EVALUATION OF IMPACTS OF RABI IRRIGATION IN GANGA RIVER SUB-BASINS OF MADHYA PRADESH (PDS NO: NIH-1_2016_1)

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Water Resources Department
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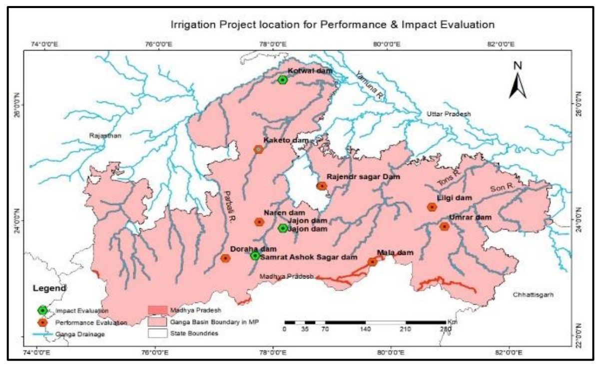
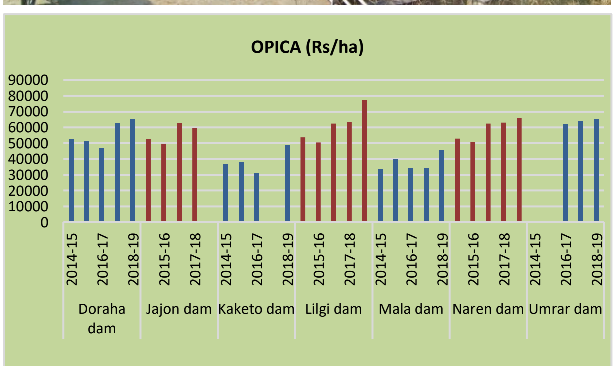
Bhopal





Lead organization

National Institute of Hydrology
Central India Hydrology Regional Centre, Bhopal

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PREFACE

Madhya Pradesh has seen remarkable growth in the irrigation and agricultural sectors over the last decade. The state needs to keep the same pace of development more consistent and sustainable. Thus it is imperative to evaluate the irrigation schemes in terms of their impacts on hydrology, agricultural production, economy, and society. This can also be achieved through the formulation of strategies based on the performance evaluation of irrigation schemes. It involves the use of suitable comparative indicators, measuring its performance, and comparing with the best practices, identifying bottlenecks, constraints, managerial laps, and other grey areas in the system. It is an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. It will help to formulate a direction for improvement in strategies to reap the full benefits of an irrigation system on a long-term basis.

In the present Purpose Driven Study (PDS), the impact evaluation analysis of rabi irrigation has been carried out for a minor irrigation project Jajon and major irrigation projects Kotwal-Pilowa and Samrat Ashok Sagar in Madhya Pradesh. The performance evaluation analysis has been carried out for eight medium and minor irrigation projects namely Kotwal-Pilowa dam, Doraha dam, Naren Dam, Mala dam, Kaketo, Lilgi dam, Umrar, and Jajon dam. These dams are located in the major tributaries of the Ganga and Yamuna basins such as Betwa, Chambal, Dhasan, Ken, Son, tone, and Sindh. Nine comparative indicators classified into four groups, Agricultural, Economic, Water-use, and Physical performance as suggested by IWMI, Sri Lanka were used for the analysis. The main utility and outcome of this PDS is the development of a knowledge product that involves the development of a Web-based dynamic application and an android-based mobile application for the performance evaluation of an irrigation project.

The present Purpose Driven study has been carried out by the National Institute of Hydrology, Central India Hydrology Regional Centre, Bhopal in collaboration with BODHI, Water Resources Department, Govt. of MP. The NIH team comprised PI, Dr. R. V. Galkate, Scientist-F, and Co-PIs, Dr. R.K. Jaiswal, Scientist-F, Dr. T.R. Nayak, Scientist-G, Dr. T. Thomas, Scientist-F, Mrs. Shashi Indwar, Scientist-D, Sh. Vivek Morya, Project Associate. The MPWRD team comprised PI, Director, Hydrometeorology, and CO-PI Dy. Director and Data Base Administrator, State Data Centre, BODHI, Bhopal, and Dy. Director, Hydrometeorology, Div No. 3.

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Signature

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Abstract

The impact evaluation of rabi irrigation schemes in terms of their impacts on hydrology, agricultural production, economy, and society and their performance evaluation is important for the formulation of strategies for improvement in the system to reap its full benefits in the long term basis. In the present PDS, the impact evaluation analysis was carried out for three selected minor and medium irrigation projects in Madhya Pradesh. Agricultural production was reported as good in the head and middle as compared to tail reach whereas the crop production in the non-command area was seen as less than even the tail reach area of the command. Farmers in the head reach area receive sufficient irrigation supply. Farmers in the tail-reach areas are not seen as satisfied with the canal water supply. Canal condition was not reported well in all three commands. The performance evaluation analysis has been carried out for eight medium and minor irrigation projects of Madhya Pradesh located in the major tributaries of the Ganga and Yamuna basins. The performances of all irrigation projects were found to improve after 2017-18 and 2018-19 in terms of improvement in crop productivity, land productivity, and water productivity. Gross return on investment was found to be better and irrigation projects are seen as financially viable and self-sufficient. The main utility and outcome of this PDS was the development of a knowledge product that involves the development of a Web-based dynamic application and an android-based mobile application for the performance evaluation of an irrigation project.

Originating unit	**National Institute of Hydrology** Central India Hydrology Regional Centre, Bhopal **Water Resources Department** Govt. of Madhya Pradesh, Bhopal
Keywords	Impact Evaluation, performance evaluation, comparative indicators, Standardized gross value production, Baseline sample survey
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LIST OF ABBREVIATION

ASCE	American Society of Civil Engineers
BMC	Bhind Main Canal
BODHI	Bureau of Design and Hydrological Investigation
CCA	Culturable Command Area
CGWB	Central Ground Water Board
CIS	Communal Irrigation Systems
CSO	Central Statistics Organization
CWC	Central Water Commission
DPR	Detailed Project Report
DRIP	Dam Rehabilitation and Improvement Program
ER	Effective Rainfall
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FRL	Full Reservoir Level
FSS	Financial self Sufficiency
GIS	Geographical Information System
GRI	Gross Return on Investment
GW	Groundwater
GWL	Groundwater Level
GWS	Ground Water Survey
HH	Households
IDSMIP	Irrigation Distribution System and Management Improvement Project
ILRI	International Livestock Research Institute
IMD	Indian Meteorological Department
INCID	Indian National Committee on Irrigation and Drainage
IT	Information Technology
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
Kc	Crop coefficients
KMIS	Kalwande Minor Irrigation Scheme
KMIS	Kalwande Minor Irrigation Scheme
LPG	Liquid Petroleum gas
MARIIS	Magat River Integrated Irrigation System
MCM	Million Cubic Meters
MPWRD	Madhya Pradesh Water Resources Department
NABARD	National Bank for Rural Development

NHP	National Hydrology Project
NIH	National Institute of Hydrology
O&M	Operation and Maintenance
OPCA	Output per Unit Command Area
OPICA	Output per Unit Irrigated Cropped Area
OPIS	Output per unit Irrigation Supply
OPUIS	Output per unit irrigation supply
OPWC	Output per unit water consumed
PDS	Purpose Driven Study
RIS	Relative Irrigation supply
RIS	Relative Irrigation supply
RO	Reverse Osmosis
RRR	Repair Renovation and Restoration
RS	Remote Sensing
RTDAS	Real Time Data Acquisition System
RWS	Relative Water Supply
RWS	Relative Water Supply
SAS	Samrat Ashok Sagar Dam
SGVP	Standardized Gross Value of Production
WALMI	Water and Land Management Institute
WDC	Water Delivery Capacity
WDC	Water Delivery Capacity
WRIS	Water Resources Information System
WUA	Water User Associations

CHAPTER - I

INTRODUCTION

Irrigation development is one of the most commonly practiced strategies to secure food self-sufficiency. Irrigation is one of the pressing needs in agriculture due to inadequate and uncertain rainfall. In many areas of the Madhya Pradesh state, the amount and timing of rainfall are not adequate to meet the moisture requirement of crops hence irrigation is essential to raise crops to meet the food and fiber need of the state. Continuous drought conditions and food shortages in the past have brought into sharp focus the importance of irrigation development in the state. In the recent decade, the Madhya Pradesh state has achieved remarkable growth in the irrigation sector. The efforts made by the state Water Resources Department under Dam Rehabilitation and Improvement Program (DRIP), Repair Renovation and Restoration (RRR) scheme, and newly developed projects have helped the state to achieve a significant rise in irrigation and agricultural production. The same pace of sustainable development in the waters sector will be a key factor to meet the increasing future water demands in the state. This can be achieved through the formulation of strategies based on continuous evaluation of the impacts of irrigation schemes in terms of their environmental and economic aspects. The performance evaluation of the projects is equally important to reap its benefit on a long-term basis. The present Purpose Driven Study (PDS) envisages the study of the impact of irrigation infrastructure development in the Ganga sub-basin area of Madhya Pradesh specially Rabi irrigation on agricultural growth, hydrology, rural economy of the state, and social upliftment of the people. It also envisages the performance evaluation of the selected irrigation projects.

The performance evaluation of the irrigation project is a part of the benchmarking process, an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. Benchmarking is introspection as it is a continuous process of measuring one's performance and practices against the best competitor and it's a sequential exercise of learning from others' experiences. It helps to identify bottlenecks, constraints, managerial laps, and other gray areas in the system and provides direction for improvement therein. Thus, the estimation of water demands and their implications on water quantity and quality is extremely important. Applying the right quantity of water at the right time in irrigation fields coupled with the right cultivation and irrigation practices can achieve better water use efficiency. The irrigation sector highlights the need for planning and management for '*more crop per drop*'. There has always been scope for considerable improvement in productivity and consequent reduction in water demand.

Madhya Pradesh is the second-largest state in the country by area and the sixth-largest state in India by population. The total geographical area the state of Madhya Pradesh covers is around 3.08 Lakh sq. km. and its average annual rainfall is about 1371 mm. The state is endowed with five major river basins, Narmada, Ganga, Yamuna, Tapti, and Godavari. The state has an agrarian economy; the major crops of Madhya Pradesh are wheat, soybean, gram, sugarcane, rice, maize, cotton, rapeseed, mustard, and arhar. The State is not short of water resources and it has enormous potential for its development. After the separation of Chhattisgarh from Madhya Pradesh, during the IX-Five Year Plan in the year 2000-2001, the irrigation potential created was 20.31 lakh ha and the actual irrigated area was 7.36 lakh ha. At the end of the XII-Five Year Plan in 2014-15, the irrigation potential created was 24.35 lakh ha and the actual irrigated area was 23.92 lakh ha (MPWRD website: http://www.mpwrd.gov.in/history). The impacts of irrigation development, repair renovation, and rehabilitation program in the state are visible. As per advance figures for 2013-14 released by Central Statistics Organization (CSO), the state has clocked a 24.99 percent agriculture growth rate (Economic Times of India, June 1, 2014). Madhya Pradesh has been bestowed the prestigious Krishi Karman award by the Government of India for the last four years in a row in recognition of its outstanding performance in the agriculture sector. This has been made possible through the water sector restructuring program aided by the Ministry of Jal Shakti, Govt. of India, the World Bank, and sustainable water resources development strategies adopted by the Madhya Pradesh state. These, in turn, facilitated the state to increase agricultural productivity and improve the rural livelihood and living standards of farmers.

To keep the same pace of development more consistent and sustainable, it is imperative to evaluate the irrigation schemes in terms of their benefits and their impacts on agricultural production, the environment, the economy, and society. These impacts can be accessed through data analysis, statistical analysis, and surveys in the project command area. Continuous evaluation of the performance of individual irrigation schemes in terms of their economic and social benefits using appropriate indicators is equally important for further improvement in water resources development and management strategies. Fresh surface water sustains ecological systems and provides habitats for many animal and plant species. Surface water bodies offer many benefits and also support many human uses such as drinking water, irrigation, wastewater treatment, livestock, industrial use, hydropower, and recreation. However, it is seen that a year-round ponding of water may cause potential health risks in terms of water-born and water-spread diseases such as malaria, schistosomiasis, worms, etc.

The present Purpose Driven Study (PDS) envisages the study of the impact of Rabi irrigation development in the Ganga sub-basin part of MP on hydrology, agricultural growth, economy, and public health of the region. It also envisages the performance evaluation of the selected irrigation projects using a suitable indicator. One of the important components of this PDS is the development of a web-based dynamic application for performance evaluation of an irrigation project, which will be integrated with India-WRIS or NHP Web portal so that PDS output can be utilized for other areas also. The web-based dynamic application will enable irrigation project managers of the region to evaluate the performance of projects under their control with the use of project-related data and information as input. It will help the project authority to compare the performance of the project with the previous years or with other projects in the region and formulate strategies for further improvement in the system. It will also help to assess the impact and evaluate the benefits of rehabilitation, restructuring, and renovation work undertaken for the irrigation project. It will also help to assess the impacts of operation and management policy on the performance of the irrigation project. The methodology to be adopted to achieve study objectives has been explained in detail in this report. The Madhya Pradesh state, up to the year 2021-22, has a setup of a total of 5897 irrigation schemes to cover 40.76 lakh ha Culturable Command Area (CCA) in the state. The state has 29 major irrigation schemes with 17.95 lakhs ha cumulative actual irrigated area, 112 medium irrigation schemes with 3.84 lakh ha cumulative actual irrigated area, and 5756 minor irrigation schemes with 9.52 lakh ha cumulative actual irrigated area (WRDMP website: http://eims1.mpwrd.gov.in/imreport/control/main). For conducting the study the irrigation schemes located in the Ganga sub-basin area of each category will be selected considering their importance, status, location, and relevant problem if any.

1.1. Objectives

- Evaluation of impacts of Rabi irrigation on hydrology, agricultural growth, economy, and public health for selected irrigation projects in the Ganga basin.
- Performance evaluation of medium/minor irrigation projects.
- Development of a web-based dynamic application for performance evaluation of irrigation projects.
- Recommendations and dissemination of knowledge, and findings through training and workshops.

Present PDS is an attempt to find answers to as yet unanswered questions in the field of sustainable irrigation infrastructure development in the Madhya Pradesh state. Agricultural production has increased manifolds due to excellent development in the water sector in the state. However, this PDS has attempted to assess the impact of the Rabi irrigation scheme on other sectors such as hydrology, economy, and the social status of the stakeholders which are equally important. The problems of vector-borne diseases are generally associated with the water resource project due to the creation of dyke ponds and interruption of the downstream flow of water causing potential breeding habitats of vector species resulting in a built-up of high vector densities. Therefore attempts were made to assess the impact of an irrigation project on the health of local people. This was achieved through the analysis of secondary data on hydrological, agricultural, and health, statistical data and information collected from state departments, and primary data through baseline field surveys. The evaluation of the performance of irrigation schemes was carried out using comparative performance indicators suggested by IWMI (International Water Management Institute). These indicators are based on a relative comparison of absolute values, rather than being referenced to standards or targets. For further application of the output of the study, a dynamic web-based IT framework application is to be developed which will help other project authorities in the region to evaluate the performance of irrigation projects under their control by using concerned project related input information in the web application.

1.2 Project Partners

Lead Research Institution:	**National Institute of Hydrology** Central India Hydrology Regional Centre, Bhopal
Partner Institutions (if any):	**Water Resources Department** Govt. of Madhya Pradesh, Bhopal

CHAPTER - II

REVIEW OF LITERATURE

The present PDS study has two main components, first is the evaluation of the impacts of rabi irrigation on hydrology, agricultural growth, economy, and public health for selected irrigation projects in the Ganga basin. Another component is the performance evaluation of medium and minor irrigation projects. The present section is the review work carried out mainly focusing on these two components.

2.1 Impact Evaluation of Irrigation Project

Many studies have been conducted in India to study the role of irrigation infrastructure in improving productivity, developing the economy, and health, and reducing poverty in the country. The Ministry of Water Resources has set the guidelines on command area development and water management program for the impact evaluation of irrigation infrastructure. Madhya Pradesh State Water Resources Department has carried out a few studies for the impact evaluation of irrigation infrastructure for selected major, medium, and minor schemes of the state. A case study has been carried out by Pangare et al. (2003) in Madhya Pradesh titled "Survey on irrigation modernization-Samrat Ashok Sagar Irrigation Project". The study deals with the impacts of irrigation modernization on the sustainable development of water resources to meet irrigation demand through a participatory irrigation management approach.

Department of Water Resources Development and Management, IIT, Roorkee has conducted a NABARD (2014) sponsored project titled "Evaluation of rural infrastructural (irrigation) project in Sagar District of Madhya Pradesh". The NIH, Regional Centre, Bhopal was the participating organization in the project. The data was collected through extensive field surveys and questionnaires given to farmers of various categories in the command area of the selected minor irrigation schemes to evaluate economic and social upliftment in the region and of individual stakeholders. Many studies demonstrated that physical infrastructure development improves the long-term production and income levels of an economy (Barro, 1990; Futagami et al., 1993). Many studies have been conducted internationally to provide insights into the role of irrigation infrastructure in improving productivity, developing the economy, and reducing poverty. The research project on "Impact assessment of irrigation infrastructure development on poverty reduction" was conducted by Sri Lanka for the JBIC (Japan Bank for International Cooperation) supported Irrigation Project in Sri Lanka (Hussain et al., 2002). The research project was carried out in collaboration with IWMI (International Water Management Institute). The study aimed to corroborate the role of infrastructure in reducing chronic and transient poverty. In this project, to collect the information, 858 households were randomly sampled from the project area.

JICA (Japan International Cooperation Agency, 2010) has piloted impact evaluations for four of its funded projects in Asian countries like Indonesia, the Philippines, and Sri Lanka under the theme "Impact Evaluation of Irrigation Projects". The series of impact evaluations examined not only the effects of irrigation infrastructure development on agricultural production but also the effectiveness of the new agricultural methods. A research project has been completed in Pakistan on "Impact assessment of irrigation infrastructure development on poverty alleviation". It was initiated by the JBIC (Japan Bank for International Cooperation) and undertaken by the IWMI, Sri Lanka (Hussain et al., 2007). This study was undertaken with the overall objective of developing an in-depth understanding of income dynamics concerning access to irrigation water to assess the impacts of irrigation infrastructure development on poverty. The study used the primary data collected through household surveys conducted three times during a year, from a sample of 707 households, using a detailed multi-topic questionnaire. The research project on the Impact Evaluation of the Irrigation Distribution System and Management Improvement Project (IDSMIP, 2014) has been carried out to strengthen the agricultural sector through increased output, productivity, and income levels in Azerbaijan (Godfrey, 2012). The purpose of this research was to improve the effectiveness and financial viability of irrigation water distribution and management.

McKay and Keremane (2006) examined the impacts of institutional arrangement in the Mula irrigation scheme, a pioneering scheme in Maharashtra state, India, and studied the perceptions of farmers on self-created water management rules. The study was conducted with the background that farmer participation in irrigation management is moving to center stage and the traditional view of having centralized control over the water resources has been changed. The study was focused on the institutional arrangements governing water use and distribution and attempts to elicit the perceptions of the members regarding the rules in use. The study revealed that the Water User Associations are successful in devising and enforcing the rules for water distribution, fee collection, and conflict resolution for over a decade. However, current socioeconomic developments such as political heterogeneity have required explicit conflict resolution mechanisms. These issues have now become issues demanding immediate attention and maybe the use of existing courts or legal institutions to help the WUA sustain itself in the future.

Estache (2010) studied various methods for impact evaluations of infrastructure projects, programs, and policies. This study reviews the main lessons from impact evaluations of infrastructure projects, programs, and policies relevant to policymakers. The study involves impact evaluations of projects derived from experimental and quasi-experimental techniques. It covers energy, water, and sanitation as well as the various transport subsectors such as ports, railways, rural roads, and highways. The survey offers an opportunity to get a sense of the creativity of researchers conducting these evaluations. It summarizes the main questions asked, the main techniques used, and when available the results available. It concluded with a discussion of some of the limitations of evaluations in the context of infrastructure interventions.

Jin et al. (2012) have carried out a study on the impact of irrigation on agricultural productivity: Evidence from India. They used plot-level production data from a nationwide survey in India; they studied the impact of irrigation on crop productivity, land prices, and cropping intensities. Their main identification strategy was based on a sufficient number of households cultivating multiple plots of different irrigation status. The observations made from the study showed that irrigation has a strong and significant impact on all outcomes with the dominant effects on cropping intensities. The results of the study provided support for continuing investments to improve access and quality of irrigation in India. A research study has been carried out on "Evaluation of the irrigation infrastructure activity in Armenia". The study report has included evaluation design for tertiary canals, and evaluation design for large infrastructure projects, based on a survey conducted in the Republic of Armenia.

Diwan (2012) conducted a study on the evaluation of water supply and irrigation infrastructure development in India. The author was confined to the evaluation of the water supply and irrigation infrastructure development. He concentrated on the issues of an ancient water supply infrastructure, ancient irrigation efforts, achievement in water supply infrastructure till IXth Five Year Plan, old irrigation infrastructure status, planned irrigation infrastructure development, and overall water scenario of the country.

Nguyen and Nguyen (2016) examined the impact of communal irrigation plants on the income and agricultural activities of rural households in Vietnam using the fixed effect method and data. Household-level and commune-level data were analyzed using fixed effect regression. They revealed no evidence of significant impacts of communal irrigation plants on household income, income structure, and rice cultivation activities. These results imply the weak operation and maintenance of public irrigation plants as well as the lack of integrated water resource management to ensure water input for irrigation systems.

Seiro et al. (2016) carried out a comprehensive analysis of the Impacts evaluation of infrastructure projects of tertiary canal irrigation and described the challenge in the impact evaluation of infrastructure and estimated the economic impacts using the panel data set from rural Thailand. The study was based on the survey and it was observed that the farmers were appreciative of tertiary canals but they could not come up with sizeable productivity gains or cost reductions due to construction. Researchers employed difference-in-differences estimation and showed that tertiary irrigation has unexpected impacts. Contrary to the predictions of local experts that it should have substantial productivity impacts as it allows better water controls for farmers, a study revealed zero profitability impacts. Another unexpected finding was that profitability was not affected. However, the cultivation probability was increased with the construction of tertiary canals during both wet and dry seasons. This finding of the study suggested that Thai farmers, despite their aging population and relatively relaxed attitude toward cultivation, are willing to expand the operation scale once they get water. Due to the more intensive use of land, the tertiary canal helped to improve the land productivity in the project over the years.

Bose et al. (2020) conducted an impact evaluation study of the mini irrigation projects located within the tribal area of Odisha State. The study was conducted in four selected areas namely; Nilagiri, Bonai, Paralakhemundi, and Thuamul Rampur for the year 2007 - 2008. The aim of the study was to emphasize mini-irrigation projects in the tribal area to raise the irrigation potential of the area, increase the productivity of land and provide assured irrigation facilities. The study was carried out for 41 mini-irrigation projects of different kinds such as water harvesting structures, diversion weirs, cross bunds, weir dams, river lifts, shallow tube wells, dug wells, etc. executed in 39 villages covering 237 tribal beneficiaries. The study was carried out to assess the impact of the projects on the enhancement of productivity of the land brought under irrigation; the extent of increase in the input use; the level of employment generation for both family Laboure and hired Labouré; increase in farm income of the beneficiaries and improvement in the socio-economic status of the beneficiaries.

2.2 Performance Evaluation of Irrigation Project

Several studies have been conducted all over the world for performance evaluation of irrigation projects. Das et al. (1992) suggested that performance evaluation parameters of irrigation canal systems should involve factors such as command area, canal network, control structures, cropping patterns, and weather conditions as well as human factors. Mohamed (1992) carried out research on analytic and optimization decision-making models for multi-objective on-farm irrigation improvement strategies He carried out a multi-objective evaluation of the performance of irrigation systems. The study concluded that the inadequate understanding of field conditions, causes, and magnitudes of priority problems were not fully identified especially in less developed countries. Most studies and reports are either based on rapid appraisals or concentrate on one part of the system.

Murray-Rust and Snellen (1993) conducted a research study on irrigation system performance assessment and diagnosis. The study concluded significant conclusion was that simplicity both in system design and in system objectives leads to higher levels of performance than complexity. A conclusion from the paper was that these management improvements can largely, but not always, be achieved without major physical investment. Once managerial capacity has been strengthened and stabilized then the likelihood increases that physical investments will be more worthwhile.

Burt et al. (1997) emphasized standardizing 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 the numerical values of the performance indicators.

International Water Management Institute, Sri Lanka in their Research Report No. 20 (Molden et al., 1998) suggested the Indicators for comparing the performance of irrigated agricultural systems. Molden et al. (1998) compared the 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 vast differences in performance among the systems due to the different managerial practices and other related issues. These indicators are used in this PDS for the performance evaluation of irrigation projects in Madhya Pradesh.

Droogers et al. (1999) used four performance indicators: yield over transpiration, yield over evapotranspiration, yield overflow 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 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 the performance of many projects was poor. The causes behind the poor performance of these projects were due to technical, financial, managerial, social, and institutional causes. They concluded that the 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 the evapotranspiration deficit (*ETp*- *ETa*), the productivity of land, the productivity of water inflow, and productivity per unit *ET*.

