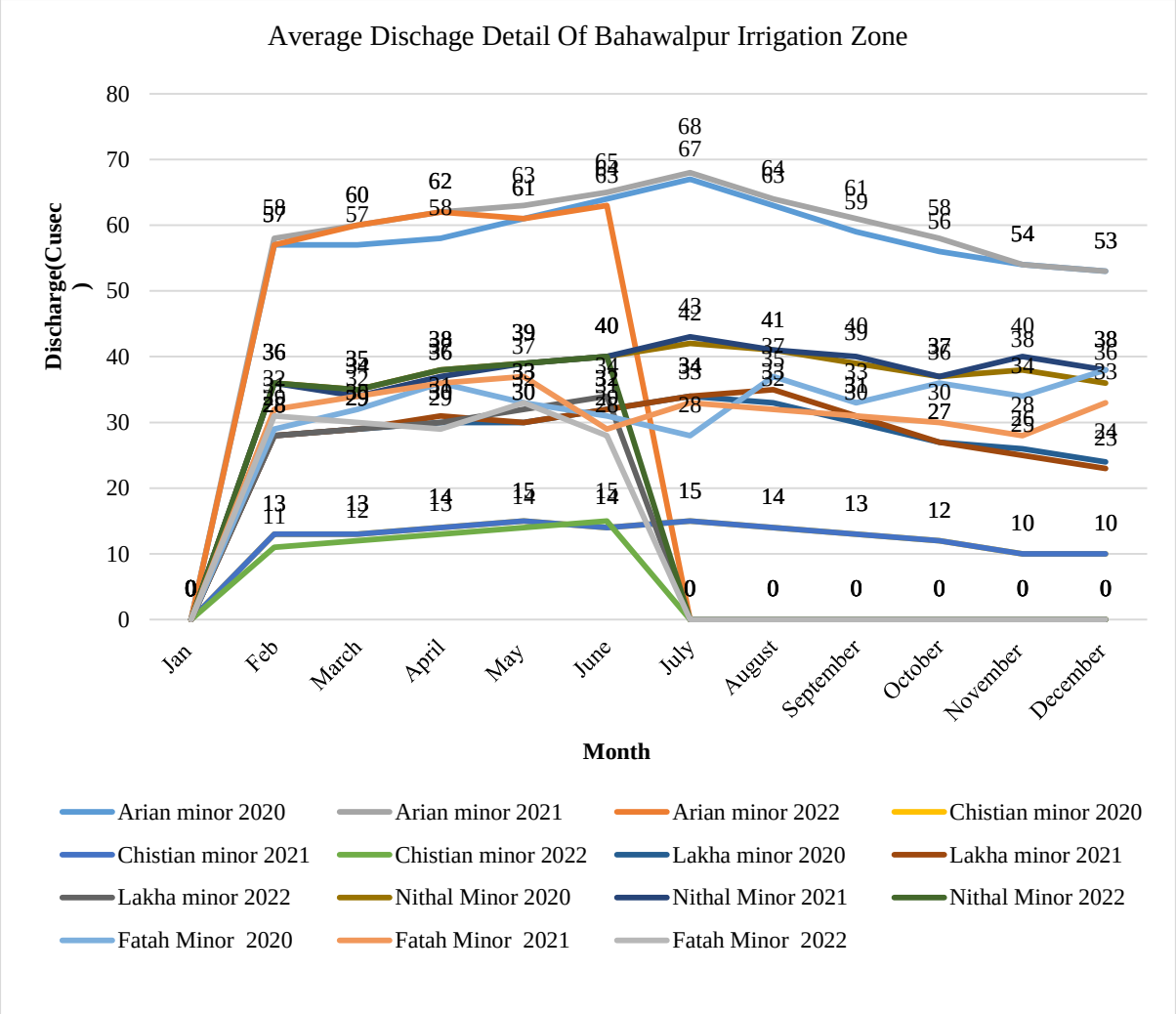
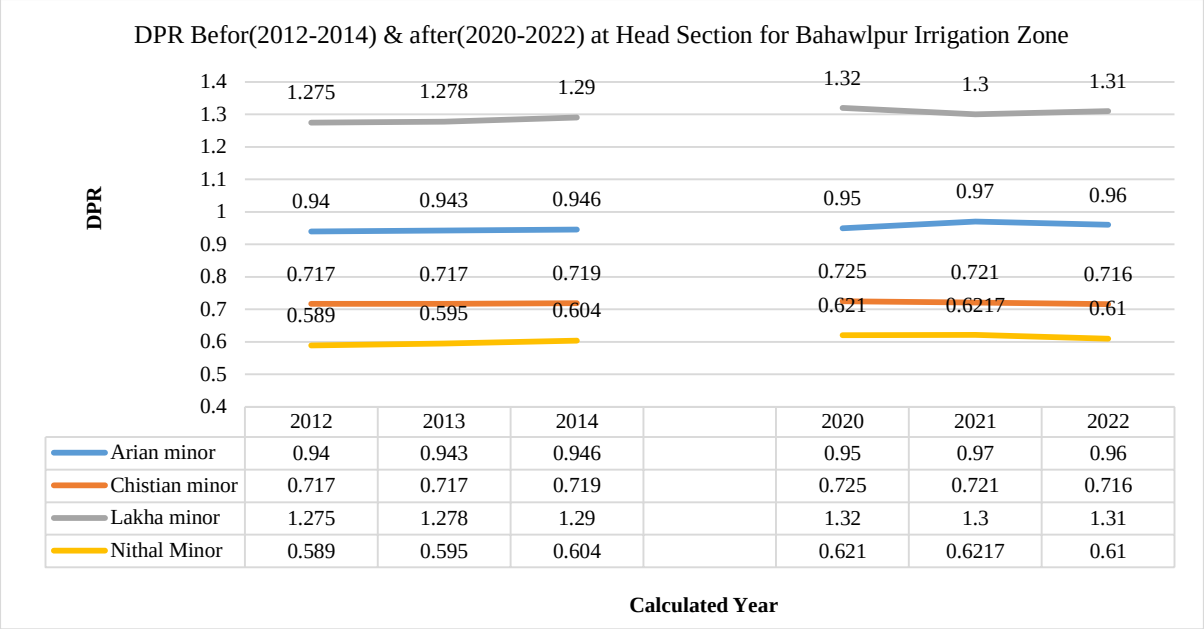