Upadhyaya et al. (2004) identified the constraints in water delivery from the canal and develop performance indicators. Analysis of performance indicators reveals that there is plenty of scope for improvement in the performance of the Patna Canal as well as water productivity in the canal command. Wichelns (2004) worked on the policy relevance of virtual water and how it can be enhanced by considering comparative advantages. He expressed the need for innovations in technology and policy dimensions of water resource management to achieve the gain in productivity required to feed the world's growing population. Bhatta et al. (2006) compared the performance of agency-managed and farmer-managed irrigation systems for a case study of Chitwan, Nepal, and discussed various relevant aspects.

A collaborative project carried out by Mekelle University, ILRI, and EARO, funded through the IWMI under the Comprehensive Assessment of Water for Agricultural Program titled Performance evaluation of community-based irrigation management in the Tekeze basin (Behailu et al., 2006). It was a case study on three small-scale irrigation schemes with the objectives to evaluate the performance of small-scale irrigation schemes, testing the comparative performance indicators in the basin, and recommend appropriate strategies to improve the performance of small-scale irrigation schemes.

Wegerich (2007) carried out a critical review of the concept of equity to support water allocation at various scales in the Amu Darya basin. He explored aspects of inquiry of water allocation amongst riparian states in the Amu Darya basin and districts within the Khorezm Province of Uzbekistan. He also discussed various issues related to equity. He concluded that equity appears to be the major objective on all water management levels, the concept as such and its implication for water management are hardly explored within the professional water debate.

Sener et al. (2007) carried out a performance evaluation of the Hayrabolu Irrigation Scheme of the Thrace district in Turkey evaluate using comparative indicators, by International Water Management Institute (IWMI) Sri Lanka. Results showed that the project has been working under the capacity of real performance and has not improved when compared to the years under government management. Nikam (2010) from Water Resources Department IIRS, Deharadun has conducted a study on performance assessment of the Mula irrigation project on Mulariver in Rahuri taluk of Ahmednagar district in Maharashtra using RS and GIS techniques.

Singh et al. (2013) case study to assess the performance of irrigation water management of the Lift Irrigation Scheme Sirsa Manjholi in the Solan area of the Shivalik Himalayas. In the study, the construction of the scheme has not induced any change neither in the cropped area nor in the cropping pattern of the command area. Thus the irrigation system has yielded low returns and the performance of the lift irrigation scheme was found unsatisfactory.

Ingle et al. (2015) studied the performance of the Kalwande Minor Irrigation Scheme (KMIS) in Chiplun, Ratnagiri district of Maharashtra using indicators by IWMI. The results showed that the output values were lower than the recommended package of practices. To increase output, crop patterns should include orchards, industrial crops, and vegetables.

Shenkut (2015) evaluated the performance of the Shina-Hamusit and Selamko irrigation schemes of the Dera and Farta districts, respectively in the South Gondar zone, Ethiopia. Shina-Hamusit and Selamko were assessed using comparative indicators. These indicators used are useful to evaluate the degree of utilization of resources such as land and water in producing agricultural outputs. The results of performance concerning both land and water productivity indicated that the Shina-Hamusit scheme performs better.

Bumbudsanpharoke and Prajamwong (2015) carried out a case study on performance assessment for irrigation water management for the great Chao Phraya irrigation scheme in Chao Phraya River Basin, central Thailand. The study aimed to assess the performance of irrigation water management using eight performance indicators such as crop yield ratio, output per unit area, operation and maintenance (O&M) cost, total financial viability, the efficiency of infrastructure, sufficiency of irrigation staff, irrigation ratio, and cropped area ratio. The outcome of the study provided a feasible mechanism for performance improvement in the irrigation and drainage sector but needs strong support from key stakeholders. The study concludes that, though there are some uncertainties concerning the quality of secondary data, experience, and insight gained from this study could provide valuable information for other schemes and will be a good starting point for benchmarking the performance of irrigation systems.

Bareng et al. (2015) carried out a comparative performance analysis of four irrigation schemes within the Cagayan River Basin using comparative performance indicators for 2008 and 2012 with an aim to establish benchmarks for both productivity and performance of irrigation schemes and to asses better performance among small and large schemes. Based on the prescribed descriptors used by the International Water Management Institute (IWMI) and Food and Agriculture Organization (FAO), they analyzed three general performance indicators such as system operation performance; agricultural productivity and economics; and financial performance. The system performance efficiency was 59%, 55%, 47%, and 36% for Magat River Integrated Irrigation System (MARIIS), Lucban, Garab, and Divisoria Communal Irrigation Systems (CIS), respectively. The annual productivity performance, of Lucban CIS dominates, was found better than three other systems. However, the financial sustainability of the systems was seen as poor in these irrigation schemes. The large schemes performed similarly to small-scale schemes, but small schemes were more variable, particularly in input-use efficiency. They concluded that the benchmarking study is helpful to provide strategic information to policymakers of agricultural and irrigation agencies on the existing weaknesses of irrigation systems and determine in more quantifiable terms levels of potential improvement and intervention targets.

Dev (2016) in his book water management and resilience in agriculture explained how water management requires multiple levels of policy action. He explained that the problem is not a shortage of water, but the absence of proper mechanisms for its augmentation, conservation, distribution, and efficient use. According to his observation, water management should be given the number one priority in agricultural policy, particularly to prevent drought, minimize the risks due to drought and build a climate-resilient agriculture

Dhawan (2017) worked on participatory irrigation management as the water sector faces the challenge of improving performance and irrigation infrastructure in India. He concluded that designing applicable institutional strategies to allocate scarce water and river flows have been an enormous challenge due to the complex legal, constitutional, and social issues involved. States like Andhra Pradesh, Madhya Pradesh, and Maharashtra, have made substantial headways in reforming their water institutions and governance structures by adopting legislation to promote participatory irrigation management. He also found that there is little agreement about appropriate institutional arrangements and criteria for successful institutional design.

Xu et al. (2018) carried out a performance analysis to improve water use efficiency and winter wheat grain yield with minimum irrigation in the Northern China Plain. They carried out field experiments to determine how single irrigation can improve water use efficiency grain yield and by manipulating the sink-source relationships. To achieve this, no-irrigation after sowing as a control, and five single irrigation treatments after sowing (75 mm of each irrigation) were established. These results demonstrated that single irrigation at jointing or booting could improve grain yield and water use efficiency and performance of the system.

Rani and Singh (2018) carried out a study on the evaluation of benchmarking indicators for the Sanjay Sarovar Irrigation Project of Madhya Pradesh. The study reflected a low level of water delivery service and irrigation performance. In Sanjay Sarovar Irrigation Project, the annual project irrigation efficiency was observed at 41% and the annual field irrigation efficiency was 51%. They observed most of the key internal indicators covering operations and service were found low. External indicators, such as irrigation efficiency, cost recovery ratio, and productivity, were also relatively low. The study suggested the immediate need to improve the service delivery of the surface water systems on priority.

Muema et al. (2018) applied benchmarking and principal component analysis in measuring the performance of public irrigation schemes in Kenya. Periodically monitoring and evaluation of the performance of public irrigation schemes is essential due to the inefficient water use, and variable and low productivity in Kenyan public irrigation schemes. They evaluated the performance of three rice-growing irrigation schemes in western Kenya using benchmarking and principal component analysis for the period from 2012 to 2016 using eleven performance indicators under agricultural productivity, water supply, and financial performance categories. The performance indicators were weighted using principal component analysis and combined to form a single performance score using the linear aggregation method. The average performance in the Ahero, West Kano, and Bunyala irrigation schemes was 48%, 49%, and 56%, respectively. Based on the performance score, the Bunyala irrigation scheme was found to be the highest-performing rice irrigation scheme in western Kenya. The three irrigation schemes have an average performance. The study suggested operation and management measures to improve the current performance of irrigation schemes.

Tripathi et al. (2019) carried out a study to evaluate the performance of the irrigated system in terms of wheat yield and water productivity for different varieties, irrigation methods, and depth of irrigation in Khapa and Magardha command areas, which are located in Mandla district of Madhya Pradesh. In this study, Different irrigation application methods i.e. sprinkler irrigation system, Border irrigation, flood irrigation, and different sowing methods were applied to the wheat crop. These practices may reduce on-farm irrigation water applications and improve crop yields. Water management technologies like sprinkler irrigation was is used to make use of available water resources efficiently and thereby improve productivity as well as profitability.

Sinha et al. (2019) assessed the impact of investments in modernizing irrigation infrastructure which is key to enhancing water security for agriculture. This research work applies a fixed effects regression model to test whether the modernization of irrigation systems in Madhya Pradesh leads to improvements in district-level yields and the protection of yields against sub-basin rainfall variability. Findings suggest that investments fail to improve yields in districts with deficient rainfall and fail to buffer crops against monsoon variability, compared to control districts with no investments. Interventions should be designed to respond to the complexities of sub-basin rainfall variability.

Hakuzimana and Masasi (2020) carried out a research study on the performance evaluation of irrigation schemes in the Rugeramigozi marshland in Rwanda. In Rwanda, despite substantial investments in irrigated agriculture, most of the irrigation schemes are performing far below their planned capacity. The study aimed at benchmarking the performance of Rugeramigozi-1 and Rugeramigozi-2 irrigation schemes located in Rugeramigozi marshland, Rwanda using irrigation indicators developed by the International Water Management Institute (IWMI). They observed that the land productivity of both schemes was generally low. The Rugeramigozi-2 irrigation scheme was seen performing better than Rugeramigozi-1 in terms of water productivity, which may be due to the adoption of deficit irrigation strategies that promoted water conservation. The water service delivery showed sufficient water use in the Rugeramigozi-1 as compared to the Rugeramigozi-2 irrigation scheme. The water delivery capacity of both schemes was seen as reasonable and revealed that the existing canal network is sufficient to meet the irrigation water requirements at peak demand. The analysis indicated poor financial performance in both schemes due to inadequate revenue collection to cover the operation and maintenance costs. The study recommended the need for intensive management and infrastructural improvements to increase productivity and enhance the sustainability of the schemes.

Rath and Swain (2020) carried out a performance evaluation of the irrigation canal system of the Hirakud dam canal system in the Odisha state of India using benchmarking techniques. The main aim behind the performance assessment of an irrigation system was to make the best utilization of the available water resources efficiently and effectively. In the present study, the evaluation of the performance of a canal system was conducted in two parts of the Hirakud canal system namely the Paramanpur distributary and the Senhapali distributary. The performance indicators in a flow irrigation system, such as adequacy, variability, efficiency, inequity, conveyance performance, and irrigation performance were used to evaluate the performance of the canals. The evaluation study indicated that more attention should be given to the canal operation strategy to get optimal output from the system.

Sharma (2021) studied regional variation in potential as well as utilization of water resources within the Madhya Pradesh state following the variations in hydro-geological aquifers, precipitation patterns, land use, and cropping structure. Palanisami et al. (2021) conducted a pan India on scaling-up technology adoption for enhancing water use efficiency. They carried out an evaluation study on farmers' participatory action research program covering 21 states of India initiated by the Ministry of Water Resources, government. The results indicated increased water productivity, income, and water saving in several crops due to technology adoption with farmers' participation. However, adoption of the improved technologies has ranged only from 12 to 15%. Hence, they concluded that the existing two technology adoption level gaps, viz., the technology transfer gap and the technology performance gaps should be properly addressed in future agriculture development programs.

2.3 Research Gaps

As evidenced by the above-mentioned review of literature, several studies have been conducted both nationally and internationally to investigate the impact of irrigation infrastructure on productivity, economy, health, poverty reduction, project modernization, institutional arrangement, and understanding of income dynamics. The majority of studies are based on extensive field surveys, baseline surveys, and a remote sensing approach. In the current study, the approach of collecting primary data through a well-designed baseline survey was used to assess the impact of rabi irrigation on hydrology, agricultural growth, economy, society, and public health in the Ganga basin region of Madhya Pradesh state.

Based on a review of studies or projects completed so far, performance evaluation has proven to be an important tool for better management of water resources and resolving issues encountered by the irrigation system that is not performing as expected. For the performance evaluation of irrigated infrastructure, many researchers have used remote sensing techniques, performance indicators, benchmarking analysis, and evaluation studies. Few studies for system performance assessment and diagnosis have used a multi-objective approach. Most studies compared the performance of irrigated agricultural systems using comparative indicators proposed by Molden et al., (1998) and adopted by the International Water Management Institute (IWMI), Sri Lanka.

Most studies are based on the performance of a single irrigation system, however, it is always better to compare irrigation projects within the same region, basin or district boundaries, state, or country. A cross-comparison of such projects will be useful in identifying the best-irrigated infrastructures and approaches. Therefore in this PDS, comparative indicators are used to evaluate the performance of minor and medium irrigation projects located in major Ganga tributaries in Madhya Pradesh. Furthermore, a cross-system comparison was performed to determine which project performed better than others. Attempts have also been made to identify the reasons and lapses behind the weak performance of the system, as well as to suggest measures to overcome these issues and to adopt appropriate practices to improve the performance of the irrigation project.

CHAPTER - III

METHODOLOGY

This section includes a description of the process of data collection and the methodology adopted to achieve the objectives of the PDS. The steps followed and methodology used has been elaborated in detail in this section

3.1 Objective1: Evaluation of Impacts of Rabi Irrigation on Hydrology, Agricultural Growth, Economy and Public Health in the Ganga Basin

The evaluation of the impacts of Rabi irrigation on hydrology, agricultural growth, socio-economy, and health has been carried out for three irrigation projects of Madhya Pradesh, details of which are given in Table 3.1. A baseline survey was conducted in command and non-command areas of these irrigation projects to collect primary data from farmers through a set of questionnaires. The map showing the location of dams selected for impact evaluation analysis is shown in Figure 3.1.

Table 3.1: Details of dams selected for impact evaluation of Rabi irrigation in MP

S. No	Scheme Name	Project Category	District	Tehsil	Gross Storage at FRL (MCM)	Lat. Long.	Sub Basin	Name of Local River	Catchment Area (Km^2)	Irrigation (Ha)
1	Samrat Ashok Sagar	Major	Vidisha	Vidisha	252.00	23°25'99" 77°41'26"	Betwa	Betwa	699.00	29942
2	Kotwal-Pillowa dam	Medium	Morena	Morena	57.45	26°29'00" 78°10'00"	Sindh	Asan	518.00	12387
3	Jajon dam	Minor	Vidisha	Basoda	7.436	23°55'00" 78°10'00"	Betwa	Local Nallah	17.35	1296

3.1.1 Data collection protocols

Primary data of the study area has been collected through field surveys in the command area of the irrigation project which included a questionnaire on water availability, landholding, crop management, farm mechanization, availing loan facility, local market growth, banking, on-farm budgeting of the farmer, health hazards or benefits observed due to irrigation project, etc.

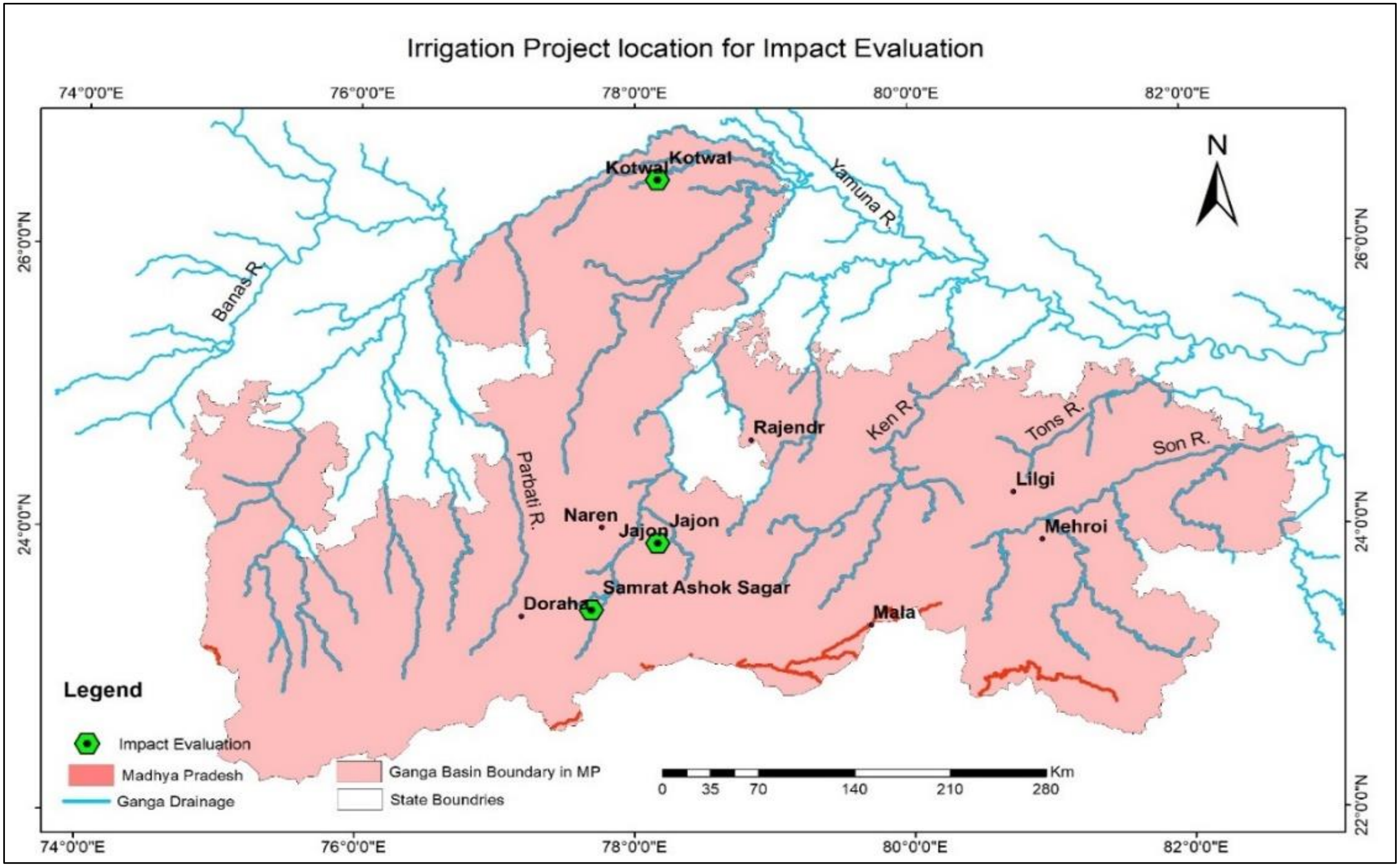


Figure 3.1: Map showing locations of dams selected for impact evaluation analysis

3.1.2 Hydrological impact analysis

The hydrological impacts of irrigation projects are generally visible after the construction of a new dam or rehabilitation work of the existing one. In this PDS, the impacts of irrigation projects on hydrology have been evaluated based on the assessment of water availability in command, downstream flow in river and nalla in the command area, and groundwater rise in the command area. This included the statistical analysis of primary data collected through baseline surveys and groundwater level data. The hydrological impacts on groundwater table rise during monsoon and fluctuation in the command area have been assessed using pre-monsoon and post-monsoon groundwater data. Data has also been collected to assess waterlogging and increased salinity problems in command areas.

3.1.3 Agricultural impact analysis

The irrigation projects have an impact on the improvement of agricultural production in the command area. For evaluation of its impact on crop production, use of improved crop varieties, irrigation intensity, crop intensity, grain quality, application of supplemental irrigation during dry spells, ability to grow cash crops and Zaid crops, crop management under droughts, etc have been studied. For the assessment of these impacts, the required information has been collected through baseline field surveys. Data has been analyzed using simple statistical methods and departure analysis, linear trend analysis, etc.

3.1.4 Socio-economic impacts analysis

To obtain this information a baseline survey of the farmers and members of Water User Associations (WUA) has been carried out in the project command area through discussion and questionnaire. The information has been collected by selecting users based on their landholding, the location of their farms such as head reach, middle reach, or tail reach, and farmers not getting water from the project. The survey was intended to obtain information on changing cropping patterns, irrigated areas, use of improved technologies such as the use of farm equipment, use of pesticides, fertilizer, and high-yielding varieties, use of bank credit facility, incremental farm income, irrigation service, farmers participation in irrigation management, conjunctive use, use of sprinkler and drip irrigation, farm budgeting, etc. the primary data has been analyzed using a simple statistical method, manual data interpretation, and comparison for impact evaluation of Rabi irrigation on the socio-economic situation.

3.1.5 Health impact assessment

The problems of vector-borne diseases are generally associated with water resource projects due to the creation of dyke ponds and interruption of the downstream flow of water causing potential breeding habitats of vector species resulting in a built-up of high vector densities. The positive impacts of irrigation projects are also seen due to the availability of adequate quantity and quality of water. Therefore it is important to assess the real impact of the increase or decrease in diseases like malaria in the irrigation project area, in addition to the benefit of the project for the community. A baseline survey included a questionnaire to obtain basic information such as the health status of the local people, the incidence of water-borne and water-spread diseases like malaria in project villages, and non-project villages and the health-seeking behavior of the community. Such information is useful to identify gaps and suggest measures to improve the health status in the community and thereby reduce economic losses. The primary data collected was analyzed using simple statistical and manual data interpretation techniques.

3.1.6 Farmers Baseline sample survey for impact evaluation

For evaluation of the impacts of rabi irrigation on various aspects has been carried out based on primary and secondary data on agricultural growth, economy, and public health of concern irrigation projects in the study area. Primary data of the study area has been collected through farmers baseline survey surveys in the command area of the irrigation project which includes a questionnaire on water availability, landholding, crop management, farm mechanization, availing loan facility, local market growth, banking, on-farm budgeting of the farmer, health hazards or benefits observed due to irrigation project, etc. Secondary data which includes hydrological information like meteorological data, groundwater data, dam details, operation rules, agricultural data, demographic data, and other statistical information available from Water Resources Department, Agricultural Department, Statistical Department, Revenue Department, IMD, Rural Health Department, Agricultural Universities and other line departments. Data thus obtained from the baseline survey was analyzed comprehensively using statistical methods like average, trend, graphs, linear relation, comparison, etc.

For carrying out a baseline sample survey, a survey format consisting of a set of questionnaires was prepared in the local language Hindi. The survey form was sent to the PDS expert committee of NHP for their comment, suggestion, and approval. The survey form was finalized after incorporating corrections and suggestions given by the experts. The survey form consists of a set of questionnaires to obtain information on hydrology, agriculture, socio-economy, and health aspects in the command and non-command areas.

3.1.7 Sample survey planning

Sample surveys are generally conducted to obtain desired information about the population which covers all items without leaving any element of chance and it can be presumed that in such surveys all items are covered. Such surveys involve a great deal of time, money, and energy. The sample survey involves sample design which gives a definite plan for obtaining a sample from a given population. The steps involved in sample design are gathering information on the type of population, sampling unit, source list, sample size, parameters of interest, budgetary constraint, and sampling procedure. The first step in developing any sample design is to clearly define the population to be studied and questioned to obtain the desired information. The sampling unit may be a geographical one such as a state, district, village, etc., or a construction unit such as a house, flat, etc., or it may be a social unit such as a family, club, school, etc., or it may be an individual. The size of the sample is the number of samples to be selected from the population that has to be fixed and one must consider the question of the specific population parameters which are of interest. The characteristics of a good sample design are that it must result in a truly representative sample, results in a small sampling error, must be viable in the context of funds available and the results of the sample study can be applied, in general, for the population with a reasonable level of confidence. Stratified sampling is generally applied to obtain a representative sample of a population from which a sample is to be drawn and does not constitute a homogeneous group. Under stratified sampling, the population is divided into several sub-populations that are individually more homogeneous than the total population.

In the present PDS, a baseline survey has been carried out in the command area of Kotwal-Pillowa, Samrat Ashok Sagar, and Jajon irrigation projects. Three field officers were appointed under PDS and trained to conduct the survey. Farmers were interviewed through a questionnaire to study the impact of an irrigation project on the society, hydrology, health, and economy of the project area. The survey was conducted in command and non-command areas both. Though the population in the command area involves cultivators and farmers, however, they are not homogeneous in terms of their location and landholding in the command area. Their farm location can either be at head reach, middle reach or tail reaches which makes a huge difference in their irrigation water availability for their need. At each of these locations, farmers can again have heterogeneity in terms of their landholding size. Looking into the non-homogeneous nature of the population i.e. farmers in the command area, stratified sampling was carried out.

For the baseline sample survey, both approaches of random and non-random sampling have been applied under the stratified approach. The survey was conducted by selecting marginal and big farmers according to their landholding size in the head, middle, and tail reach area of the command area using a non-random method. The farmers within those groups were selected randomly. The survey format which has been got approved and vetted by NHP, Nodal Officer, NIH has been given in *Annexure -I.*

3.1.8 Sample survey design

- Survey method: Stratified Random sample method
- Classification of Groups :
  - Stratified selection of villages falling in the head, middle, or tail reach
  - Marginal and big farmers according to their land-holding size
  - Selection of farmers House Holds (HH) in the village: Random sampling method
- Sample Survey size for household surveyed
  - A survey was carried out at a 99% Confidence Level and a Confidence Interval of 5.

The confidence interval and confidence level are two important terms used in the sample survey. The confidence interval is also called the margin of error, it is a plus or minus figure reported in any survey results. For example, if you use a confidence interval of 5 and 60% percent of your sample picks an answer it means the entire relevant population between 55% (60-5) and 65% (60+5) would have picked that answer. The confidence interval indicates how sure you can be and is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means you can be 95% certain; the 99% confidence level means you can be 99% certain. Most of the surveys are conducted using a 95% confidence level hoever in the present baseline survey has been carried out at 99% confidence level and confidence interval of 5 to obtain a higher accuracy in the results.

Based on the above survey design total number of villages falling in each irrigation project, out of that number of villages selected for the survey, the total number of households (HH) in command, and the number of HH selected for the survey are given in Table 3.2. Apart from this random sampling was carried out to select HH for the survey in non-command areas also. The villages located just outside the command area were selected for the survey and numbers are included in the table below.

Table 3.2: Sampling survey design for baseline survey

Name of Irrigation project	Total Village in command	No. of village Selected	Total household (HH)	Number of HH Selected
Kotwal-Pillowa	384	218	49536	959
Samrat Ashok Sagar	108	72	16308	385
Jajon dam	13	12	1989	103

(Survey was started in October 2019 and has to be stopped in the last week of March 2020 due to COVID-19 Lockdown. It again started in August 2020 and was completed in January 2021.)

3.2 Objective 2: Performance Evaluation of Medium and Minor Irrigation Projects

For carrying out the performance evaluation, eight minor and medium irrigation projects located in the major tributaries of the Ganga and Yamuna basins such as Betwa, Chambal, Dhasan, Ken, Son, tone, and Sindh were identified and selected for the study as given in Table 3.3. The locations of all selected irrigation schemes for impact evaluation and performance evaluation in Madhya Pradesh are shown in Figure 3.2.

Table 3.3: Details of selected irrigation schemes in MP for Performance Evaluation

No	Scheme Name	Project Category	District	Tehsil	Gross Storage at FRL (MCM)	Lat. Long.	Sub Basin	Name of Local River	Catchment Area (Km^2)	Irrigation (Ha)
1	Doraha dam	Medium	Sehore	Sehore	15.54	23°23'57" 77°10'59"	Chambal	Utabli	49.21	2794
2	Naren Dam	Medium	Vidisha	Sironj	18.82	24°01'42" 77°45'37"	Betwa	Local Nallah	61.44	3450
3	Mala dam	Medium	Damoh	Jabera	16.76	23°19'59" 79°42'00"	Ken	Mala	161.3	2750
4	Rajendra Sagar dam	Medium	Tikamgar	Tikamgarh	16.99	24°38'39" 78°50'39"	Dhasan	Local Nallah	62.72	3036
5	Kaketo	Medium	Sivpuri	Pohari	79.3	25°53'50" 77°41'50"	Sindh	Parwati		3271
6	Lilgi dam	Minor	Satna	Maiher	2.20	24°15'43" 80°44'13"	Ton	Local River	11.20	1024
7	Umrar	Medium	Umaria	Bandhav garh		23°29'34" 80°49'32"	Son	Umrar Nallah		
8	Jajon	Minor	Vidisha	Basoda	7.43	23°55'00" 78°10'00"	Betwa	Local Nallah	17.35	1296

3.2.1 Performance evaluation of irrigation project….Why?

The Performance Evaluation analysis of the irrigation project is an introspection and continuous process similar to Benchmarking of an Irrigation system (INCID, 2002). The main features and objectives of the benchmarking process are given below.

Benchmarking of Irrigation System

- It is suggested by Indian National Committee on Irrigation and Drainage (INCID).
- It is the process of measuring one's performance and practices against the best competitor and it's a sequential exercise of learning from others' experiences.
- It helps to identify the best management practices.
- It provides opportunities for improvements through internal assessment and comparative measurements with the best practices.
- It helps for generating competition among various agencies or projects, units or distributaries, and or Water User Association (WUA).
- Central Water Commission (CWC) has given guidelines for benchmarking in 2002: Benchmarking of Irrigation Systems in India by INCID.

Performance Evaluation of Irrigation System

Perforance Evalaution aims to assess the general health of the system, assess progress against strategic goals, assess the impact of interventions, diagnose constraints of the system, to better understand determinants of performance, and compare performance with other systems or with the same system over time and to improve system operations. Why we need this exercise is explained pointwise below.

- India has achieved significant progress in creating several major, medium and minor irrigation projects since independence which has resulted in increasing agricultural production and rural livelihood in the country
- However, dissatisfaction with the performance of irrigation projects is widespread.
- Irrigation projects typically perform far below their potential due to inadequate management at the system and field level
- Hence it is necessary to carry out benchmarking or performance evaluation of irrigation projects before starting measures
- It will help to identify bottlenecks, constraints, managerial laps, and other grey areas in the system
- It will help to determine gaps between current practice and best practices

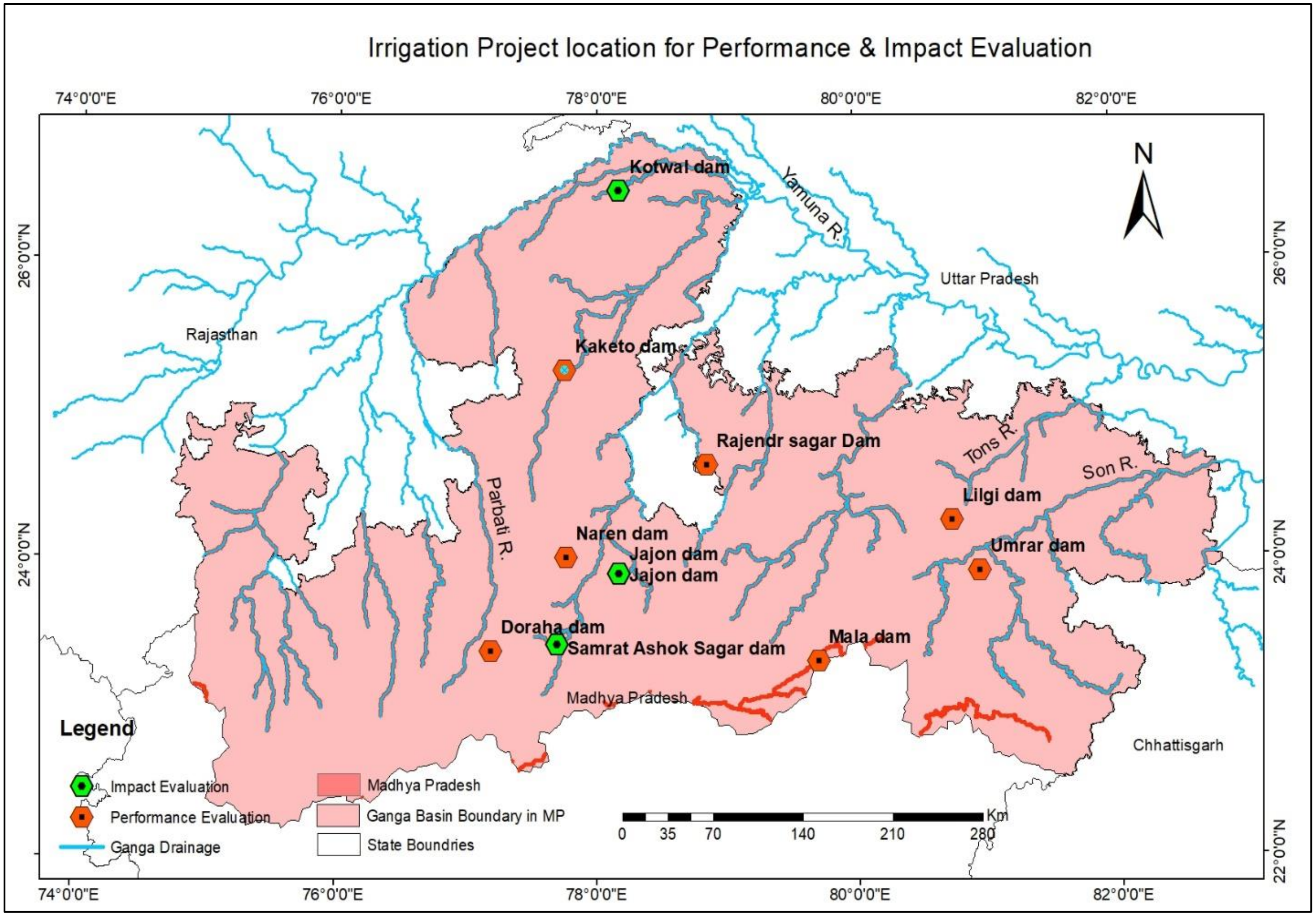


Figure 3.2: Locations of irrigation schemes selected for impact and performance evaluation in Madhya Pradesh

- It will help to formulate a strategy to improve the performance of the irrigation system to reap its full benefits on a long-term basis.
- The ultimate goal of the whole exercise is to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system.

3.2.2 Comparative indicators

In the present study performance of the irrigation scheme has been evaluated using nine comparative indicators, classified into four groups, namely, agricultural, economic, water-use, and physical performance suggested by International Water Management Institute (IWMI) (Molden *et al.*, 1998). The agricultural performance evaluation was carried out using four indicators related to the output of different which are Output per cropped area (Rs/ha), Output per unit command (Rs/ha), Output per unit irrigation supply (Rs/mm), and Output per unit water consumed (Rs/mm). The Standardized Gross Value of Production (*SGVP*) can be developed for cross-system comparisons regardless of where they are or what kinds of crops are grown in the command. SGVP is the output of the irrigated area in terms of the gross or net value of production measured at local or world prices. The crop water demand has been estimated with the help of Reference Evapotranspiration which was calculated using the Cropwat program (FAO, 1992) and crop coefficient value K_c for the main crops using FAO guidelines (Doorenbos and Kassam, 1986, Doorenbos and Pruitt, 1977).

The other five indicators used for further investigation and performance evaluation of the irrigation project are the Relative water supply indicator, Relative irrigation supply indicator, Water delivery capacity indicator (%), financial self-sufficiency indicator (%), and Gross return on investment indicator (%). All selected irrigation schemes have been analyzed based on the comparative indicator to assess progress against strategic goals, assess the general health of a system, diagnose constraints, compare the performance of a system with others or with the same system over time, and improve system operations. All comparative indicators are discussed in detail below.

3.2.3 Standardized Gross Value of Production (SGVP)

The Standardized Gross Value of Production (SGVP) was developed for cross-system comparison, as obviously there are differences in local prices at different locations throughout the world. To obtain SGVP, the equivalent yield is calculated based on the local prices of the crops grown, compared to the local price of the predominant, locally grown, internationally traded base crop. The second step is to value this equivalent production at world prices. Standardized Gross Value of Production (SGVP) is developed for cross-system comparisons regardless of where they are or what kinds of crops are grown in the command area. SGVP has been calculated as described in Molden et al. (1998).

$$SGVP=\left[\sum A_i Y_i \frac{P_i}{P_b}\right] P_{world}$$

Where,

A_i is the area cropped with crop *i*

Y_i is the yield of the crop *i*

P_i the local price of the crop *i*

P_b is the local price of the base crop

P_{world} is the value of the base crop traded at world prices

In the current study, the crop and command areas are specified in hactare, crop yield is expressed in tonnes per year, crop prices are expressed in rupees per tonne, and the SGVP value is calculated in rupees.

3.2.4 Comparison of the irrigation projects (Agriculture performance)

To compare the previous year's data of the irrigation projects, the four comparative indicators were used because these "external" indicators provide the basis for the comparison of irrigated agriculture performances across systems (Molden et al., 1998).

Output per unit cropped area (*Rs/ha*) $= \frac{\text{SGVP}}{\text{Irrigated cropped area}}$

Output per unit command area *(Rs/ha)* $= \frac{\text{SGVP}}{\text{Command area}}$

Output per unit water consumed *(Rs/m³)* $= \frac{\text{SGVP}}{\text{Volume of water consumed by ET}}$

Output per unit irrigation supply (*Rs/m³*) $= \frac{\text{SGVP}}{\text{Diverted irrigation supply}}$

Where:

Standardized Gross Value of Production (SGVP) is the output of the irrigated area in terms of the gross or net value of production measured at local or world prices.

Irrigated cropped area is the sum of the areas under crops during the time of analysis.

The command area is the nominal or designed area to be irrigated.

Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater.

Volume of water consumed by ET is the actual evapotranspiration of crops which is calculated using the following equation (Doorenbos and Kassam, 1986)

$$\text{ET}= K_c \times \text{E}T_o$$

Where, ET is the actual evapotranspiration and volume of water consumed, K_c is the crop coefficient which is dependent on crop type and crop stage and it has been modified for the study area using the FAO-56 manual. ET_o is the reference evapotranspiration estimated using the CROPWAT model program (FAO, 1992). The long-term climatological data required for the estimation of ET_o was collected from IMD Pune.

3.2.5 Evaluation of the individual irrigation project (Water use performance)

The three indicators in the minimum set for comparative performance indicators are Relative Water Supply (RWS), Relative Irrigation supply (RIS), and Water Delivery Capacity (WDC). They are meant to characterize the individual system concerning water supply and finances (Molden et al, 1998). Relative water supply and relative irrigation supply are used as the basic water supply indicator.

Is there enough water available to meet crop water demand: The relative water supply relates the water made available for crops, including surface irrigation, groundwater pumped, and rainfall to the amount needed by the crops. The irrigation water losses due to seepage and deep percolation through the soil are to be considered while calculating crop water demand. This indicator provides information about the relative abundance or scarcity of water.

$$\text{Relative Water Supply} = \frac{\text{Total water supply}}{\text{Crop water demand}}$$

Are crops getting enough water: The relative irrigation supply indicates how canal irrigation supply and demand have matched a RWS value over 1 would suggest too much water is being supplied, possibly causing waterlogging and negatively impacting yields; a value less than 1 indicates that crops aren't getting enough water.

$$\text{Relative irrigation supply}=\frac{\text{Irrigation Supply}}{\text{Irrigation Demand}}$$

Where:

The total water supply is the surface diversions plus net groundwater plus rainfall. Crop water demand is the potential crop ET or the ET under well-watered conditions. Irrigation supply is the only surface diversion and net groundwater draft for irrigation. Irrigation demand is the Crop ET less Effective Rainfall (ER). The effective rainfall represents part of the total rainfall which retains in the root zone for the use of plants after runoff, evaporation deep percolation. In the present study, the effective rainfall has been calculated as per the equation suggested by FAO as given below.

$$ER = 0.6*P-10, \text{ if } P<75 \text{ mm/month}$$

$$ER = 0.8*P-25, \text{ if } P>75 \text{ mm/month}$$

Both RWS and RIS relate supply to demand and give some indication as to the condition of water abundance or scarcity, and how tightly supply and demand are matched. If the irrigation system design constrains agricultural production then the water delivery capacity can suggest changes in irrigation infrastructure or cropping patterns are needed to maximize cropping intensity.

The water delivery capacity (WDC) is given below:

$$\text{Water delivers capacity (\%)} = \frac{\text{canal capacity to deliver water at system head}}{\text{peak consumptive demand}}$$

Where:

The capacity to deliver water at the system head is the present discharge capacity of the canal at the system head, and

Peak consumptive demand is the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system.

WDC is meant to indicate the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands.

3.2.6 Economic indicators

$$\text{Gross return on investment (\%)} = \frac{\text{SGVP}}{\text{Cost of Irrigation Infrastructure}}$$

$$\text{Financial self Sufficiency} = \frac{\text{Revenue from Irrigation}}{\text{Total O\&}M\ Expenditure}$$

- The cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the SGVP
- Revenue from irrigation, is the revenue generated, either from fees, or other locally generated income, and
- Total O&M expenditures are the amount expended locally through O&M plus outside subsidies from the government.

3.3 Objective 3: Development of Web-Based Dynamic Application for Performance Evaluation of Irrigation Projects

One of the key components of the PDS is the development of a web-based dynamic application for evaluating the performance of irrigation projects, which involves mathematical calculations at both the front and back end. The website will be user-friendly and will compute multiple comparative indicators divided into four categories: agricultural, economic, water-use, and physical performance. The irrigation project in-charge must fill out the required input information for the irrigation project and command areas online. The end result will be an online evaluation of all indicators, as well as reports in the form of tables and graphs. Higher-level administrators can access the report and make policy decisions.

The web application will aid in assessing the impact and weighing the benefits of the irrigation project's rehabilitation, restructuring, renovation work, etc. It will also aid in determining the effects of irrigation project operation and management policies on project performance. With the use of project-related data and information as input, the web application will allow irrigation project managers in the region to evaluate the performance of projects under their control. It will assist the project authority in comparing the project's performance with previous years or with other projects in the region and developing strategies for further system improvement. This website can be linked to India-WRIS, the NHP Web portal, or the MPWRD portal.

3.4 Objective 4: Recommendations, Dissemination of Knowledge and Findings through Training and Workshops

Based on the results obtained in the case of eight selected irrigation projects, recommendations are given for the reduction in the severity of negative impacts and enhancement of positive impacts to improve the performance of irrigation projects. Two Stakeholders Workshops were organized for field engineers and irrigation project officers at Bhopal jointly by the MP Water Resources Department and the National Institute of Hydrology, Bhopal. The first workshop was organized in April 2019 to assess the problem and formulate strategies to achieve the objectives of the study. The second workshop was organized in March 2021 to discuss the findings and application of the developed techniques with field engineers and officers of MPWRD and Line departments of the State and Central Government in MP. Information was disseminated to stakeholders in the form of presentations, leaflets, and fliers.

3.5 Data Collection

The study involves a collection of both primary and secondary data from field and Government departments respectively. Primary data was collected through field surveys and participator approach discussions held with beneficiary farmers, and members of the Water User Association which included types of crops, crop production, crop prices, details of borewells used for irrigation, etc. in the individual farms, and the command area.

Secondary data such as long-term rainfall data, meteorological data, surface data, groundwater data, dam details, crop type, area under different crops, total agricultural yields, prices of irrigated crops, area irrigated per crop per season or per year, crop types, production cost per season or year, and the cropping pattern were required for the analysis. These data were collected from India Meteorological Department, Pune and State Data Centre, MP Water Resources Department, Bhopal, Divisional and circle offices of MP Water Resources Department, District level offices of Agricultural Department, Statistical Department, and Revenue Department. Details of data collected, data period, and sources of data are given in Table 3.4.

Table 3.4: Details of data collected for the study

Type of Data	**Name of Station/Dam**	**Period**	**Source**
Rainfall Data	Bhopal Gwalior Tikamgarh Sehore Jabera Umaria Satna Basoda Sironj Bhind 52 District places	1960 to 2017 1960 to 2017 1960 to 2017 1960 to 2017 1961 to 2017 1960 to 2017 1960 to 2017 1978 to 2018 1978 to 2017 1960 to 2017 1980 to 2018	India Meteorological Department, Pune and State Data Centre, MP Water Resources Department, Bhopal
Surface Data Including Temperature, wind speed, Relative humidity, etc.	Gwalior Sagar Bhopal Jabalpur	1996 to 2016 2004 to 2016 2010 to 2016 1969 to 2016	State Data Centre, MP Water Resources Department, Bhopal
Ground Water level data	Bhind District Vidisha District Bhopal district	1985 to 2019 1985 to 2019 1985 to 2019	Ground Water Survey, State Data Centre, MP Water Resources Department, Bhopal
Dam and command area information such as DPR, Salient Features, Reservoir Capacity Table, Water levels of reservoir, Total water supply, Irrigation supply, Groundwater draft, Diverted irrigation supply, Canal capacity Revenue from irrigation Total O&M expenditure Crop area, crop yield, price of crop, Command area, Irrigated cropped area	Kaketo dam Rajendra Sagar dam Doraha dam Mala tank Umara dam Lilgee dam Jajon dam Naren dam Kotwal dam Samrat Ashok Sagar dam	2013 to 2019 2013 to 2019 2013 to 2019 2013 to 2019 2013 to 2019 2013 to 2019 2013 to 2019 2013 to 2020 2013 to 2020 2013 to 2020	Divisional and circle offices of MP Water Resources Department, Superintending of Land Record, District Statistic Office, District Agriculture office, etc.
Primary Data Generated	Jajon dam Kotwal dam Samrat Ashok Sagar dam		Farmers baseline survey

CHAPTER – IV

RESULTS AND DISCUSSION

4.1 Data Collection and Analysis

The required primary data was collected through field surveys and discussions held with beneficiary farmers, and members of the Water User Association which included types of crops, crop production, crop prices, details of borewells used for irrigation, etc. in the command area. The long-term secondary data like rainfall and groundwater data of the concerned districts in which the dams are located have been collected from State Data Centre and Ground Water Survey, WRDMP, Bhopal. Long-term rainfall data of 52 district places has been collected from IMD Pune and WRD Bhopal. The long-term rainfall data is required to develop a dynamic website for the performance evaluation of irrigation projects. Rainfall data from stations near all dam sites selected for the study have been collected and rainfall analysis has been carried out. Detail data of dam and command area, crop type, cropping area, etc. of Kotwal-Pilowa, Rajendra Prasad dam, Samrat Ashok Sagar dam, Doraha dam, Jajon dam, Mala dam, Naren dam have been collected from WRD Divisional offices Damoh, Tikamgarh, Vidisha, Bhind, Sihore, etc.

4.2 Field Visits

Field visits to the irrigation project were important to collect primary data, understand the irrigation mechanism, operational policies, physical status, peculiarities, and associated problems, have one-to-one discussions with field officers and executives, and collect related information. As the required information is many times not available with the line departments, it can be obtained through discussion with the concerned project in-charge, members of the Water User Association, and beneficiary farmers in the command area. Therefore extensive field visits were conducted to all minor and medium irrigation project sites which are selected for impact evaluation and performance evaluation studies. Photographs of field visits are given in Figures 4.1a and 4.1b. It includes Kotwal-Pillowa dam, Bhind district, Rajendra Prasad Sagar, Tikamgarh district, Samrat Ashok Sagar dam, Jajon, and Naren dam in Vidisha district, Doraha dam in Sihore district and Mala dam in Damoh district, Lilgi dam in Satna district and Umrar dam in Umaria district. The information on dam details, salient features, command and catchment details, crops grown, crop area, dam level, water release data, etc. have also been collected.

Figure 4.1a: Field visit to Umara dam in Umaria district

Figure 4.1b: Field visit to Kaketo dam in Gwalior district

4.3 Rainfall Analysis

Long-term daily rainfall data of all selected dam sites or the nearest blocks were obtained from the Water Resources Department Govt of MP and used for the analysis. The list of nearest rain gauge stations to the selected irrigation project is shown in Table 4.1. The daily rainfall data from the period from 1961 to 2017 were analyzed to estimate the long-term average of monthly, annual, and seasonal rainfall. The standard deviation of the rainfall time series was evaluated to understand rainfall variation in the study area. The statistical analysis of the rainfall data of all dams have been shown in Table 4.2 and Table 4.3.

Table 4.1: List of nearest rain gauge stations to the selected irrigation project

S No	Name of Irrigation Project	Name of nearest Rain-gauge station	District
1	Doraha Dam	Sehore	Sehore
2	Kaketo Dam	Gwalior	Gwalior
3	Kotwal-Pillowa Dam	Bhind	Bhind
4	Lilgi dam	Maihar	Satna
5	Mala tank	Jabera	Damoh
6	Rajendra Sagar Dam	Tikamgarh	Tikamgarh
7	Naren dam	Sironj	Vidisha
8	Jajone dam	Basoda	Vidisha
9	Umrar Dam	Umaria	Umaria
10	Samrat Ashok Sagar	Vidisha	Vidisha

Table 4.2: Long-term average of monthly, annual, seasonal rainfall at dam sites (Data 1961-2017)

Dam	Average rainfall (mm)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann-ual	Seas-onal
Doraha	8.6	9.8	3.5	1.7	8.9	129.7	346.5	295.2	168.9	25.6	10.8	6.7	862.8	819.8
Kaketo	5.8	9.4	3.0	2.1	2.8	92.0	259.5	251.5	142.4	23.7	5.7	7.6	759.0	799.4
Kotwal	8.0	11.5	4.2	2.9	6.7	65.7	206.8	220.9	129.2	24.7	4.9	5.4	692.4	645.9
Lilgi	8.3	10.7	3.9	2.3	7.8	97.7	276.6	258.0	149.1	25.1	7.8	6.1	1008.3	946.1
Mala	8.2	11.1	4.0	2.6	7.2	81.7	241.7	239.4	139.1	24.9	6.4	5.7	1250.1	1193.4
Rajendra Prasad	11.4	12.5	5.6	1.8	6.9	111.6	299.6	320.9	160.9	29.4	9.1	6.9	976.1	921.9
Naren	10.1	8.4	5.2	3.5	2.5	147.3	328.9	367.6	151.1	29.5	11.4	9.9	1075.5	1024.5
Jajone	10.1	8.4	5.2	3.5	2.5	147.3	328.9	367.6	151.1	29.5	11.4	9.9	1075.5	1024.5
Umrar	10.6	9.7	5.3	2.9	3.9	135.4	319.1	351.8	154.4	29.5	10.6	8.9	1036.0	966.7
SAS	10.3	9.0	5.2	3.2	3.2	141.7	324.0	359.7	152.7	29.5	10.9	9.5	1044.9	992.2

The dams selected for the study are spread evenly and located in all major river sub-basins in Madhya Pradesh. From the analysis of Table 4.2, showing the long-term average of monthly, seasonal and annual rainfall it was observed that the rainfall occurs in all selected stations in the study area mainly due to the southwest monsoon experiencing rainfall from June to October. July and August are found to be the principal rainy months contributing major quantities of rainfall. The rainfall during pre-monsoon and post-monsoon seasons has also seen evident at all dam locations. The typical monthly rainfall at Jabera rain gauge station located near Mala tank in Damoh district is shown in Figure 4.2. Similar monthly rainfall distribution can be seen at all dam locations.