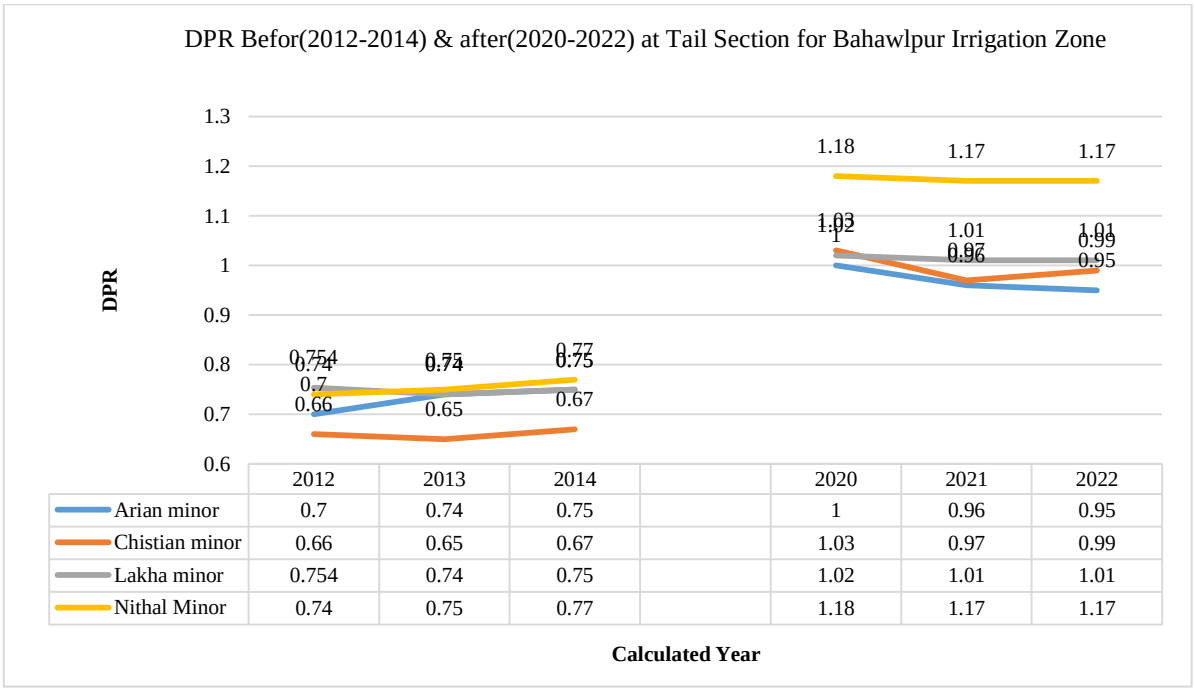
Fig. 3 Average Discharge Detail of selected districts & minors for Bahawalpur Irrigation Zone