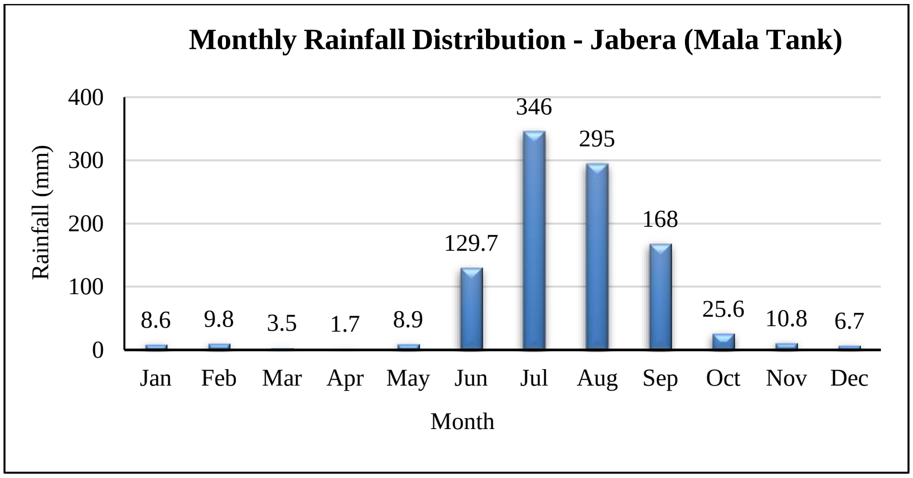


Figure 4.2: Monthly rainfall at Jabera located near Mala tank in Damoh district

These dams are located at a long distance from each other in different tributaries of the Ganga and Yamuna sub-basins and different agroclimatic zones in Madhya Pradesh. All stations are showing very high spatial variation for annual, seasonal, and monthly rainfall. The lowest annual rainfall of 645.9 mm was seen at Kotwal in Bhind district located in the northern part of MP and the highest at 1250 mm at Mala dam in Damoh district located in the central-eastern part of the Bundelkhand region of MP indicating a range of very high spatial variation. Dams located in the eastern part of the state such as Lilgi, Mala, and Umrar receive a good amount of rainfall as compared to dams located in the central part of the state such as Kaketo, Doraha, and Kotwal.

Table 4.3: Standard Deviation rainfall at dam sites (Data 1961-2017)

Dam	**Average rainfall (mm)**													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Ann-ual**	**Seas-onal**
Doraha	18	18	7	3	21	119	132	187	113	39	28	19	320	316
Kaketo	18	17	9	6	8	94	123	117	129	37	17	28	212	212
Kotwal	15	20	10	6	12	77	121	116	92	45	15	13	255	269
Lilgi	19	26	14	9	12	105	180	150	142	57	21	15	356	365
Mala	27	39	17	13	9	136	184	169	166	37	11	11	475	448
Rajendra Prasad	19	22	14	4	13	148	142	157	155	64	28	20	350	342
Naren	21	19	12	9	6	126	177	138	117	47	31	26	293	289
Jajone	21	19	12	9	6	126	177	138	117	47	31	26	293	289
Umrar	34	28	24	8	11	111	129	150	137	43	21	18	190	180
SAS	16	14	5	5	20	106	178	175	111	48	33	16	293	289

Table 4.3 shows the standard deviation indicating temporal variation in the long-term rainfall time series at different dam sites selected for the study. The highest variation in seasonal and annual rainfall of 475 and 448 mm has been seen at the Mala dam in the Damoh district. The rainfall variation has been seen on the higher side at Lilgi, Nagda, and Doraha dams located in Satna, Tikamgarh, and Sihore districts respectively ranging from 475 to 350 mm. However, at other dam locations, it seems to be at a moderate range from 255 to 293 mm. From the analysis of monthly rainfall data, rainfall variation has also been found in the same pattern.

4.3.1 Drought analysis at all dam locations

Droughts may be defined as a prolonged period or a season, a year or more of deficient rainfall relative to the statistical multi-year average for a region. It is generally defined as a water shortage caused by an imbalance between water supply and demand. Drought is a normal, temporary, and recurrent feature of climate and may occur worldwide. Droughts are categorized as meteorological, hydrological, agricultural, and socioeconomic droughts. Recurrent droughts are causing severe loss and causing adverse impacts on the surface as well as groundwater resources, agricultural production, and rural livelihood. The drought can significantly affect reservoir operation policy and irrigation planning in command areas. Even after having adequate irrigation project planning, irrigation projects may not perform to its expectation during drought years due to reduced water availability.

As per the classification suggested by Indian Meteorological Department (IMD), an area or a region can be considered drought affected if it receives annual or seasonal rainfall less than 75 % of its normal value (Appa Rao 1986). The annual rainfall departure can be computed as the deviation of the rainfall from the mean divided by the long-term mean rainfall of that station. The year having annual or seasonal rainfall deficiency of more than or equal to 25 % is considered a drought year or season. IMD has further classified droughts into broad categories such as moderate drought when the deficiency of rainfall is between 25 and 50% of the normal rainfall, severe drought when the deficiency of rainfall is between 50 to 75% of the normal rainfall, and extreme drought when deficiency exceeds 75%.

The probability distribution of annual or seasonal rainfall can be used to predict the relative frequency of occurrence of annual or seasonal rainfall with reasonable accuracy. The estimated probability of an event is taken as the relative frequency of occurrence of the event when the numbers of observations are too large. The probability distribution analysis can be used to find out the drought proneness of the selected. If the probability of occurrence of 75% of mean annual rainfall is less than 80%, then the area can be considered drought-prone (CWC, 1982).

To understand the drought scenario, frequency, return period and drought proneness of all the dam sites, annual rainfall departure, and probability distribution analysis has been carried out using 55 years of rainfall data from 1961 to 2017 of the nearest rain gauge station to these dams or the blocks in which these dams are located. The departure analysis and probability distribution curves for the rainfall data of the Umaria rain gauge station located near Umrar dam are shown in Figures 4.3 and 4.4. The results of drought frequency, return period and drought proneness of all the dam sites are shown in Table 4.4.

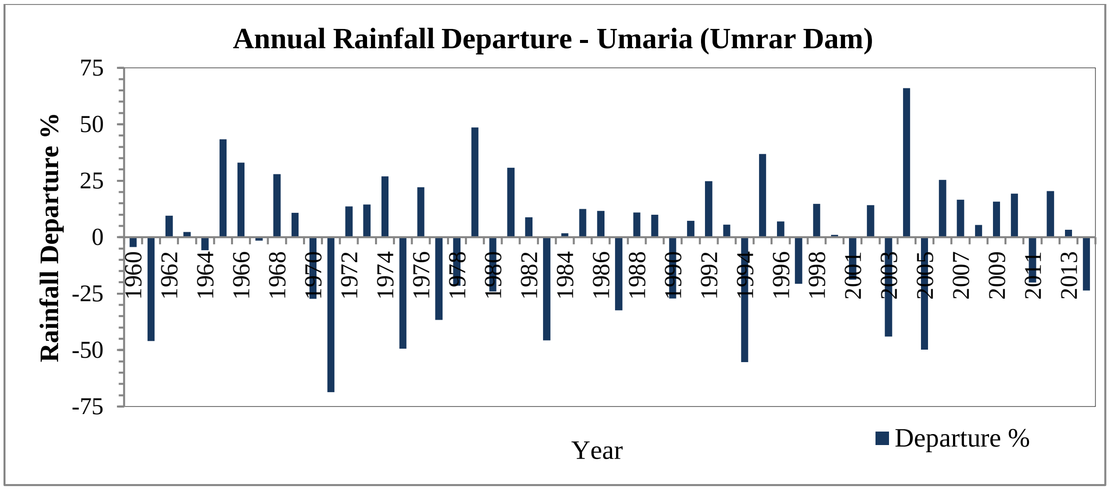


Figure 4.3: Annual Rainfall Departure - Umaria (Umrar Dam)

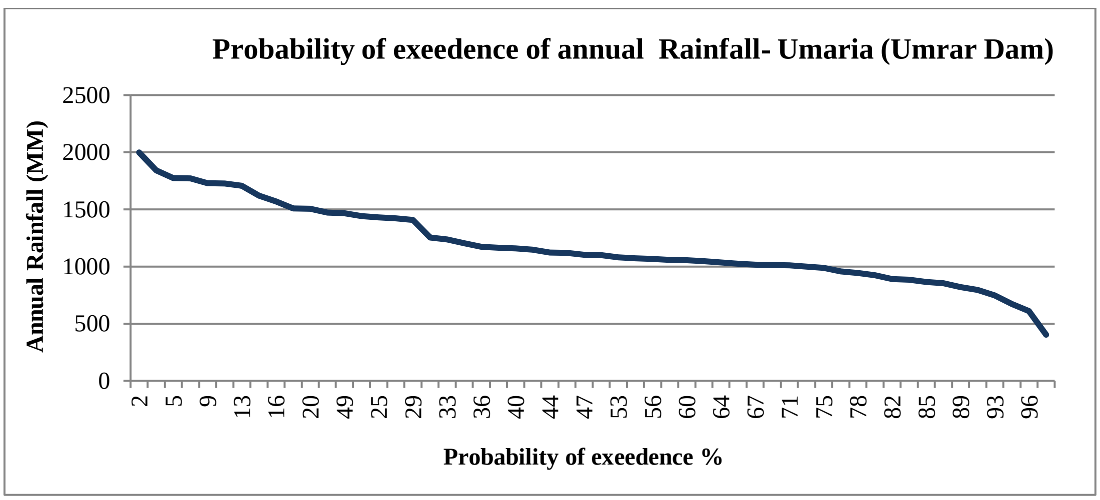


Figure 4.4: Probability of exceedance of annual rainfall - Umaria (Umrar Dam)

From Table 4.4 it can be seen that out of 9 dams 5 dams Kotwal, Mala, Kaketo, Doraha, and Naren are indicating a water scare situation due to drought. The analysis indicated one drought year after every 4 to 5 years in those areas and all dams are located in drought-prone areas. The frequent and severe droughts may affect the performance of these irrigation projects and pose challenges to formulating appropriate reservoir policy and command area management strategy. In the case of the other 4 dams Rajendra Sagar, Umrar, Jajon, and SAS situation has been seen better as the drought frequency is a little low indicating drought one year after 5 to 6 years and they are not under drought-prone conditions.

Table 4.4: Drought frequency analysis and probability distribution for annual rainfall (55 years of rainfall data from 1961 to 2017)

S No	Name of the Dam	RG Station	District	Drought Return period (years)	Prob of exceedance of rainfall equivalent to 75% of normal annual rainfall (%)	Status
1	Kotwal	Bhind	Bhind	3	62	Drought Prone
2	Mala	Jabera	Damoh	5	71	Drought Prone
3	Kaketo	Gwalior	Gwalior	4	74	Drought Prone
4	Doraha	Sihore	Sihore	5	72	Drought Prone
5	Rajendra Sagar	Tikamgarh	Tikamgarh	6	81	--
6	Umrar	Umria	Umria	6	82	--
7	Jajon	Basoda	Vidisha	6	82	--
8	Naren	Sironj	Vidisha	4	74	Drought Prone
9	Samrat Ashok Sagar	Vidisha	Vidisha	5	82	--

4.4 Impact Evaluation Analysis of Irrigation Project

The impacts of irrigation projects and rabi irrigation on hydrology, agricultural growth, socioeconomics, and health were assessed for three irrigation projects in Madhya Pradesh using primary data collected through a baseline survey and secondary data collected from line departments. This section goes over the results of the analysis in detail.

4.4.1 Impact of an irrigation project on hydrology (Groundwater analysis)

The impact assessment of rabi irrigation on the hydrology of the region has been carried out by understanding and comparing groundwater level scenarios in command and non-command areas in Samrat Ashok Sagar dam (SAS). The comparison has also been carried out for groundwater scenarios in the head reach, middle reach, and tail reach areas of the command. It has always been interesting to analyze and study the impact of irrigation on groundwater availability in different reaches of the command. This is indicative of the use of groundwater in conjunction with surface irrigation water in different reaches of the command and gives an idea of abundance or deficient irrigation supply causing groundwater depletion in that area. For this analysis, the long-term groundwater level data collected from GWS, MPWRD, Bhopal of observation wells falling in command and nearby non-command areas of SAS was used. Groundwater level data for the period 35 years from 1984 to 2020 of 13 observation wells were analyzed, out of which 9 were falling in command and 4 were falling in the non-command area of SAS. The Post and pre-monsoon groundwater levels and average groundwater levels of observation wells selected in the head, middle, and tail reach in the Command area and non-command area are given in Table 4.5. The groundwater scenario has been summarized in Table 4.6.

Table 4.5: Post and pre-monsoon groundwater levels of the SAS command and non-command area

Sl No	Location in Command Area	Name of village	Location		Average Post-monsoon Depth to water level (m)	Average Pre-monsoon Depth to Water Level (m)	Average GW Fluctuation (m) - Post to Pre-monsoon
			Long E	Lat N			
1	**Head Reach**	Khamkheda	77.64	23.59	0.5	2.5	2.0
2		Bamankheda	77.65	23.50	2.3	5.0	2.7
3		Billori	77.69	23.58	4.3	8.3	4.9
			Average		***2.4***	***5.3***	***3.2***
4	**Middle Reach**	Imliya	77.71	23.55	2.3	6.3	4.1
5		Karaia	77.77	23.60	4.0	7.6	3.6
6		Bamoriya	77.76	23.62	2.5	5.2	2.7
			Average		***2.9***	***6.4***	***3.5***
7	**Tail Raech**	Vidisha	77.83	23.53	5.0	10.2	5.2
8		Rangi	77.78	23.51	6.2	11.0	4.8
9		Hinotia	77.78	23.71	5.2	11.8	6.7
			Average		***5.5***	***11.0***	***5.6***
10	**Non-Command**	Satpada	77.68	23.69	6.4	9.4	2.9
11		Nateran	77.78	23.77	4.2	7.4	3.2
12		Gulabganj	77.59	24.11	5.3	10.8	5.5
13		Santapur	77.92	23.72	3.6	9.2	5.7
			Average		***4.9***	***9.2***	***4.3***

Table 4.6: Groundwater scenario in command and non-command area of SAS

Groundwater level under different Situation	Depth to Groundwater (m)			
	Command area			Non-Command
	Head Reach	Middle Reach	Tail Reach	
Average Post-Monsoon level	2.4	2.9	5.5	4.9
Average Pre-monsoon level	5.3	6.4	11.0	9.2
Average Fluctuation: Post to pre-monsoon	3.2	3.5	5.6	4.3
Maximum level Post-Monsoon	6.6	6.2	8.0	8.2
Minimum level Post-Monsoon	0.2	0.8	1.9	1.3
Maximum level Pre-Monsoon	9.2	9.2	14.0	12.5
Minimum level Pre-Monsoon	0.8	4.0	8.4	4.8

The post-monsoon, pre-monsoon groundwater level analysis and post-monsoon to pre-monsoon fluctuation in SAS command and non-command have been worked out using GIS and shown in Figures 4.5, 4.6 and 4.7 respectively. The comparison of average GWL variation in the head, middle, and tail reach of SAS Command and the non-command area has been shown in Figure 4.8.

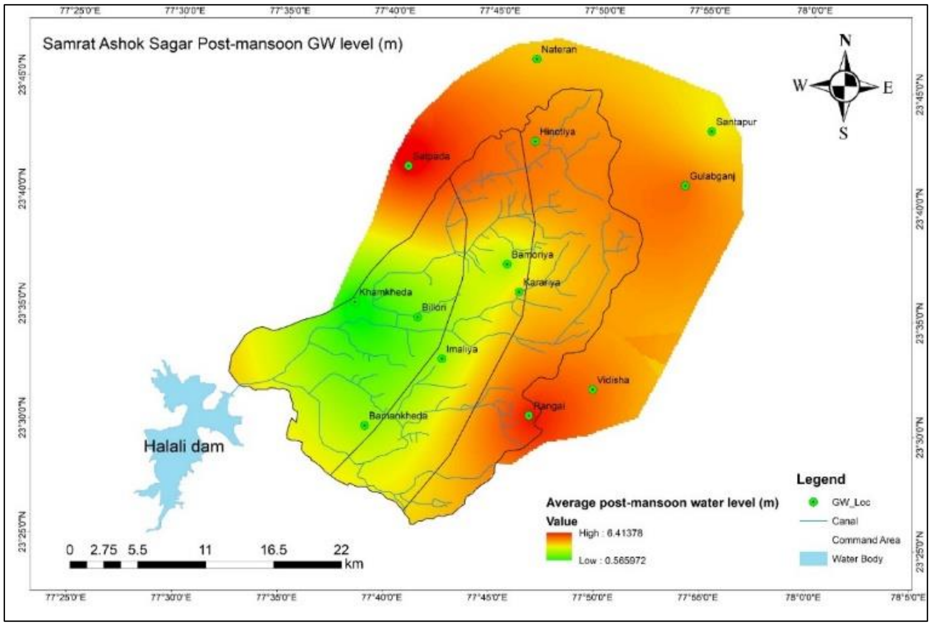


Figure 4.5: Post-monsoon groundwater level scenario in SAS

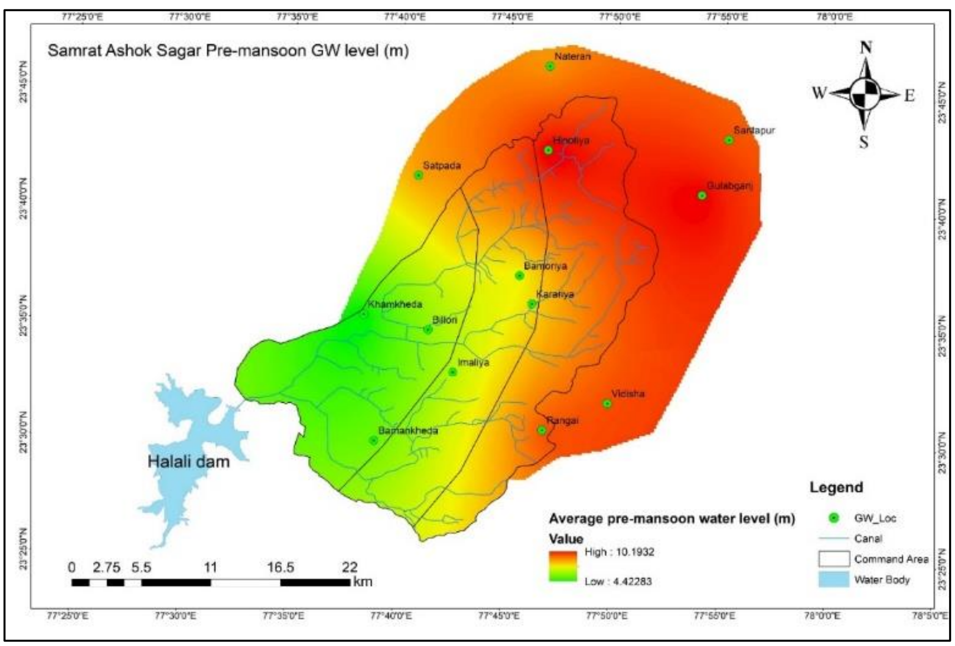


Figure 4.6: Pre-monsoon groundwater level scenario in SAS

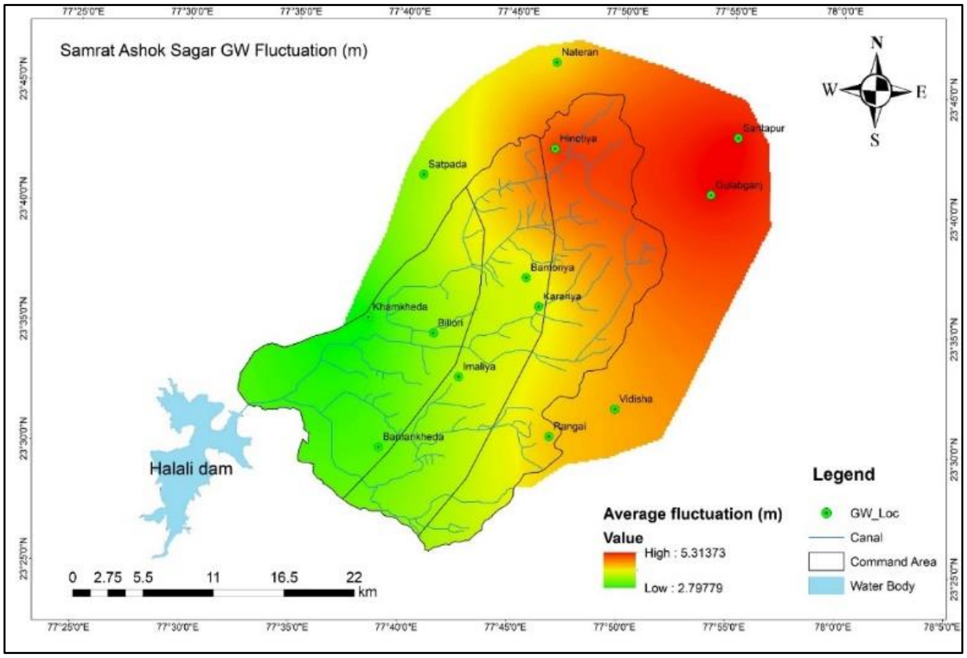


Figure 4.7: GW level fluctuation in SAS command and non-command

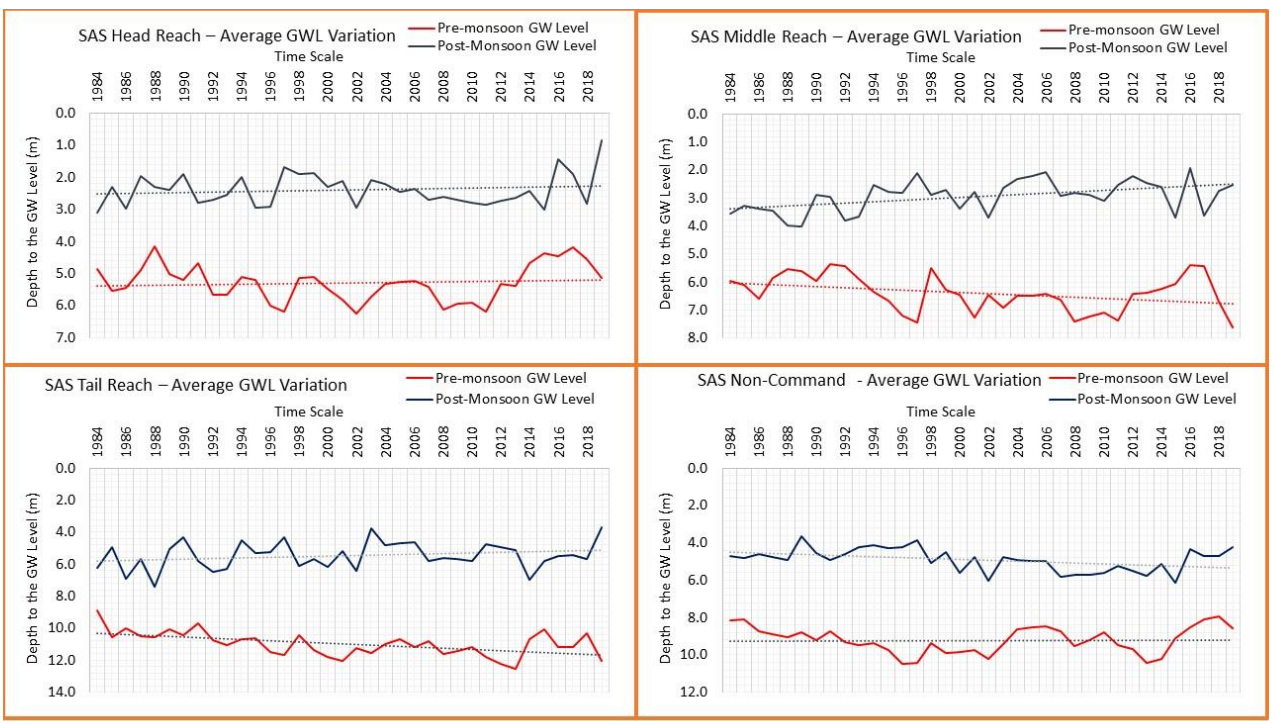


Figure 4.8: Comparison of average GWL variation in Head, Middle, Tail Reach of SAS Command and non-command area

The average groundwater levels (GWL) of the head, middle, and tail reach areas in command and the non-command areas of SAS are given in Tables 4.5 and 4.6. The analysis was carried out to study the impacts of rabi irrigation on groundwater levels using GWL level data of 13 observation wells for the period of 35 years from 1984 to 2020. The analysis indicated the quite usual GW scenario, which can be seen very often in other irrigation projects also. Groundwater situation has been found better in head and middle reach as compared to the tail reach of the SAS command area.