Figures 4 and 5 show the graphical trends of DPR before and after lining for selected minors & distributaries in the Bahawalpur Irrigation zone. The graphical behaviour of selected minors and distributaries shows that DPR before 2020 due to unlined canals decreased due to seepage losses, vegetation, silting, breaching sections, and due to tempering issues, the range of DPR was (0.77-0.8). Due to these issues, the authorized discharge at the tail section was not reached to overcome these issues, water management techniques were applied overall length of minors and distributaries. By applying this water management technique, hydraulic efficiency (DPR) increased, which was (1-1.17) at the tail sections of selected distributaries, which were analyzed in the above graphical representations.



	2012	2013	2014		2020	2021	2022
Arian minor	0.94	0.943	0.946		0.95	0.97	0.96
Chistian minor	0.717	0.717	0.719		0.725	0.721	0.716
Lakha minor	1.275	1.278	1.29		1.32	1.3	1.31
Nithal Minor	0.589	0.595	0.604		0.621	0.6217	0.61

Fig. 4 Comparison of DPR before and after lining at the Head Section for the Bahawalpur Irrigation Zone



	2012	2013	2014		2020	2021	2022
Arian minor	0.7	0.74	0.75		1	0.96	0.95
Chistian minor	0.66	0.65	0.67		1.03	0.97	0.99
Lakha minor	0.754	0.74	0.75		1.02	1.01	1.01
Nithal Minor	0.74	0.75	0.77		1.18	1.17	1.17

Fig. 5 Comparison of DPR before and after lining at the Tail Section for the Bahawalpur Irrigation Zone

3.3. DG. Khan Irrigation Zone

Figure 6 presents the average discharge values measured after lining of selected DG Khan distributaries and minors at tail sections. Monthly average discharges are calculated at tail sections, and their respective trends are represented in the above figure. The lining impact

shows that hydraulic efficiency increased 45% as the tail sections' water losses are minimized.

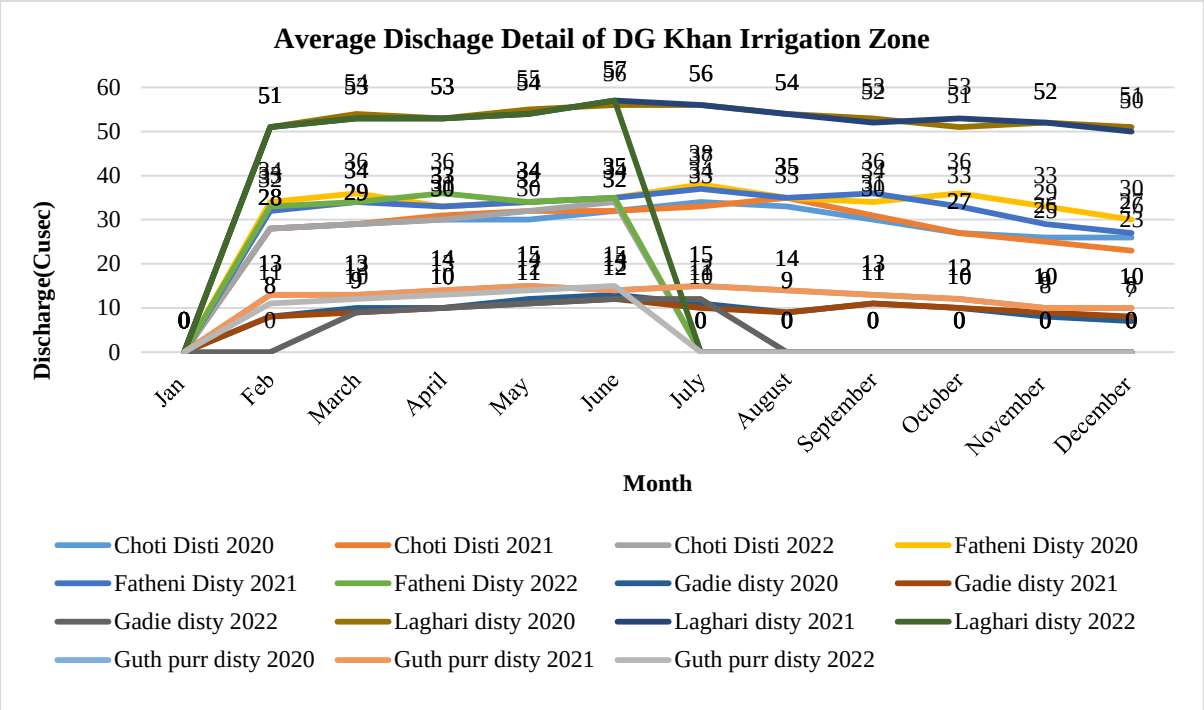


Fig. 6 Average Discharge Detail of DG Khan Irrigation Zone

Figures 7 and 8 show the graphical trends of DPR before and after lining of selected minors & distributaries for the DG Khan Irrigation zone. After calculating the DPRs of different minor and distributary canals at tail sections in DG Khan irrigation zone, the DPR before 2020 decreased due to seepage losses, vegetation, breaching sections, silting, and tempering issues. The authorized discharge at the tail section has not reached the calculated range of DPR (0.58-0.81) to overcome these issues. After application of water management techniques, protection of the overall length of minors & distributaries berms, and repairing of installed outlets, the calculated range of DPR at tail sections became (0.99-1.02).