The GWL analysis was carried out to understand how GWLs are fluctuating from post to pre-monsoon season in response to the Rabi irrigation supply from the canal and GW withdrawal in the command and non-command of the SAS irrigation project. The average GWL depletion in the head reach of the command area was observed as non-significant, which is found to decline from 2.4 m in post-monsoon to 5.4 m deep in the pre-monsoon season. The average GWL fluctuation from post to pre-monsoon was observed at 3.2 m in Head reach. The groundwater situation has been found better in the head reach area and causing waterlogging in a few areas, the reason behind this is the sample irrigation supply during Rabi season and no use of groundwater. The average GWL depletion in the middle reach of the command area was observed to moderate, which is found to decline from 2.9 m in post-monsoon to 6.4 m deep in the pre-monsoon season. The average GWL fluctuation from post to pre-monsoon was observed at 3.5 m in middle reach. The groundwater situation has been found better in the head reach areas, the reason behind this is sufficient irrigation supply during the Rabi season and limited use of groundwater.

The groundwater situation has not been seen as good in the tail reach of command. The average GWL depletion in the tail reach of the command area was observed very high, which is found to decline from 5.5 m in post-monsoon to 11.0 m deep in pre-monsoon season. The average GWL fluctuation from post to pre-monsoon was observed at 5.6 m in tail reach. The GWL in tail reach was observed at a very deep level and has seen high depletion from post to pre-monsoon season, the reason behind this is insufficient irrigation supply from the canals and high use of groundwater for irrigation.

The non-command area also has a similar problem of high groundwater depletion from post to pre-monsoon as the agriculture in this area is mainly dependent on groundwater. The GWL was found to decline from 4.9 m in post-monsoon to 9.2 m deep in pre-monsoon season. The average GWL fluctuation from post to pre-monsoon was observed at 4.3 m in middle reach. These scenarios can also be seen and analyzed in Figures 4.5, 4.6 and 4.7 showing a comparison of post-monsoon, pre-monsoon season GWL and GW fluctuation in the head, middle, tail, and non-command areas. Figure 4.5 shows very high GWL variation in the tail and non-command area as compared to the head and middle reach of the SAS command.

4.5 Farmers Baseline Sample Survey for Impact Analysis

For impact evaluation of the irrigation project, a baseline survey has been conducted in the command area of Kotwal-Pillowa dam, Jajon dam, and Samrat Ashok Sagar dam are shown in Figures 4.9a, 4.9b and 4.9c respectively. The survey form consists of a set of questionnaires to obtain information on hydrology, agriculture, socio-economy, and health aspects in the command area.

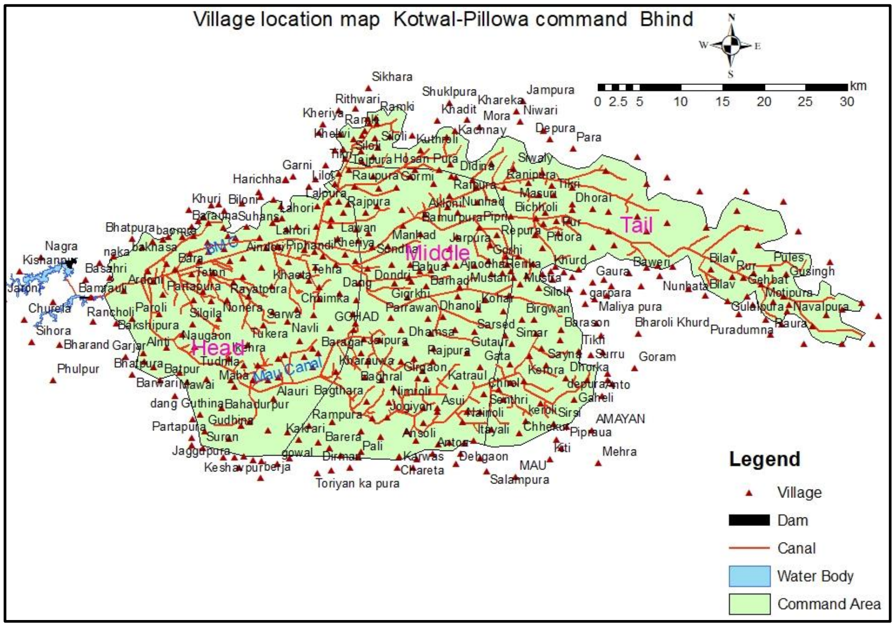


Figure 4.9a: Kotwal dam command and villages command area

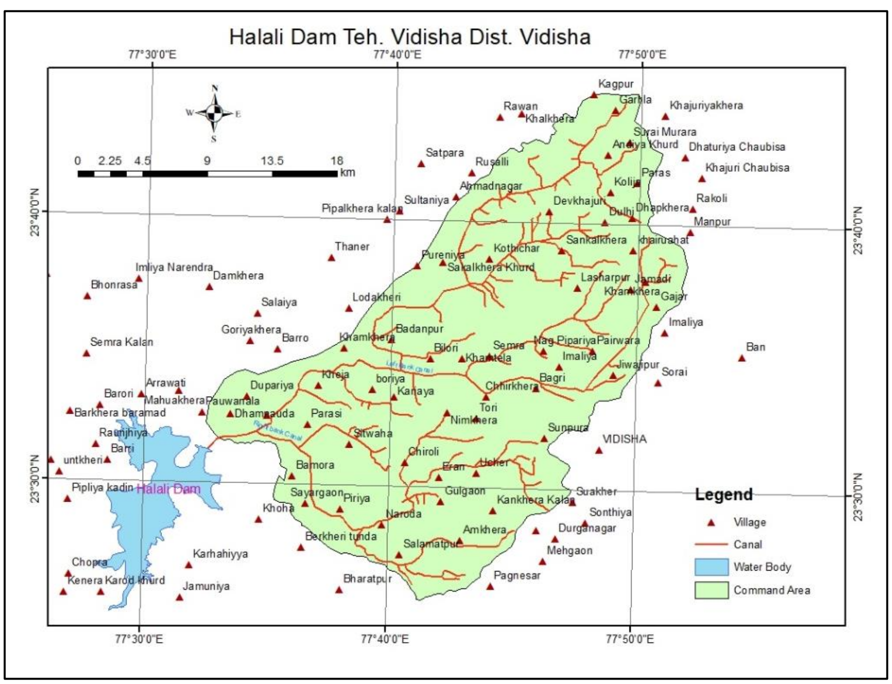


Figure 4.9b: Samrat Ashok Sagar (Halali) dam command and villages command area

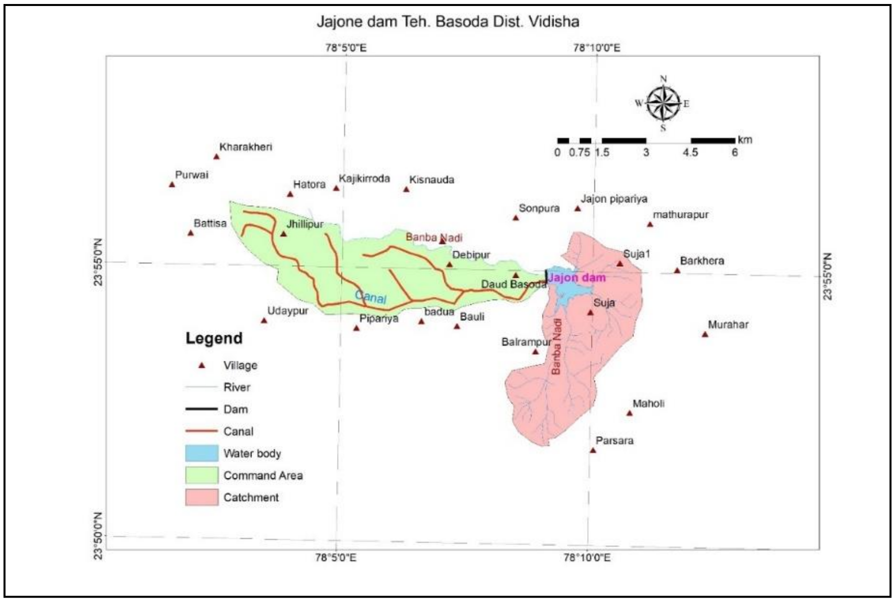


Figure 4.9c: Jajon dam command and villages command area

The sample survey for the collection of primary data was designed scientifically to derive reliable information from this exercise. The sample survey was designed by selecting the appropriate method of sampling, selecting villages, and households for the survey, the size of the population and samples, its confidence level, and the confidence interval. The survey involved both methods of stratified random and non-random methods. The survey was conducted by selecting marginal and big farmers according to their landholding size in the head, middle, and tail reach area of the command using a non-random method. The farmers within those groups were then selected randomly. The survey is also being conducted in non-command areas nearby. The survey was carried out at a 99% Confidence level and a Confidence Interval of 5 to obtain more accurate results. Thus Kotwal-Pillowa dam command and non-command area have 384 villages having nearly 49536 House Holds (HH) and out of that 218 villages were selected for the survey and 959 houses were surveyed. The Samrat Ashok Sagar command has 108 villages having nearly 16308 (HH), out of that 385 HH were surveyed in selected 72 villages. The Jajon dam has a comparatively small command area covering 13 villages with nearly 1989 HH and a survey was conducted in 103 HH of 12 selected villages. The survey was started in October 2019 and has to be stopped in the last week of March 2020 due to COVID-19 Lockdown. It was again started in August 2020 and completed in January 2021. The survey format thus prepared was found proper and adequate to derive desired information. The data collected from the field survey was computerized and analyzed. The photographs of field survey Field Assistants are shown below in Figures 4.10a and 4.10b.

Figure 4.10a: A field survey in Sapaua village in Samrat Ashok Sagar command area

Figure 4.10b: A field survey in Rithora village in Kotwal command area

The baseline survey was conducted in Jajon, Samarat Ashok Sagar, and Kotwal-Pillowa irrigation projects in Madhya Pradesh. The primary data collected from the baseline survey were analyzed and are discussed in detail in the following section to understand the impact of Rabi irrigation on society, economy, agriculture, and health aspects in command areas.

4.5.1 Land holding of farmers

The information on the land holdings distribution of farmers within the command area is very important to analyze the impacts of these irrigation schemes on socio-economic and agricultural aspects. The farmers having land holding less than 2 ha are small and marginal farmers. Farmers having land holding between 2 to 10 ha are medium farmers and farmers having land holding more than 10 ha are large farmers.

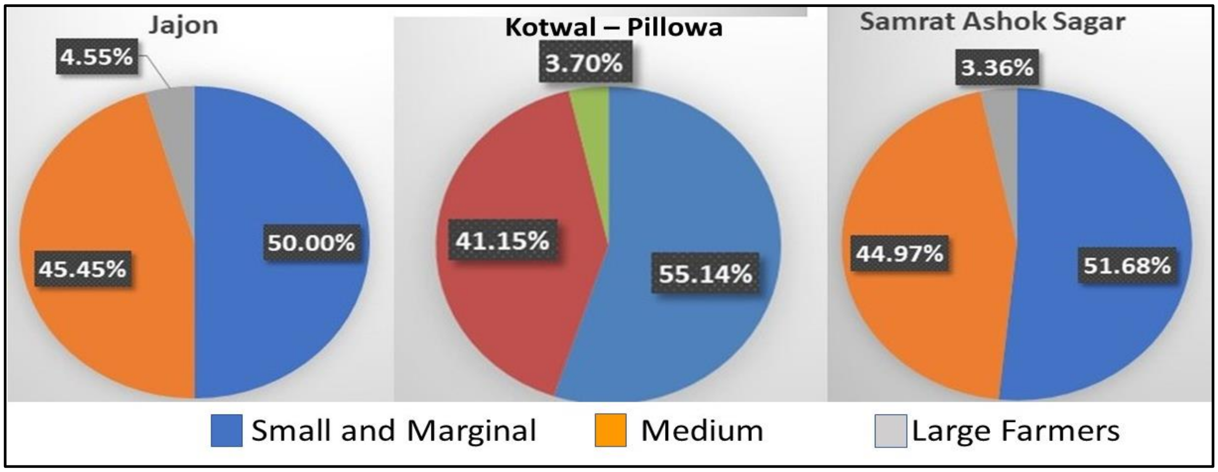


Figure 4.11: Farmers Land holding distribution in commands of irrigation projects

Based on the primary data obtained from the baseline survey, Figure 4.11 shows the status of land holdings in the head, middle and tail reach of three commands. The overall distribution patterns were seen as quite similar in all three projects in respect of the percentage of farmers according to their land holdings. Overall, 50- 55% are small farmers having land holding less than 2 ha, around 41- 45% of farmers are medium farmers having land holding between 2-10 ha and the percentage of large farmers have more than 10 ha of land were seen very small i.e., between 3.5 to 4.6%. The Jajon project is a small irrigation project as compared to others and has a good number of large farmers as high as 4.55% however, Kotwal-Pillowa is a major project and has 3.36% of large farmers.

4.5.2 Irrigation numbers, intervals and crop production for Wheat

From the analysis of primary data collected from the baseline survey, it was observed that the various crops grown in the rabi season in all three selected irrigation projects are wheat, gram, masoor, mustered, lentil, etc. However major crop grown in commands was the wheat crop hence its irrigation frequency and production were analyzed separately.

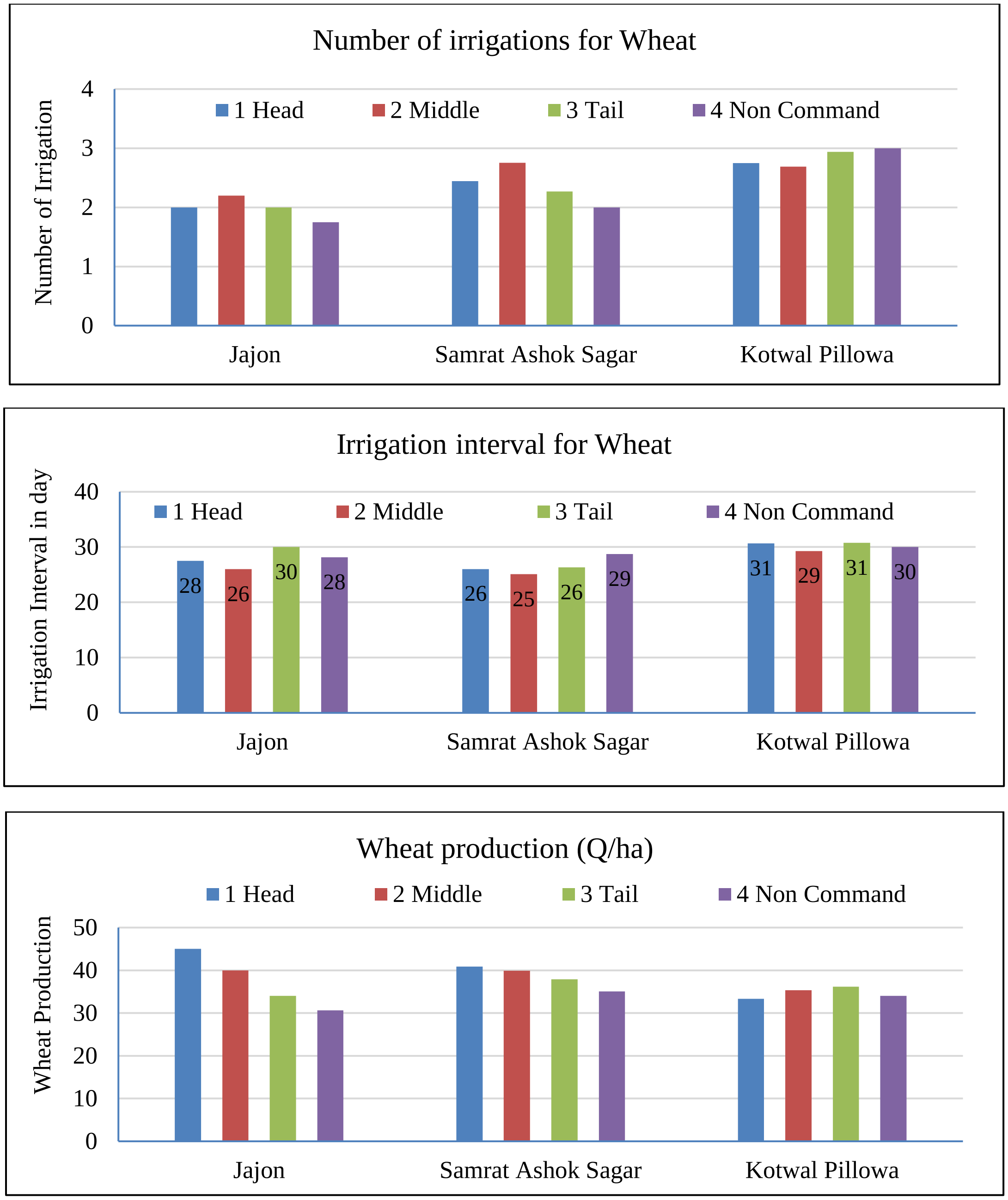


Figure 4.12: Wheat crop - irrigation numbers, irrigation intervals and production

The survey data analysis as shown in Figure 4.12 indicated that Jajon and Samrat Ashok Sagar command gets almost two to three irrigations in the season and achieves good wheat production in Head (41-45 Q/ha) and middle (39-40 Q/ha) reach. Kotwal command area gets almost three irrigation but does not show its significant impact on wheat production. Irrigation interval was reported longer in the tail-end area and but it had not seen a significant impact on wheat production. Irrigation interval was found 26 to 30 days for all schemes. The crop production in the non-command area reported was less than even the tail reach of the project. Thus it could be seen that having excess irrigation water does not guarantee an increase in production.

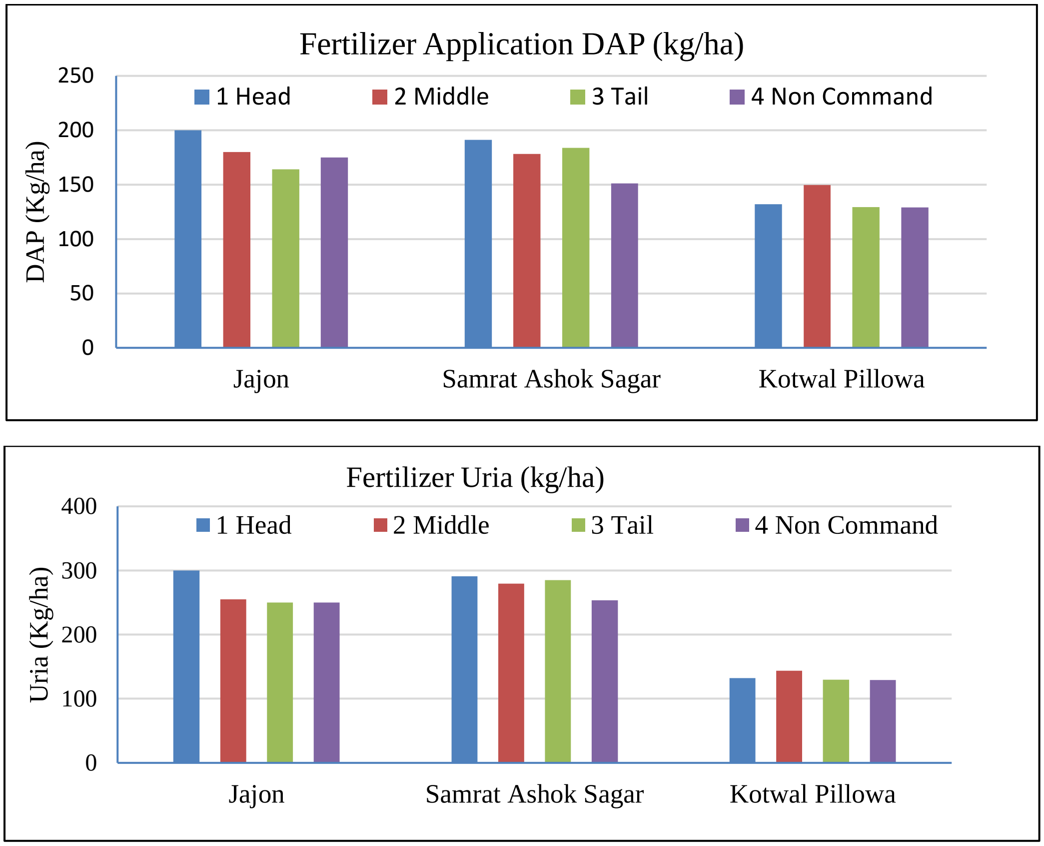


Figure 4.13: Fertilizer application

From the analysis of survey data as shown in Figure 4.13 it was observed that the farmers in Jajaon and SAS commands are using more fertilizers and production was also seen higher in these projects. Application of fertilizers was seen comparatively less in Kotwal-Pillow command but seems to have achieved good production. Agricultural production was reported higher in the head and middle reach as compared to the Tail reach area except for the Kotwal-Pillow dam. A water logging problem was reported in the Kotwal command in the head reach area.

4.5.3 Irrigation interval, irrigation number and production of other crops Gram, Masoor and Musterd

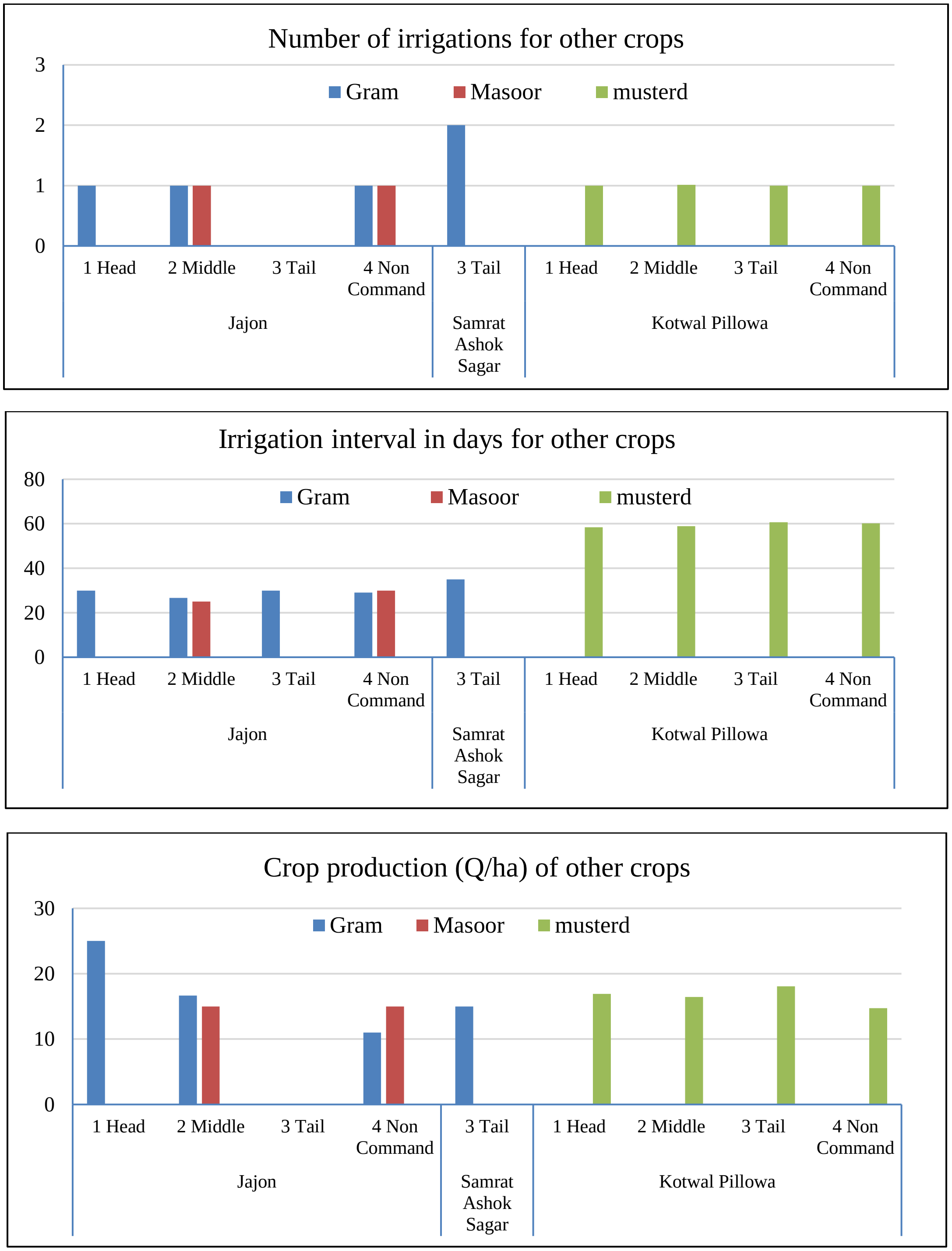
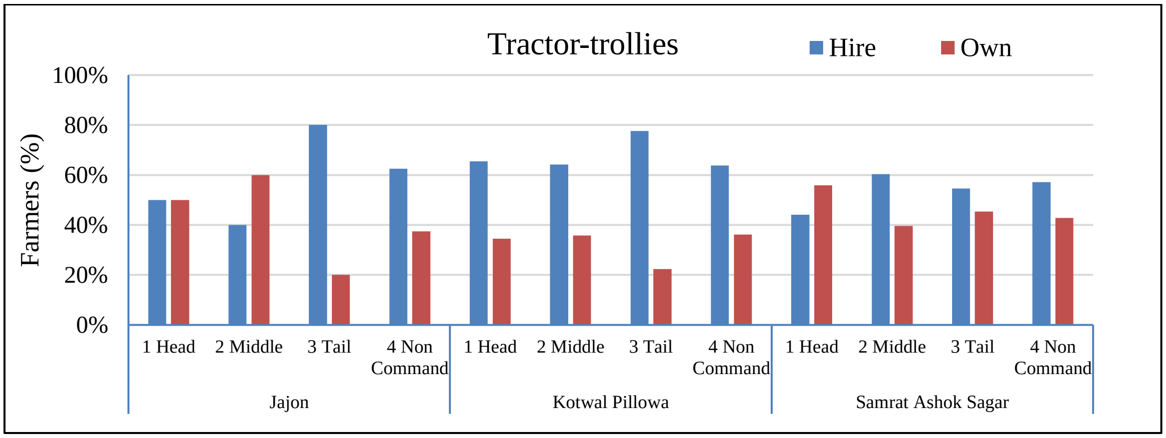


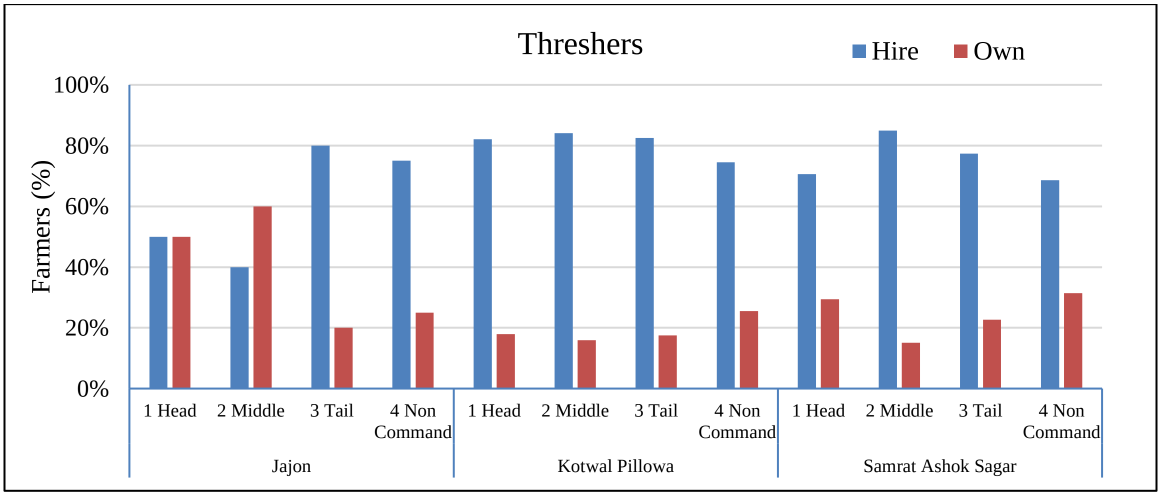
Figure 4.14: Irrigation interval, number and crop production for other crops

As shown in Figure 4.14, from a survey it was reported that apart from wheat as a major crop Jajon command area has other crops like gram and masoor as alternative crops but grown mostly in the head reach area and receives one irrigation in 30 days of interval and have a production maximum up to 25 Q/ha. Samrat Ashok Sagar has sufficient water available to irrigate and gram is grown as an alternate crop in the tail reach area providing irrigation with 35 days of intervals and producing 15 Q/ha of the crop. But in all the reaches of Kotwal Pillowa, mustard was found as the only alternate crop which is reported receiving irrigation with 60 days of interval and produces 16-18 Q/ha.

4.5.4 Use of modern equipment in farming

The irrigation projects have an impact on agricultural production which ultimately improves the economic situation of the farmers. The farmers with their increased agricultural production and increased farm income become capable to invest more in agriculture in terms of using modern types of equipment on the farms like tractors, and threshers pump sets which are indicative of economic and social development in the area.





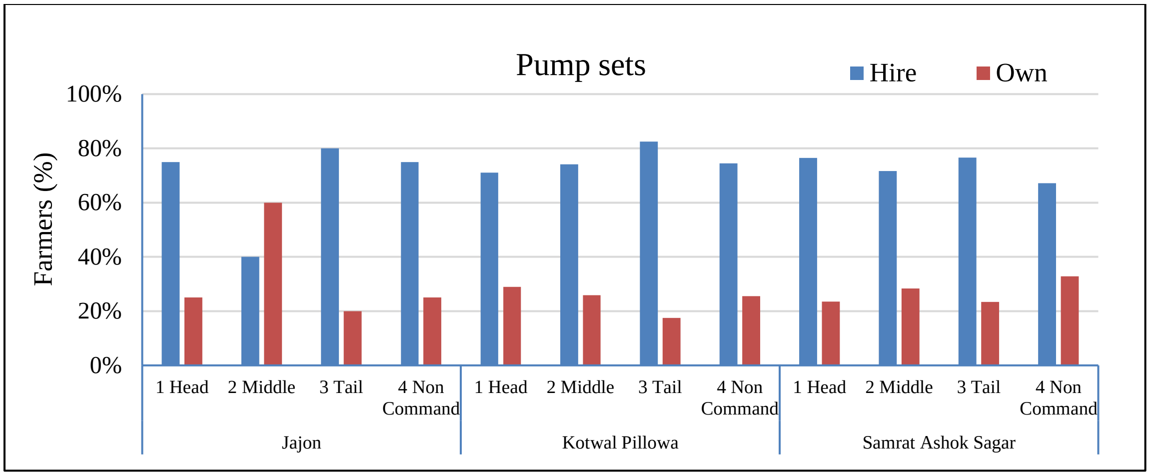
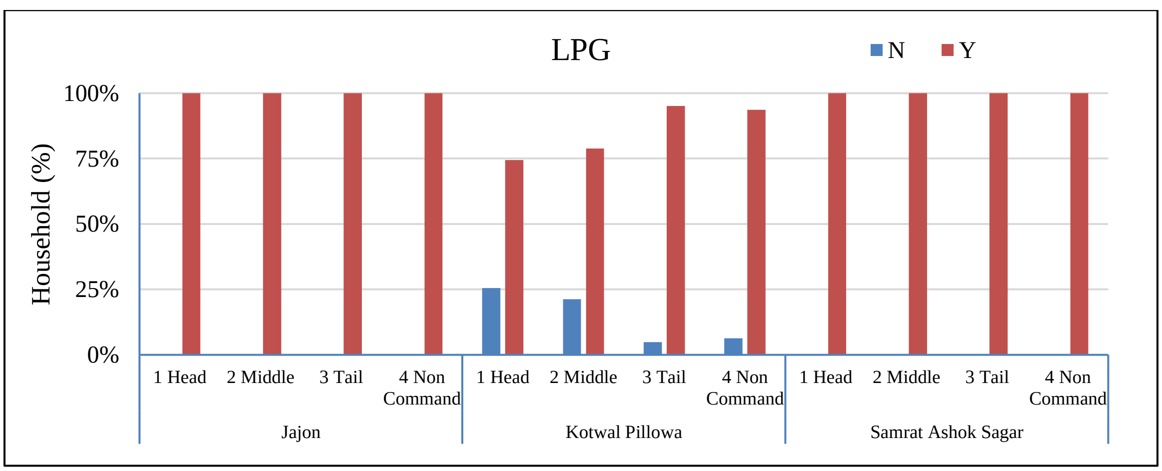


Figure 4.15: Use of field equipment like Tractor-Trolly, Thresher and pumpset

The data obtained from the survey for the use of field equipment or instruments like tractors, threshers, and pump sets in the farm practices are shown in Figure 4.15. From the analysis of data, it was observed that around 60 to 80% of farmers have their own tractor trollies, and around 20 to 40% of farmers have their threshers and pump sets. Most of the farmers in the tail reach area are performing farm operations using hired equipment. Contrarily in the head and middle reach area, the percentage of farmers who owns this modern equipment was seen as higher than those who hire it. An almost similar situation was seen in the non-command area. This has shown the good impacts on the economical activities and growth in the region.

4.5.5 Home appliances available in villages



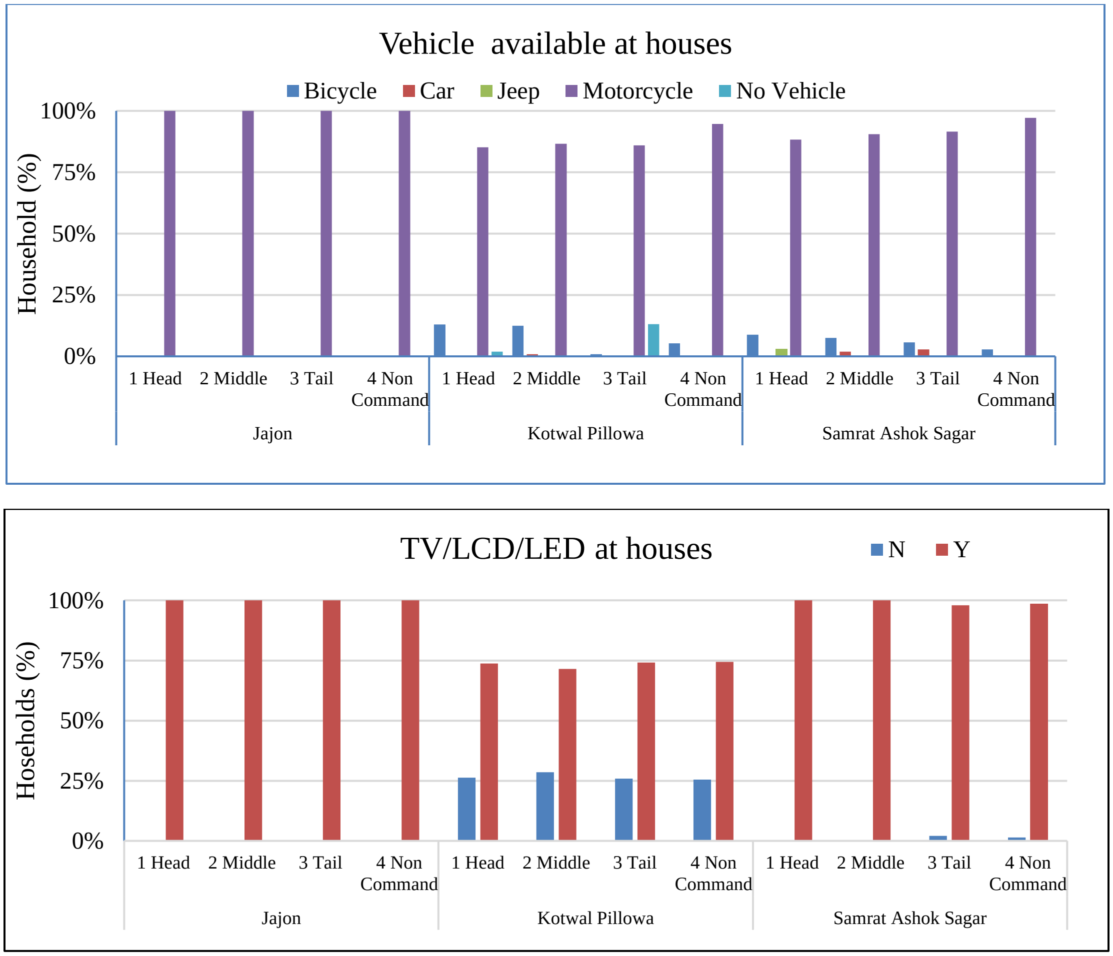


Figure 4.16: Facilities available at Households

Certain facilities available at farmers houses highlight the economic conditions of the farmers. The facilities such as LPG connection, type of vehicle owned by them, and television set available at the farmers houses are shown in Figure 4.16. Almost all the farmers except a few in Kotwal-Pillowa have LPG connections in their houses. The same is seen in the case of owning two-wheeler automobiles except for a few farmers in Kotwal-Pillowa where all the farmers have a two-wheeler. An identical situation can be observed for owning a television set. A similar situation was seen in the non-command areas as well.

4.5.6 Irrigation status in command and non-command

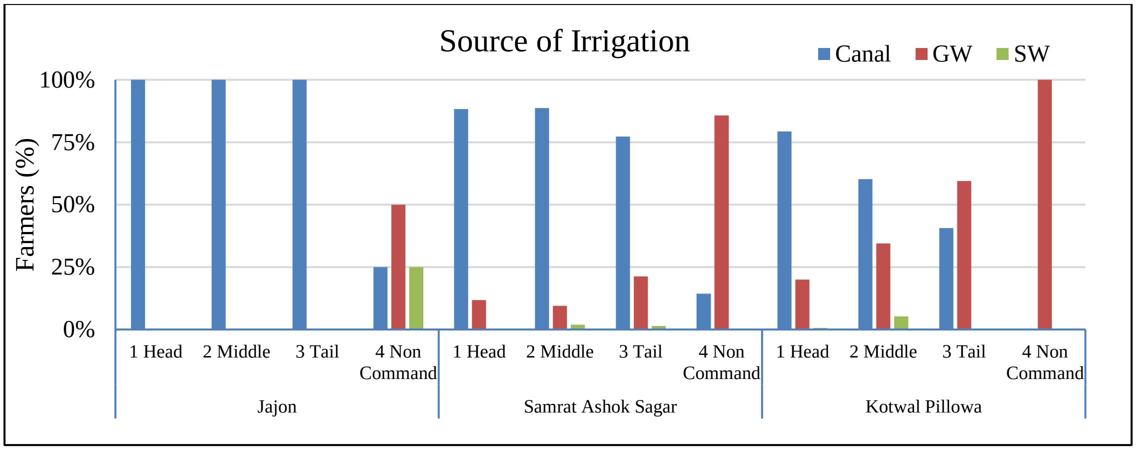


Figure 4.17: Source of Irrigation

Figure 4.17Figure 4.17: shows the different sources of irrigation reported in command. The main source of water supply for irrigation in the Jajon and Samrat Ashok Sagar dam is reported as canal water. In Kotwal command farmers are seen using groundwater in conjunction with the canal water for irrigation and the usage of groundwater as compared to canal water was observed increasing from head to tail reach area of the command.

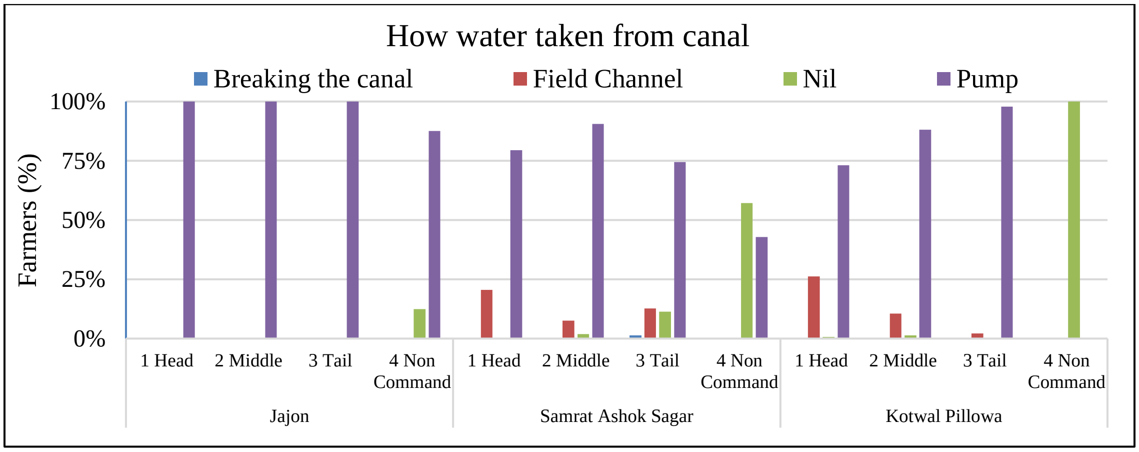


Figure 4.18: How water is taken from a canal

Figure 4.18 indicates how water is being taken by the farmers from the canal in the head, middle and tail reach of all the commands. All the farmers in the Jajon command are extracting water from the canal using pumps. While in Samrat Ashok Sagar and Kotwal-Pillowa dam, only 70-90% of farmers used to pump and the rest used field channels to extract the canal water.

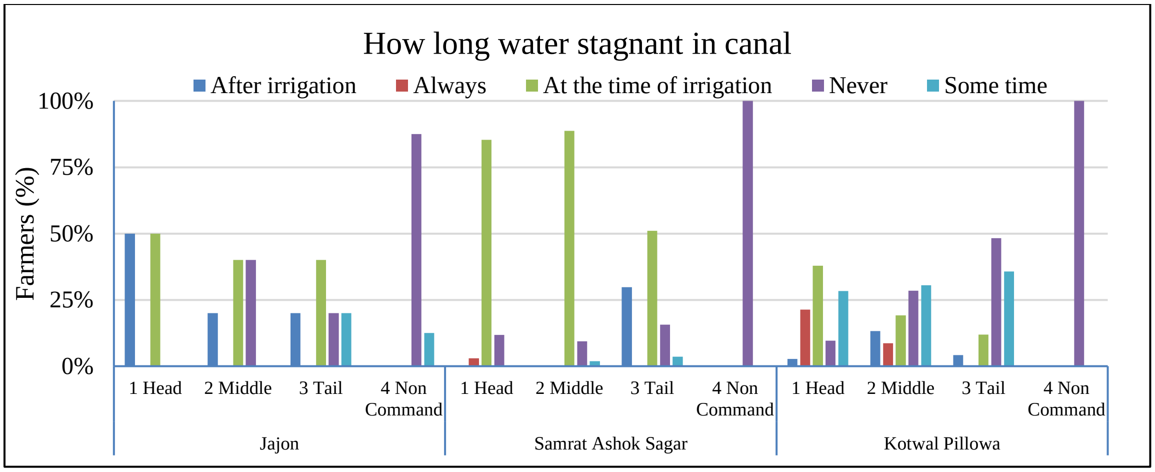


Figure 4.19: Response on how long the water stagnant in the canal

Based on the survey outcome as shown in Figure 4.19, only 3% of farmers in the head reach of Samrat Ashok Sagar, and 21% and 9% of farmers in the head and middle reach area reported that the water is available in the canal throughout the season. The majority of farmers of all the reaches of Kotwal-Pillowa command experienced the non-stagnation of water in the canal throughout the rabi season. In Ashok Sagar's command, most of the farmers reported stagnation of water in the canal at the time of irrigation.

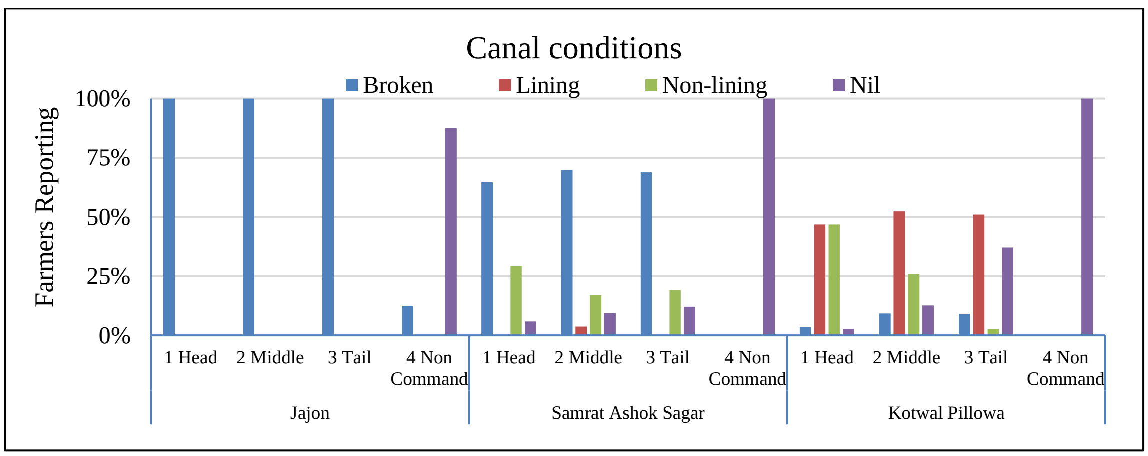


Figure 4.20: Canal conditions

Figure 4.20 shows the response of farmers describing canal conditions in all three reaches. Almost all farmers in the Jajon command area have said that the canal was mostly breached causing water loss. In Ashok Sagar command 65%, 70%, and 69% of farmers in the head, middle, and tail reach respectively responded that the canal was mostly breached and the rest of others said that the canal is in non-lining condition, only 4% of farmers in middle reach said that the canal was in good condition and lined. In Kotwal's command around 50% of farmers in all the reach said that the canal was lined and was in condition. Thus farmers are not seen much satisfied with the canal conditions in command.

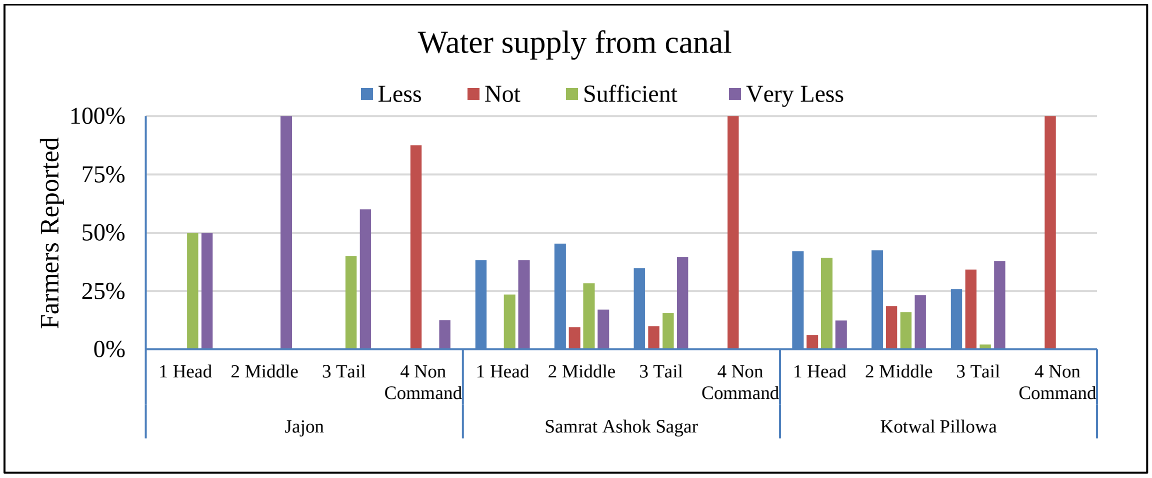


Figure 4.21: Do Farmers get sufficient water supply

Based on the survey, Figure 4.21 indicates the status of irrigation supply in the head, middle and tail reach of the command areas. Around 40% to 50% of farmers of head and tail reaches of Jajon are receiving sufficient irrigation supply, while others receive very less supply. In Ashok Sagar command 35% to 45% of farmers are receiving less supply, 16% to 24% are receiving sufficient supply while 9% to 10% of farmers in the middle and tail reaches are not getting irrigation supply from the canal. An almost similar condition was reported in the case of the Kotwal-Pillowa command and the percentages of farmers who are not receiving irrigation supply have been seen increasing from Head to tail reaches.

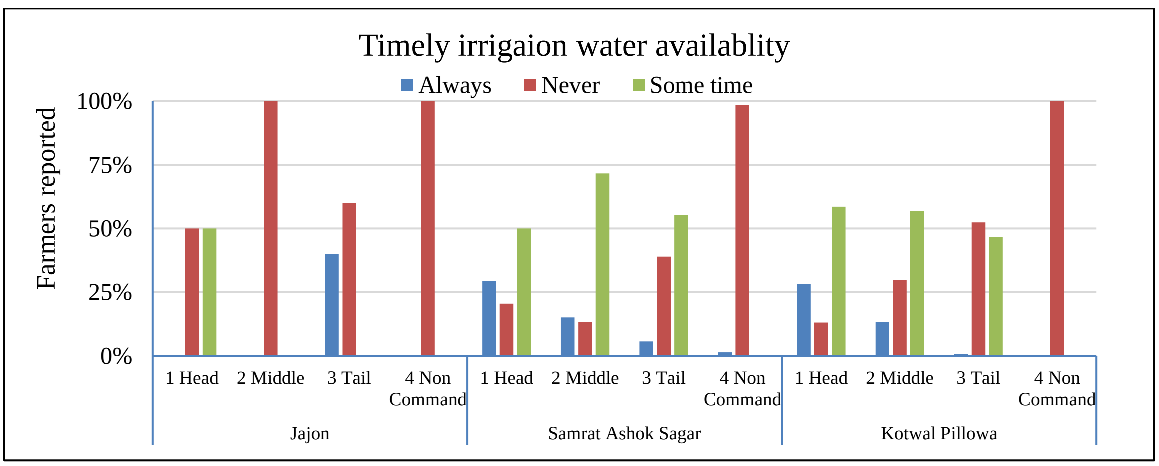


Figure 4.22: Do farmers get water when they need

Figure 4.22 depicts that many of the farmers don't receive the water when they need it most, only 40% of farmers in the tail reach of Jajon, 29%, 15%, and 6% of farmers in the head, middle, and tail reach respectively of Ashok Sagar dam and 28%, 13% and 1% of farmers in the head, middle, and tail reach of Kotwal-Pillowa dam receives water in time when they needed it.