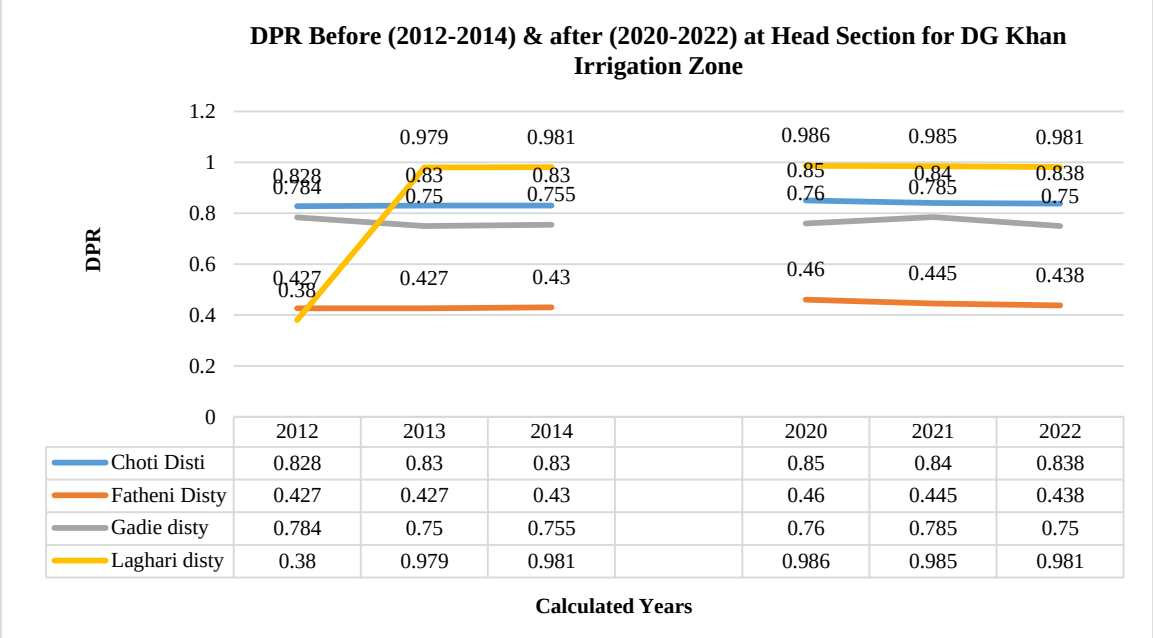


Fig. 7 Detail of DPR at Head Section for DG Khan Irrigation Zone

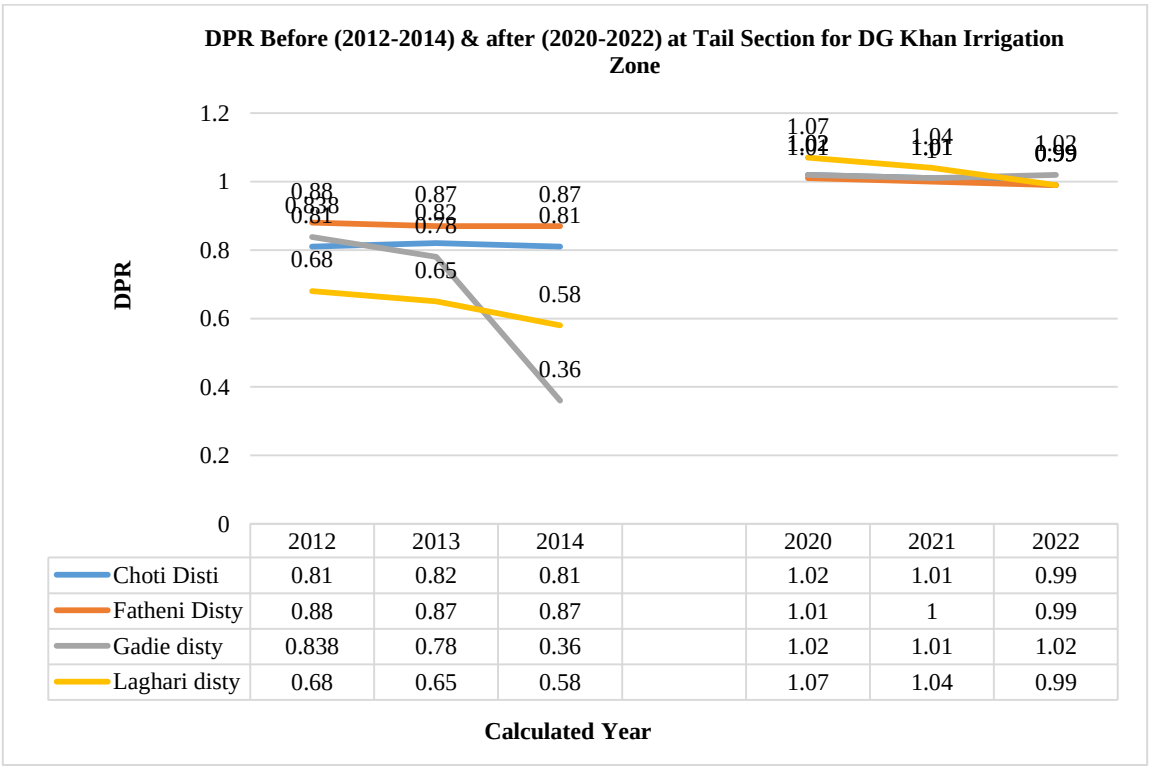


Fig. 8 Comparison of DPR before and after lining at Tail Section for DG Khan Irrigation Zone

3.4. Faisalabad Irrigation Zone

Figure 9: Average discharge values are measured after lining of selected Faisalabad distributaries and minors at tail sections. Monthly average discharges are calculated at tail sections, and their respective trends are represented in the above figure. The lining impact shows that hydraulic efficiency increased by 48% at the tail sections.