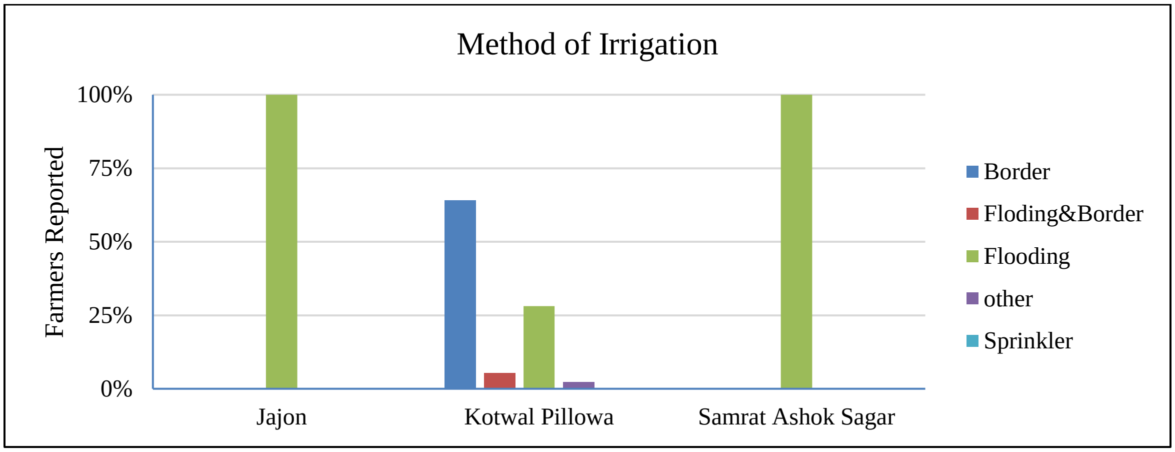


Figure 4.23: Method of irrigation

In the kotwal-Pillowa command around 64%, 28%, and 8% of farmers reported that they are using a border, flooding, and other methods respectively for irrigation. In Jajon and Ashok Sagar commands 100% of the farmers said that they are using the flooding method of irrigation as shown in Figure 4.23.

4.5.7 Social Impacts

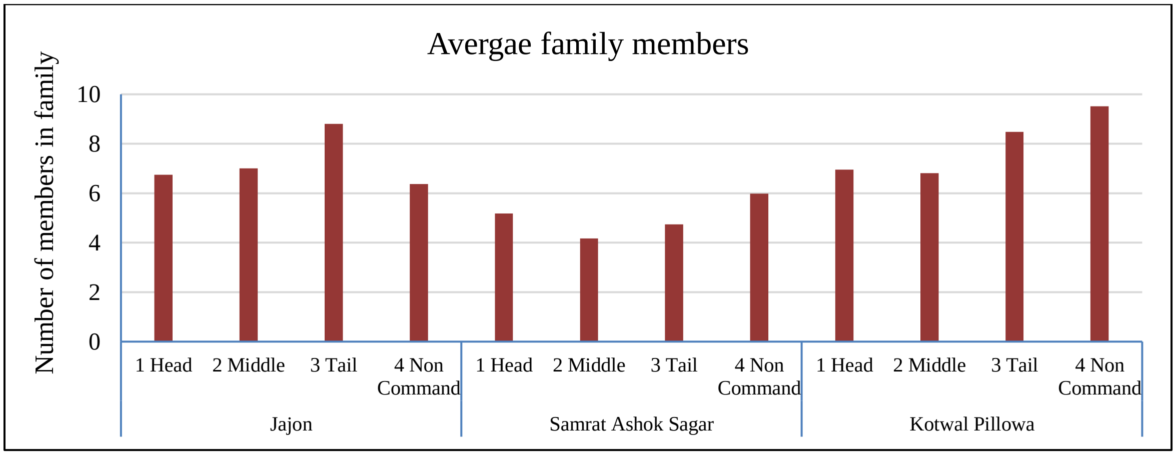


Figure 4.24: Average members in a family

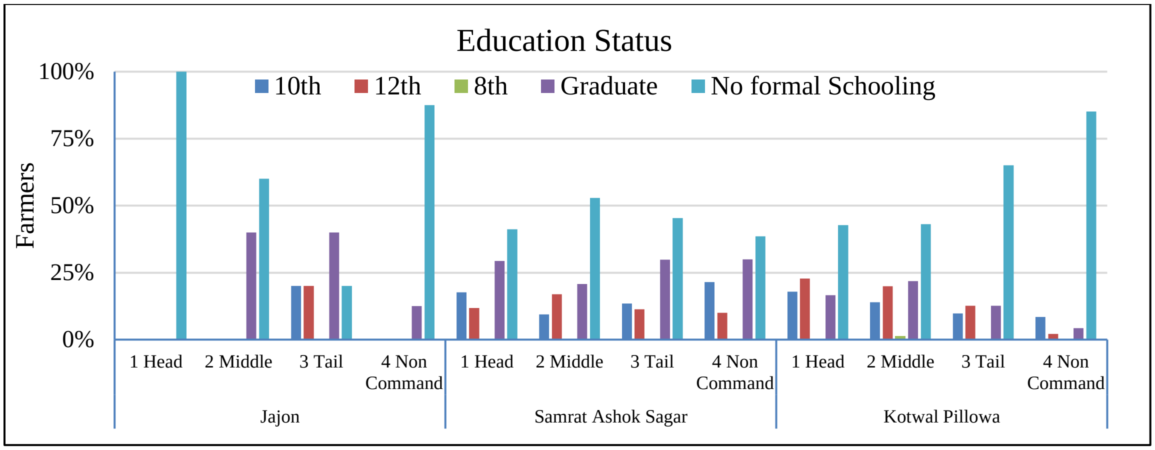


Figure 4.25: Education status

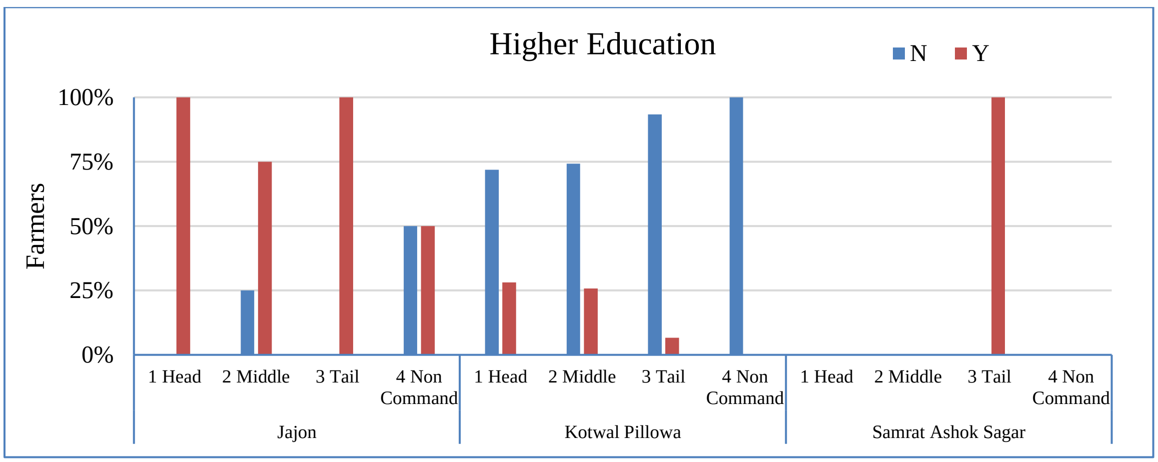


Figure 4.26: Higher education status

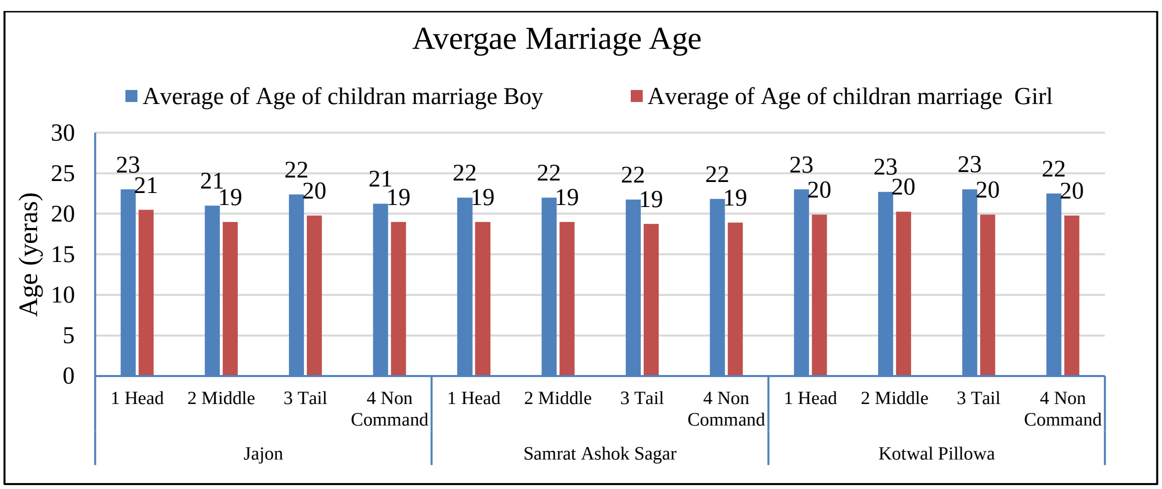


Figure 4.27: Average marriage age

As shown in Figures 4.24 to 4.27, the social status of the farmers has been evaluated by asking questions based on the number of family members, their education status, higher education status, and marriage age. From the survey In Jajon command farmers in head and middle reaches have an average of 6 to 7 members in the family while tail reaches Famers have 8 to 9. In the Ashok Sagar command head, middle, and tail have 4 to 6 members and the Kotwal command has 7 to 9 members in a family in all reaches. When it comes to education status, the maximum percentage of farmers with no formal schooling was observed 90 to 100% in the head reach of the Jajon command while more than 30% are seen to achieve graduate degrees in the middle and tail reach of Jajon. Moreover, in Jajon command a maximum number of farmers in the middle, and all the farmers in head and tail had to send their children outside cities to pursue higher education. But this percentage was seen as very low in Ashok Sagar command. The average marriage age was reported as 21 to 23 among boys and 19 to 20 among girls.

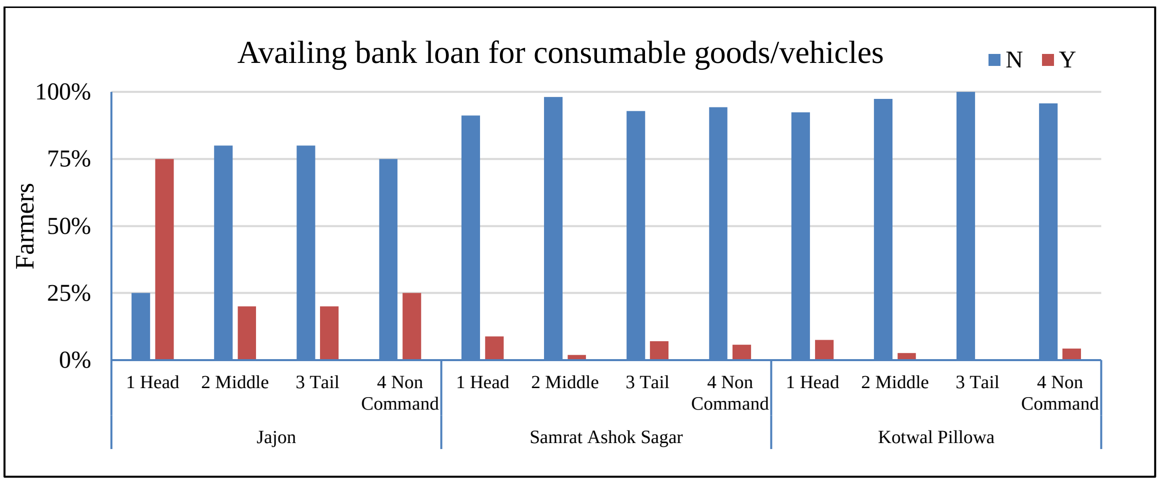


Figure 4.28: Availing Bank loan for consumable good/vehicles

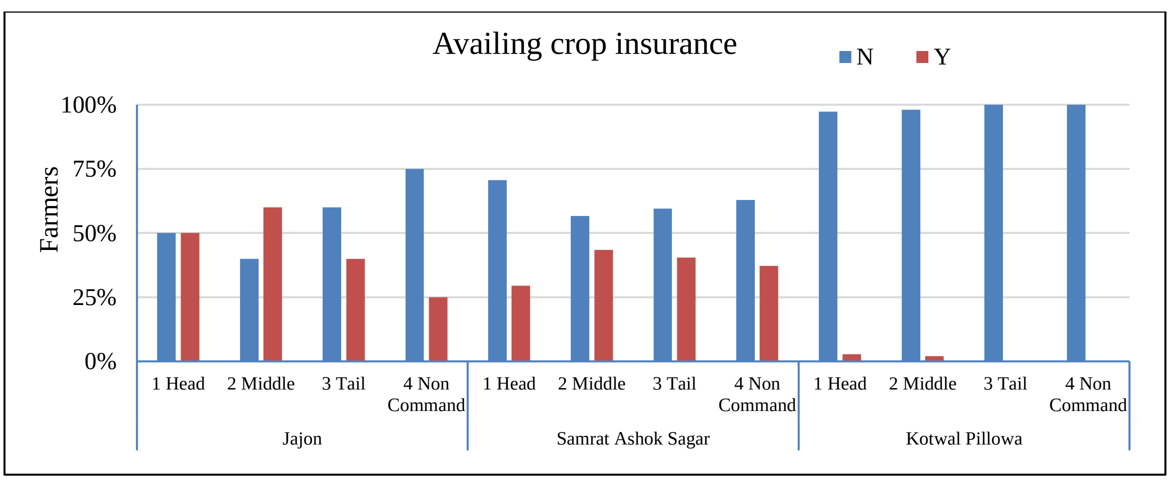


Figure 4.29: Availing crop insurance

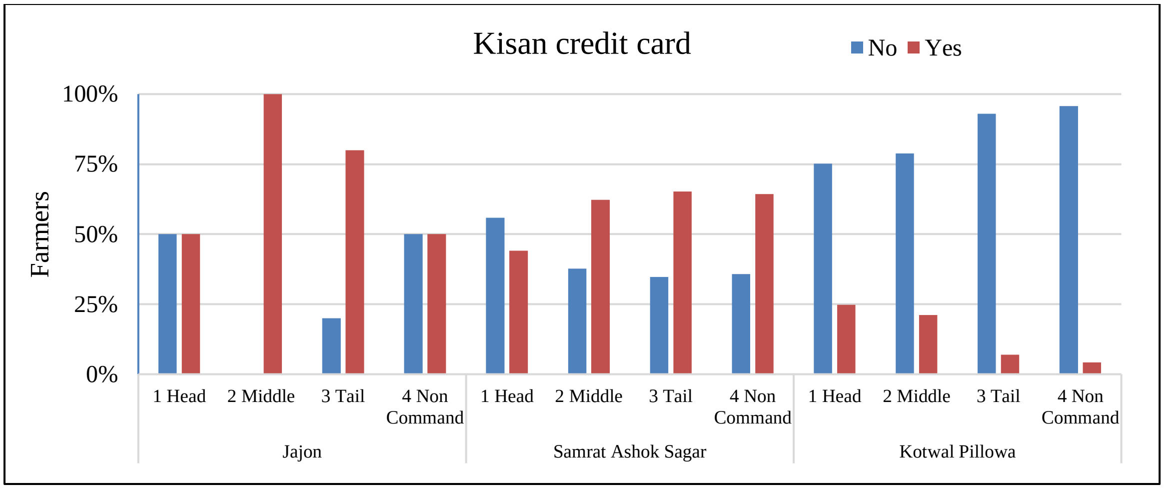


Figure 4.30: Kisan Credit Card

As shown in Figure 4.28 on the economic front, only up to 10% of farmers have availed bank loans for goods or vehicles in all the reaches of Ashok Sagar and Kotwal command, but in the Jajon command, this percentage was seen as comparatively high i.e. up to 20% in middle and tail reach and 70% in Head reach. As shown in Figure 4.29, the majority of the group of command and non-command areas of farmers were not found opting for crop insurance facilities. Around 40 to 60% of farmers had availed a crop insurance facility in Jajon and Samrat Ashok Sagar command. Based on the survey, as shown in Figure 4.30, the majority of the group of command and non-command area of farmers have had a Kisan credit card facility, but 40 to 60% of farmers have not opted for crop insurance in Kotwal command.

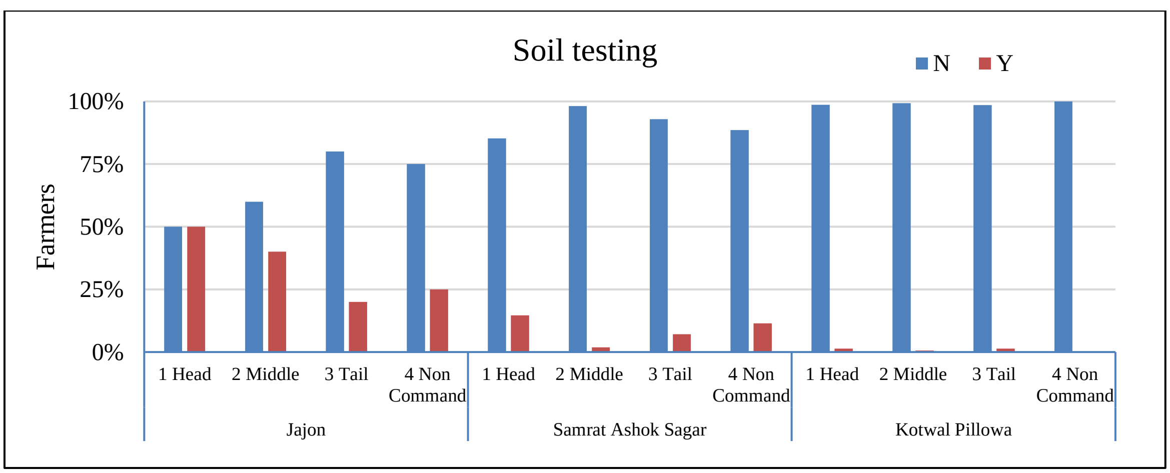


Figure 4.31: Soil Testing

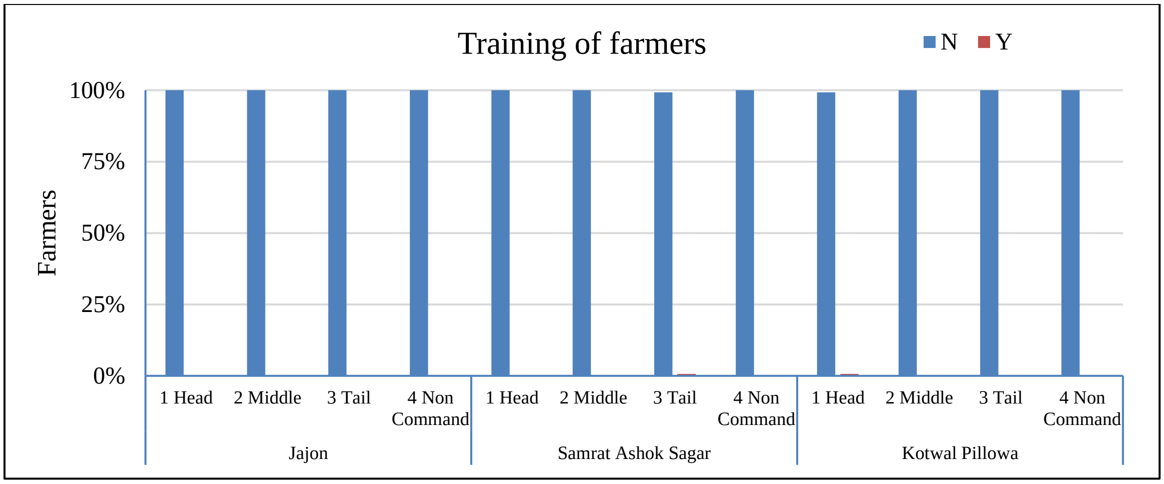


Figure 4.32: Training of Farmers

Based on the survey as shown in Figure 4.31, the majority of farmers have not got their soil tested, only 50%, 40%, and 20% in head, middle, and tail respectively have tested the soil for crop planning. In Ashok Sagar command only 14% in head, 1% in middle, and 7% in tail reach have conducted soil testing, indicating a lack of awareness among the farmers about soil testing for better crop planning in this region. When asked about the training on advanced farming, less than 1% of farmers in the tail reach of Ashok Sagar and the head reach of Kotwal command have reported that they have undertaken training or capacity building program related to agriculture or irrigation as shown in Figure 4.32.

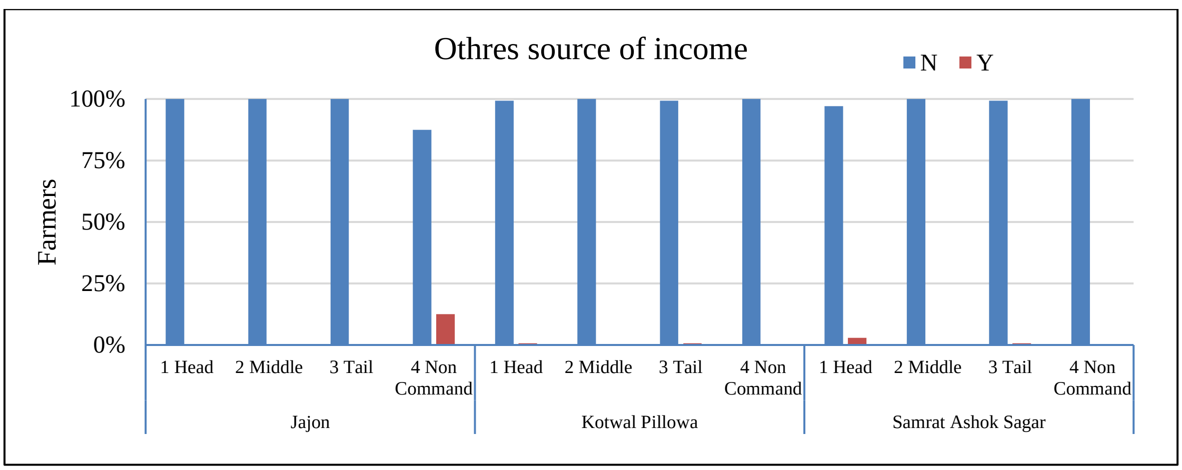


Figure 4.33: Other Sources of Income

As shown in Figure 4.33, only 12% of farmers of nearby Jajon command and 2% of farmers in Head reach of Kotwal reported having other sources of income

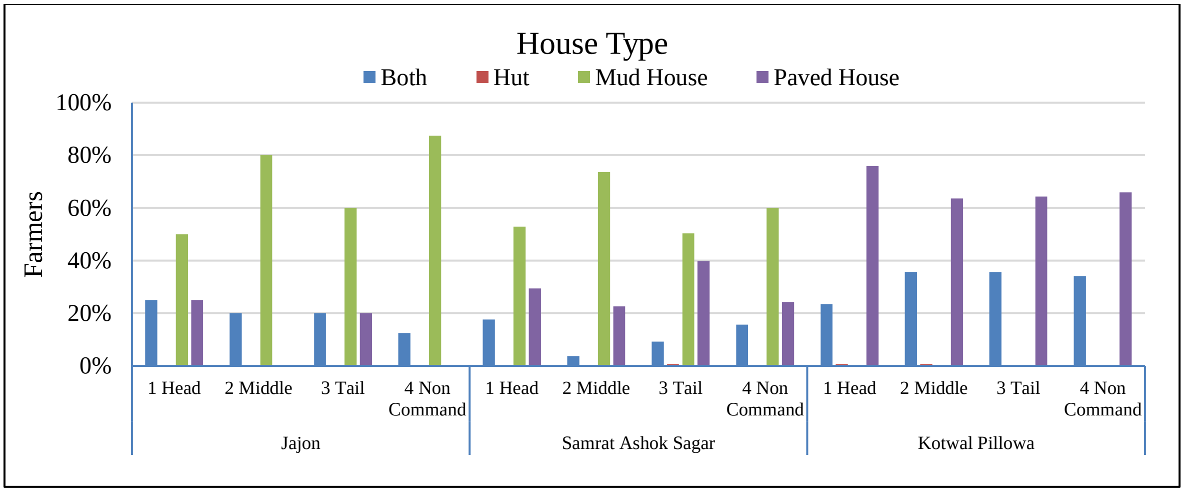


Figure 4.34: House Type

Figure 4.34, illustrates the percentage of farmers with different types of houses in all command areas. In Jajon and Ashok Sagar command, 50% to 85% have said that they have mud houses while in the Kotwal command majority (79-80%) of farmers are living in paved houses.