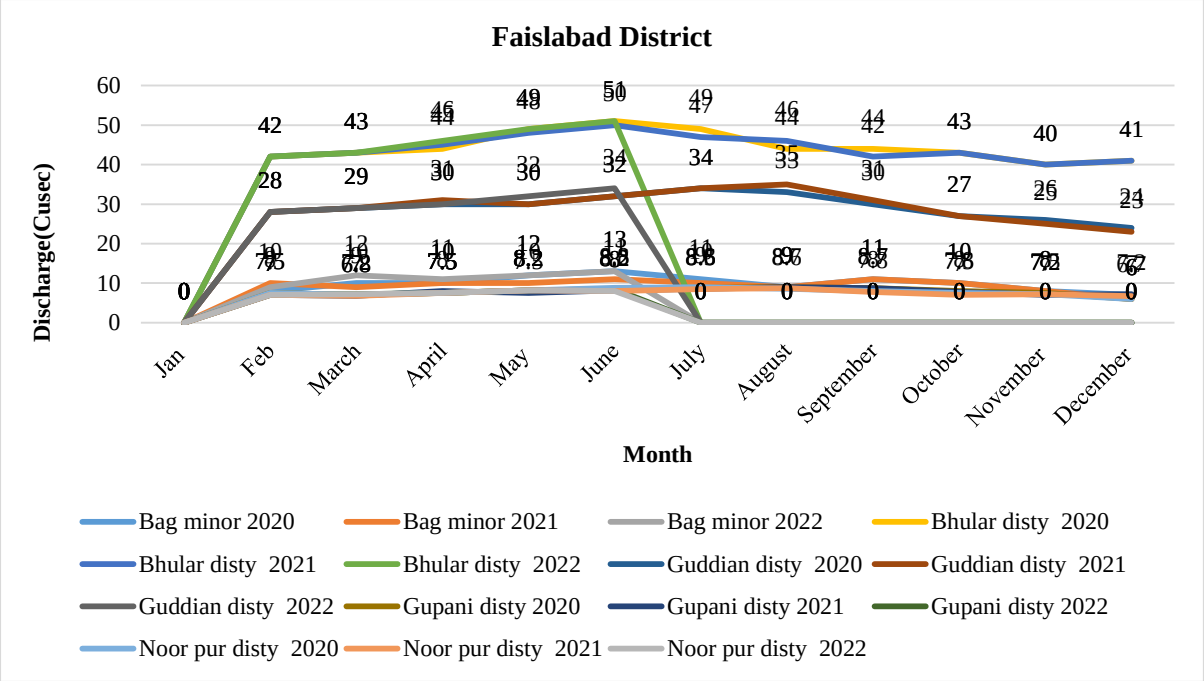
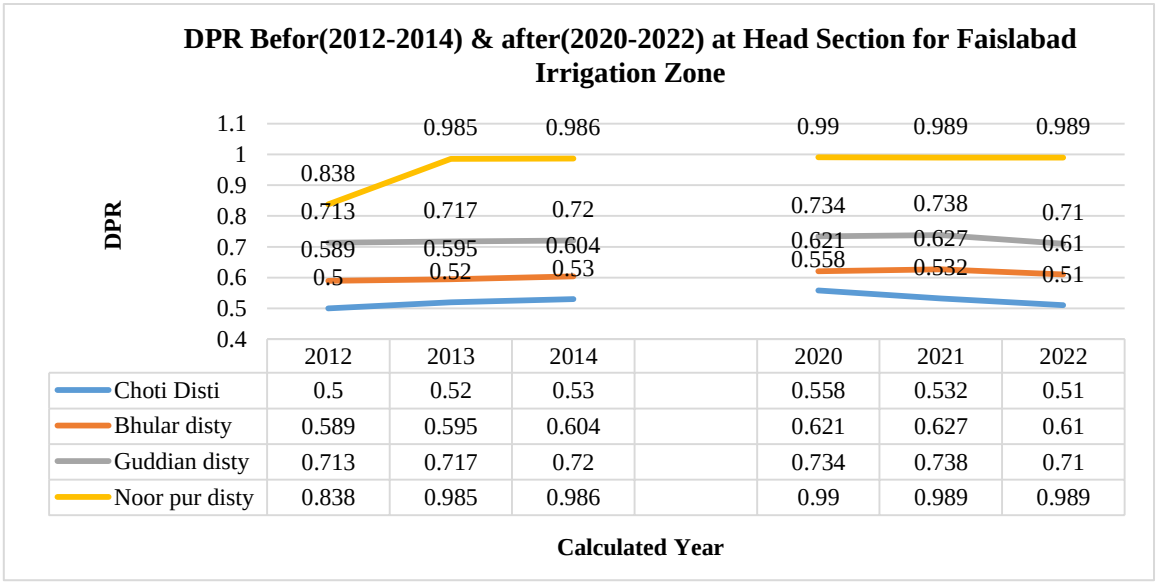


Fig. 9 Average Discharge Detail of Faisalabad Irrigation Zone

Figures 10 and 11 show that the delivery performance ratio (DPR) is calculated before and after lining of different minor and distributary canals for the Faisalabad irrigation zone. The behaviour of DPR for these minor and distributary canals shows that the range of DPR before lining was (0.61-0.82), and after lining, it was calculated at the tail section (0.83-1.04). The graphical trend shows that hydraulic efficiency increased at the tail section after lining due to the minimization of water losses.



	2012	2013	2014		2020	2021	2022
Choti Disti	0.5	0.52	0.53		0.558	0.532	0.51
Bhular disty	0.589	0.595	0.604		0.621	0.627	0.61
Guddian disty	0.713	0.717	0.72		0.734	0.738	0.71
Noor pur disty	0.838	0.985	0.986		0.99	0.989	0.989

Fig. 10 Comparison of DPR before and after lining at the Head Section for the Faisalabad Irrigation Zone

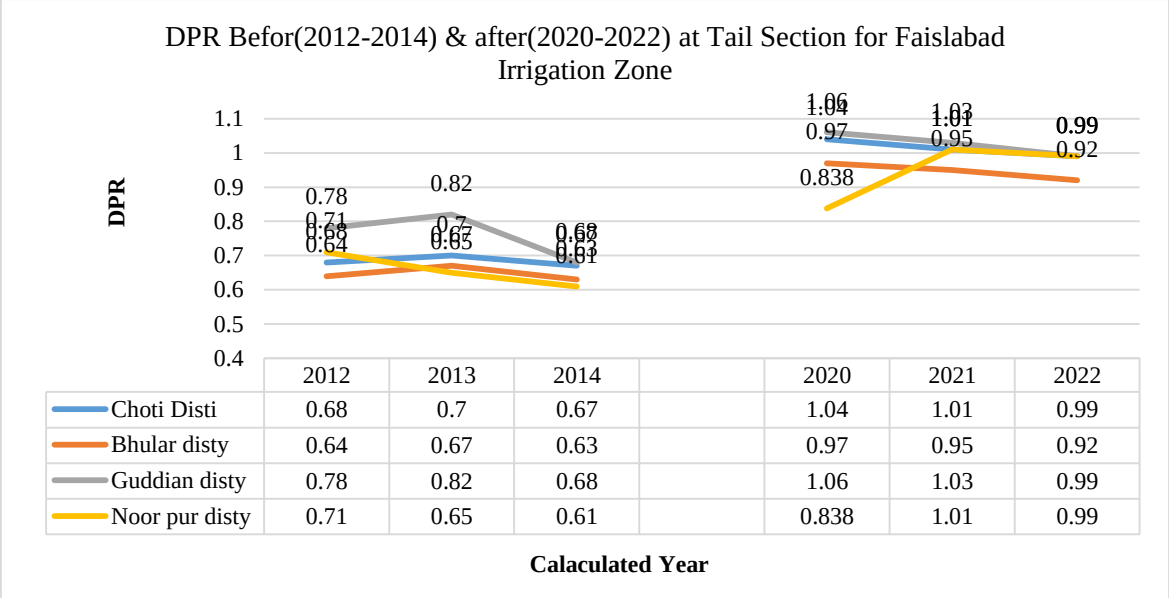


Fig. 11 Comparison of DPR before and after lining at the tail section for the Faisalabad Irrigation Zone

3.5. Summary of Results

- Quality of civil work & hydraulic efficiency on the basis of research work conducted on the selected area, it is concluded that the performance of the tail before lining was very low; most farmers at the tail could not get their water share properly.
- The DPR of selected canals before lining was low, and after completing lining in 2020, the canal water delivery efficiency increased to a satisfactory extent.
- At the tail sections in the Bahawalpur irrigation zone, the DPR get 45% increased after the lining of different distributary and minor canals.
- Water efficiency increased after lining of distributary and minor canals in DG Khan zone and Faisalabad irrigation zone. Due to the lining of canals, the observed increase in DPRs at the tails of canals is 37% and 46% respectively.

3.6. Data Interpretation and Analysis for Civil Works

3.6.1. Bahawalpur Irrigation Zone

Fig. 12 presents three parameters, namely, quality of civil work, operation & maintenance level, and efficiency, which were analysed through evaluation of different indicators. The results were represented in the form of pie charts. On the basis of the adopted comprehensive evaluation analysis, the observed overall component of civil works seems to be partially successful (69%).

Fig. 12 Quality of civil works, operations & maintenance level, and efficiency in the Bahawalpur zone

3.6.2. DG Khan Irrigation Zone

Fig. 13 shows that on the basis of an adopted comprehensive evaluation analysis, the observed overall component of civil works has seemed to be partially successful, i.e., 62% in the DG Khan Irrigation zone.

Fig. 13 Quality of civil works, operations & maintenance level and efficiency in DG Khan zone

3.6.3. Faisalabad Irrigation Zone

Figure 14 represents the comprehensive analysis of the civil works component for the Faisalabad irrigation zone. The overall construction quality of the civil works was found to be 67%. On the basis of the adopted comprehensive evaluation analysis, the observed overall civil work components, i.e., quality, operation & hydraulic efficiency, have been seen to be partially successful.

Fig.14 Quality of civil works, operations & maintenance level, and efficiency in Faisalabad zone

4. Conclusions

The overall quality of civil works was found to be satisfactory across all three irrigation zones, with specific evaluation percentages of 69% for Bahawalpur, 62% for DG Khan, and 67% for Faisalabad.

Minor quality issues were identified in the DG Khan and Bahawalpur irrigation zones, including prevalent minor cracks and significant cracking at various distributaries. These issues are primarily attributed to inadequate maintenance, challenging geotechnical conditions, tampering, and water theft.

Vegetation growth and excessive silt deposition were observed at multiple sites across all three irrigation zones, highlighting a common challenge in canal maintenance.

To ensure the efficiency and sustainability of the irrigation system, it is crucial to establish more effective monitoring and maintenance mechanisms.

References

[1]. Ali. I. Irrigation and Hydraulic Structures. Institute of Environmental Engineering and Research, NED University of Engineering and Technology, Karachi, Pakistan, (1993).

[2]. Ararso G. S., B. Schultz, and P. Hollanders. Planning water management for secure food production in sub-Saharan Africa. Journal of International Commission on Irrigation & Drainage (ICID). Published online in Wiley Inter Science (2009).

[3]. Ahmad et al conducted research on Surezai Minor of Warsak Gravity Canal Irrigation System in NWFP irrigation and drainage performance assessment practical guidelines Canals". Irrigation and Drainage. Irrig. And drain. 63:12–21 (2014), (1999).

[4]. Amin Sohani et al studied to analyse the capability of farmers managing parts of the irrigation systems, Scientia Horticulture 138 (2012) 221–226, (1997).

[5]. Bos M.G., M.A. Burton and D.J. Molden. Irrigation and drainage performance assessment practical guidelines. Wallingford, UK: CABI Publishing, (2005).

[6]. Ghumman A. R., M. Z. Khan, and M. J. Khan. Use of numerical modelling for the management of canal irrigation water. Journal of Irrigation and Drainage Engineering, Wiley-Interscience, v. 55, p. 445–458, (2006).

[7]. Ghahroodi E. M., H. Noory and A.M. Liaqat. Performance evaluation study and hydrologic and productive analysis of irrigation systems at the Qazvin irrigation network (Iran). Agricultural Water Management. v. 148, p. 189–195, (2015).

[8]. Kanooni et al. offer the water delivery performance ratio (DPR) at both the intake & offtake sections, v.133, p.132-143, (2014)

[9]. Latif et al. Hydrologic Modelling of a Canal-Irrigated Agricultural Watershed with Irrigation Best Management Practices: Case Study." J. Hydrol. Eng., 16(9), 746–757, (2014).

[10]. Njokweni Elliot Ntsonto. The Impact of Irrigation Technology on the Financial And 135Economic Performance of Smallholder Irrigation in Africa. Irrigation and Drainage. Irrig. And drain. 63: 430–439, (2005).

[11]. Osman. The effect of Floodplain Roughness on Flow Structures, Bed-forms, and Sediment Transport rates in Meandering Channels with Overbank Flows: Part I. IAHR Journal of Hydraulic Research, v. 47, n. 1, p. 5-19, (2015).

[12]. Qaiser et al., Modelling tools for minimizing water losses and managing planning for the available water at tail reaches, Irrigation & Drainage (ICID) v. 55, Issue. S2, p.251-264, (2013).

[13]. Rossi and Ricks. Local transformation of a state-initiated institutional innovation: the example of water users' associations in an irrigation scheme in Morocco, Journal of International Commission on Irrigation & Drainage (ICID) – Vol. 56, Issue-2, 3:346-356, (2015).

[14]. Tafte. Optimal management of irrigation systems and economic productivity. Engineering, Wiley Inter science, v. 55, p. 440–448, (2014).

[15]. Waqar, A. J et al. Conjunctive water management techniques and institutional capacity building reforms, v.123, n.3, p.165-172, (2002).

[16]. Rechna Doab Won-Ho Nam et al. Water management strategies and impact of climate change v.138, p.152-163, (2015).