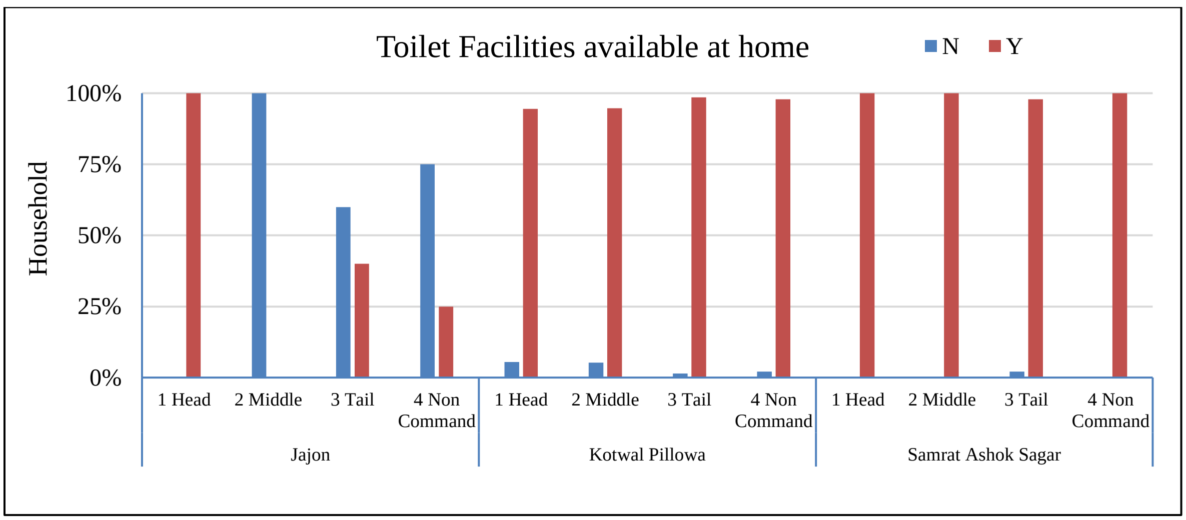


Figure 4.35: Toilet facilities at Home

Based on the survey analysis as shown in Figure 4.35, it was seen that the toilet facility is available at home in the head, middle, and tail reach of the command and nearby command (non-command). Around 50% of farmers have said that the toilet facility is available at their home in Jajon command, while almost 95% of farmers have said that the toilet facility is available at home in Samrat Ashok Sagar and Kotwal command. The farmers are seen as aware of the toilet facility in this region.

4.5.8 Hydrological impacts

The survey questionnaire included questions related to hydrological aspects of the command area like soil type, the water level in nearby wells, and availability of water in nearby drains due to regenerated flow, waterbody to be fed by the project, and whether they have adopted soil and water conversations measures.

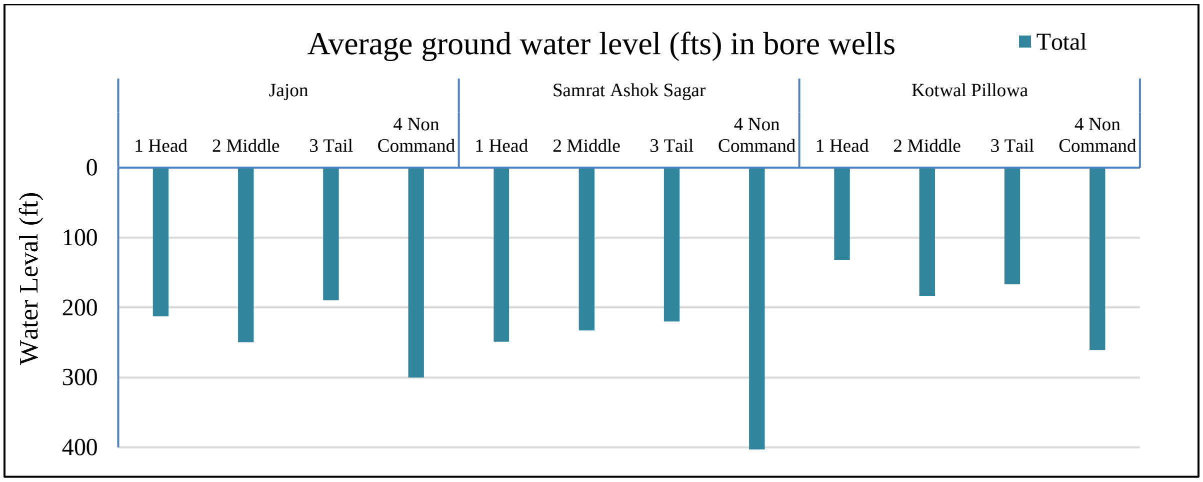


Figure 4.36: GW level in nearby bore wells

In Jajon command farmers have reported the groundwater availability in deep borewells at about 190 to 250 feet depth while farmers outside of the command area opinioned that groundwater level at about 300 feet depth. The same condition was seen in Ashok Sagar command where the groundwater level was reported between 220 to 250 feet in the non-command area. In Kotwal command the farmers reported groundwater level in the command area at about 132 to 182 feet depth as shown in Figure 4.36.

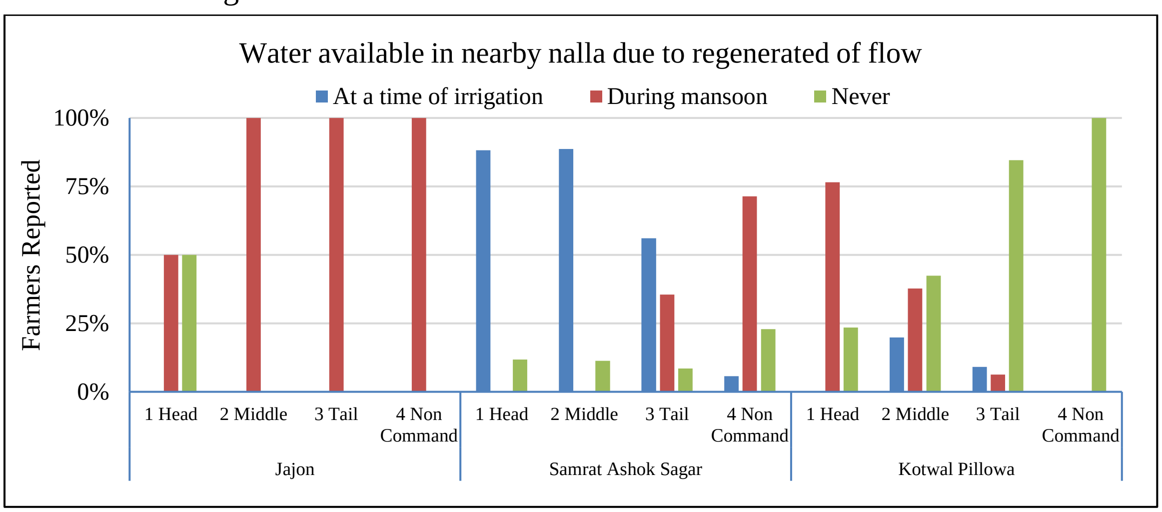


Figure 4.37: Water availability in nearby nalla due to regenerated flow

As shown in Figure 4.37 in the Samrat Ashok Sagar command area, around 80% of farmers in the head and middle reach area and around 56% of farmers in the tail reach area have reported having regenerated flow during the irrigation time. This may be due to bad conditions of canals and excessive irrigation due to flooding methods in this area. This issue can be addressed by planning for optimal utilization of water by adopting the appropriate method of irrigation and systematic irrigation scheduling. In the case of Kotwal dam, the surprisingly regenerated flow was seen in the middle and tail reach region of the command. In the Jajon command area, being a minor project the regenerated flow from irrigation was not seen very often.

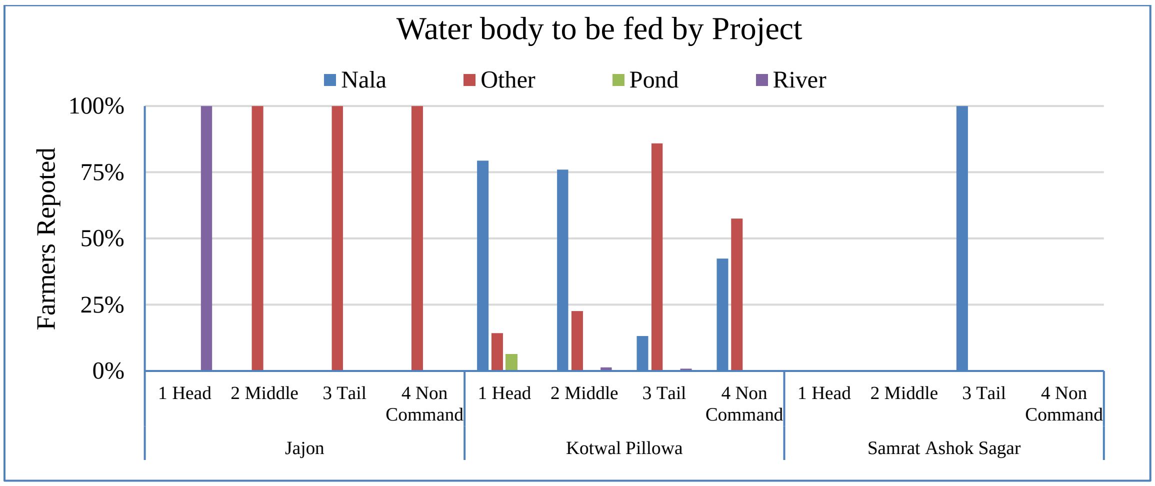


Figure 4.38: Water body to be fed by Project

As shown in Figure 4.38, in the Jajon Command area, farmers in the head reach area reported that the nalas and rivers in that area receive regenerated flow from the irrigation project. The farmers in the head and middle reach areas of all three commands have reported the regenerated flow in nalas and other water bodies fed by the project. However farmers in the tail reach area of all projects have informed that there is no regenerated flow in nalas due to irrigation in that area, this may be due to a lack of sufficient irrigation supply in the tail reach of the command.

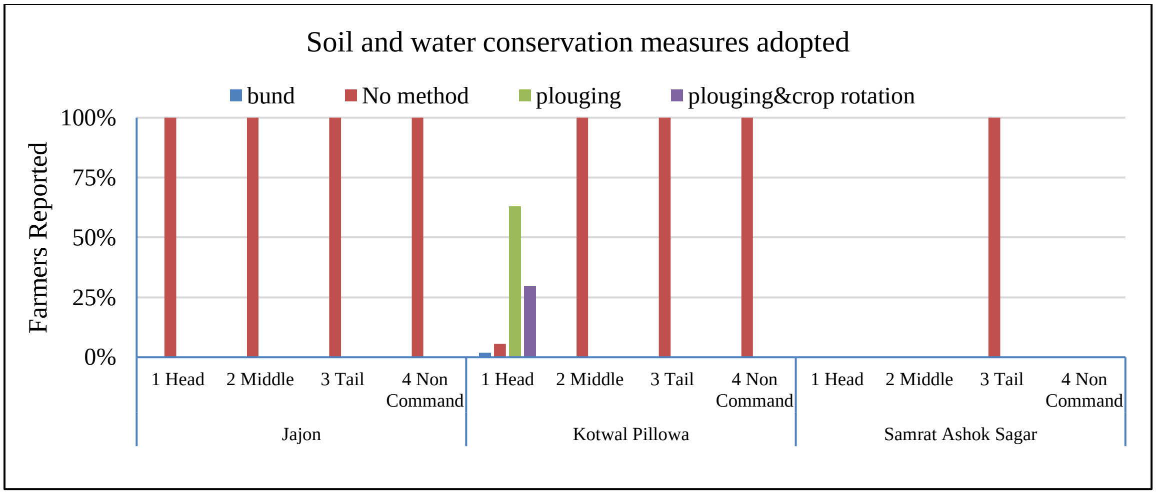


Figure 4.39: Soil and Water conservation measures adopted

As shown in Figure 4.39, almost all the farmers of all three selected projects except a few farmers in the head reach area of Kotwal command have reported that they have not adopted soil and water conservation measures for moisture conservation in their fields. It urges the need to educate and provide awareness among the farmers to adopt appropriate measures for soil and water conservation in the agriculture fields which will help to manage irrigation requirements of the crop and to improve crop production.

4.5.9 Economic impacts

The survey questionnaire included questions related to economic aspects of the command area like a small-scale industry in the village, bank facility in the village, Entrepreneurs' development schemes, Self-business scope, school, hospital, and electricity. These questions show the economic status of farmers, how to improve their economic status

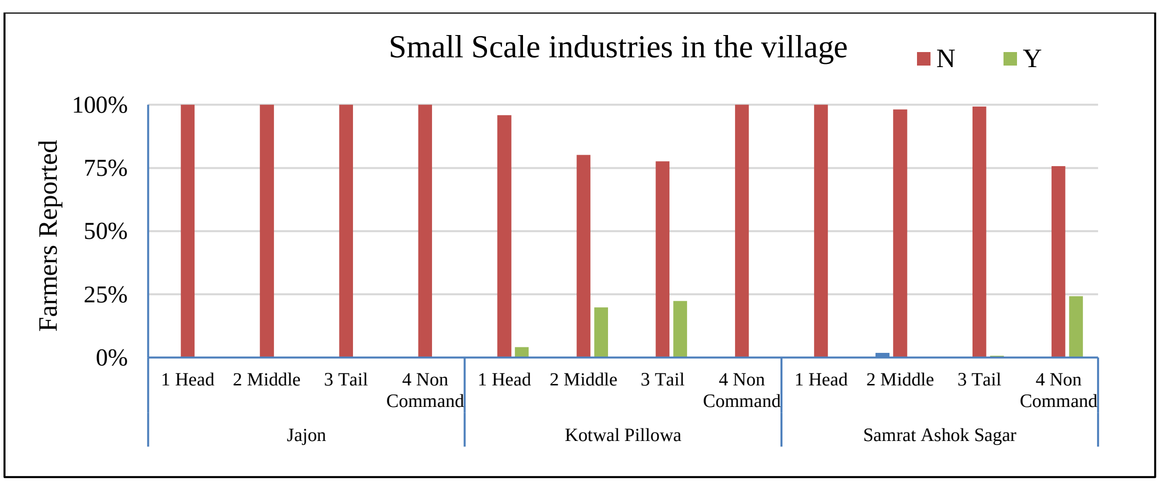


Figure 4.40: Small Scale industries in the village

As shown in Figure 4.40 all three command farmers reported that there is a lack of small-scale industry establishment in villages. Exceptionally few villages in Kotwal and Samrat Ashok Sagar commands have reported agriculture-based small-scale industry in the village. There is scope to develop small agro-based industries in the region for sustainable development.

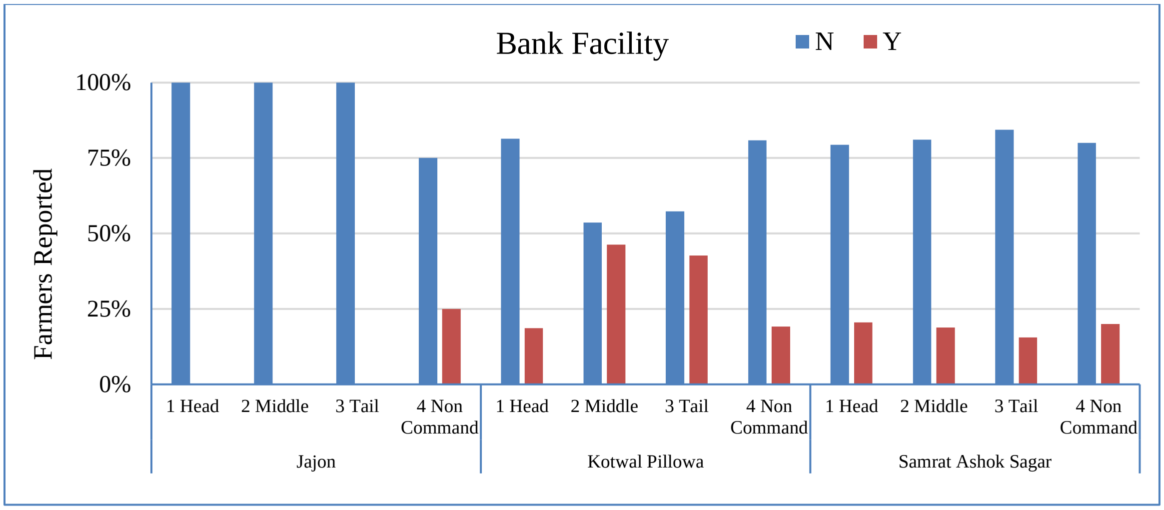


Figure 4.41: Bank Facility in the village

As shown in Figure 4.41, 25% of farmers of Kotwal, Samrat Ashok Sagar command, and tail reach of Jajon command have reported the availability of bank facilities in their villages. However, 75% of villages have reported of lack of bank facilities in their villages. Despite good agricultural production, a good financial institutional network could not be established in these regions which can affect the overall development, livelihood, and economic scenario.

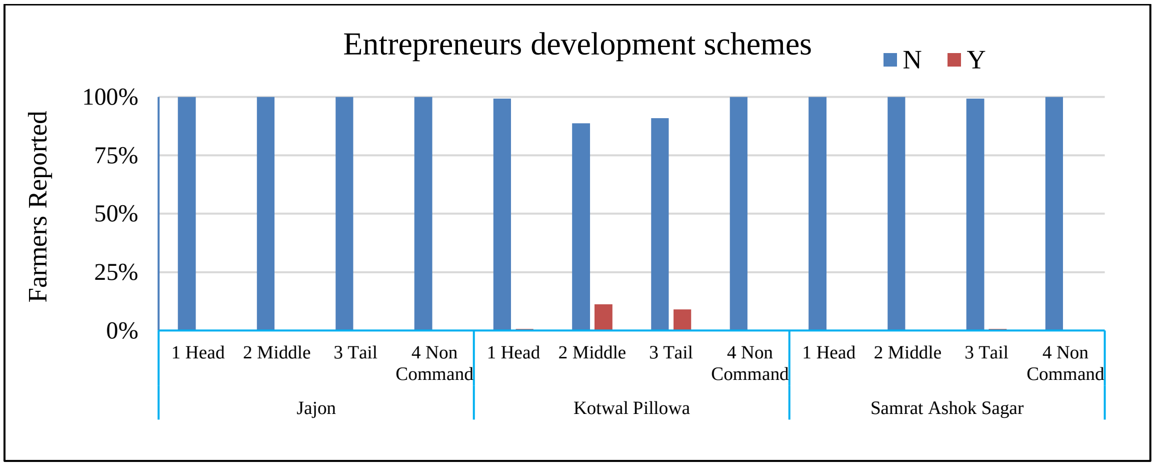


Figure 4.42: Entrepreneurs development schemes

As shown in Figure 4.42, 5 to 10% of farmers in the middle and tail reach of the Kotwal command area have been befitted from Entrepreneurship development schemes. More than 80% of farmers of all three project commands have not come across such Entrepreneurs' development schemes which need to be addressed on priority.

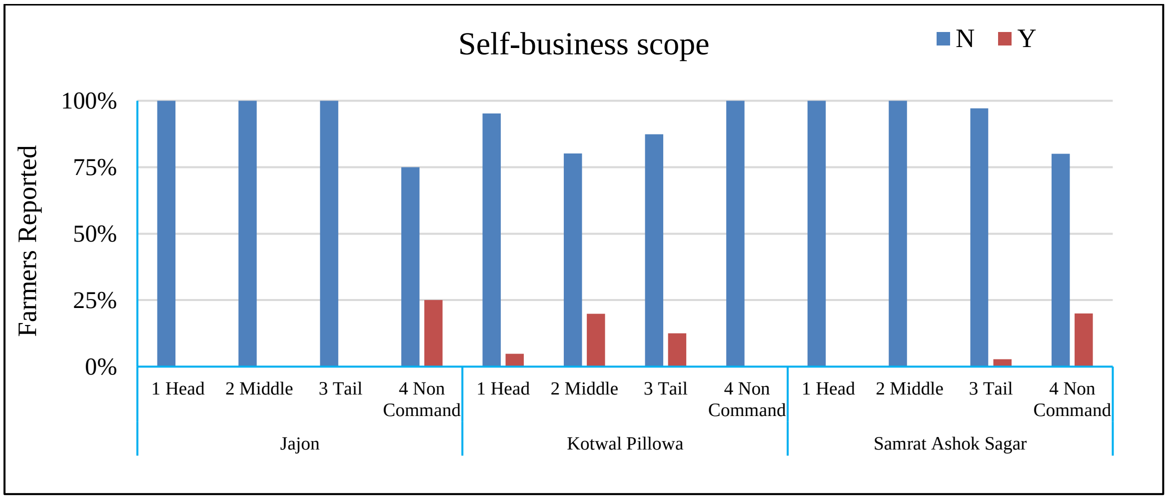


Figure 4.43: Scope of Self-business

As shown in Figure 4.43, 5 to 10% of farmers in Kotwal and Samrat Ashok Sagar command reported about the opportunity and scope of self-business in villages. However, more than 80% of farmers of all three commands don't find any scope for self-business in their locality. This aspect is very important in terms of developing rural livelihood and rural economy.

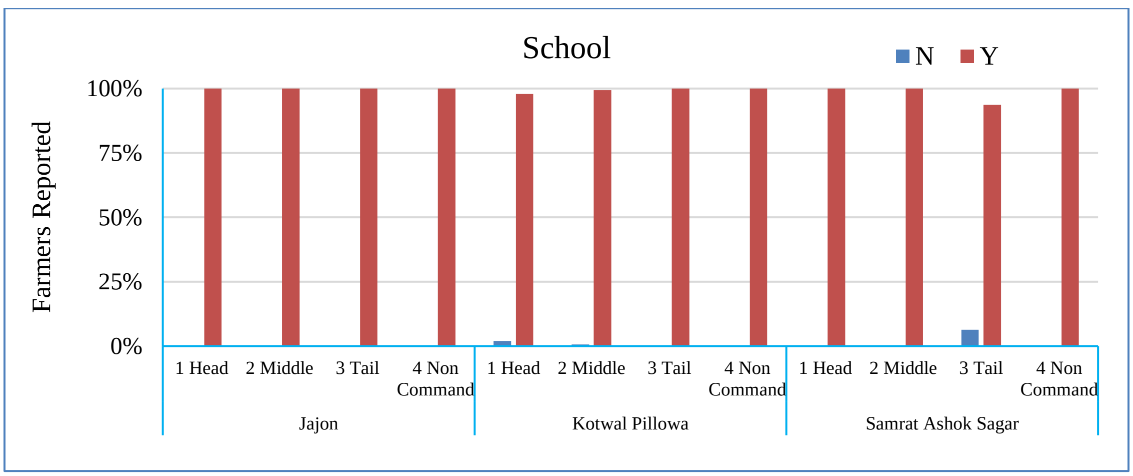


Figure 4.44: Availability of School

As shown in Figure 4.44, farmers in all three command areas have reported the availability of school facilities in their villages which is a sign of improvement in primary education in rural areas. Few villages in the tail-reach region have no schools in their villages.

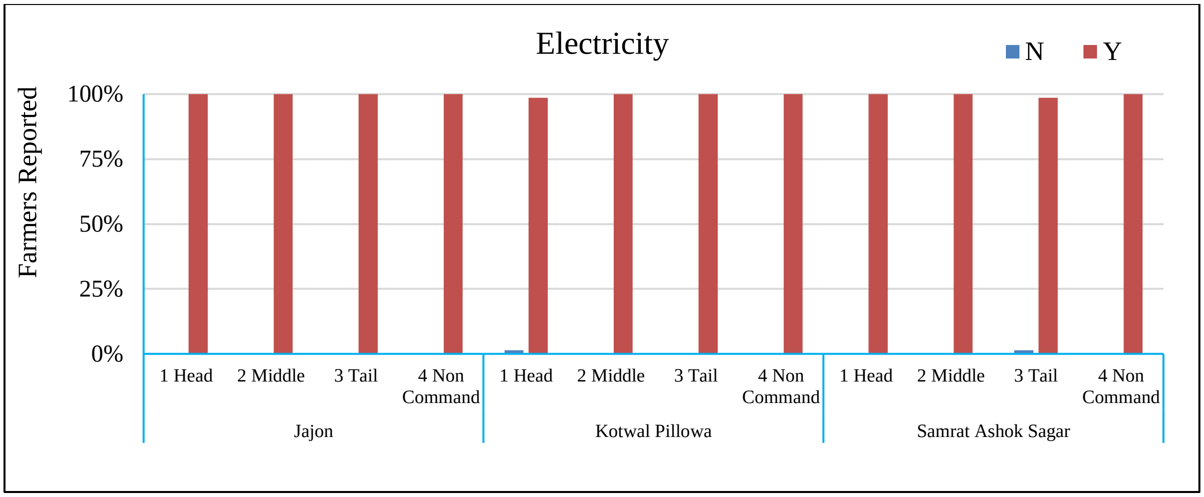


Figure 4.45: Electricity Connection

As shown in Figure 4.45, farmers reported good electricity facilities available in their village. In very few villages located in the tail reaches of Samrat Ashok Sagar and Kotwal-Piloowa command electricity facility was not seen as not up to the mark and facing the problem of power cut during a crucial period.

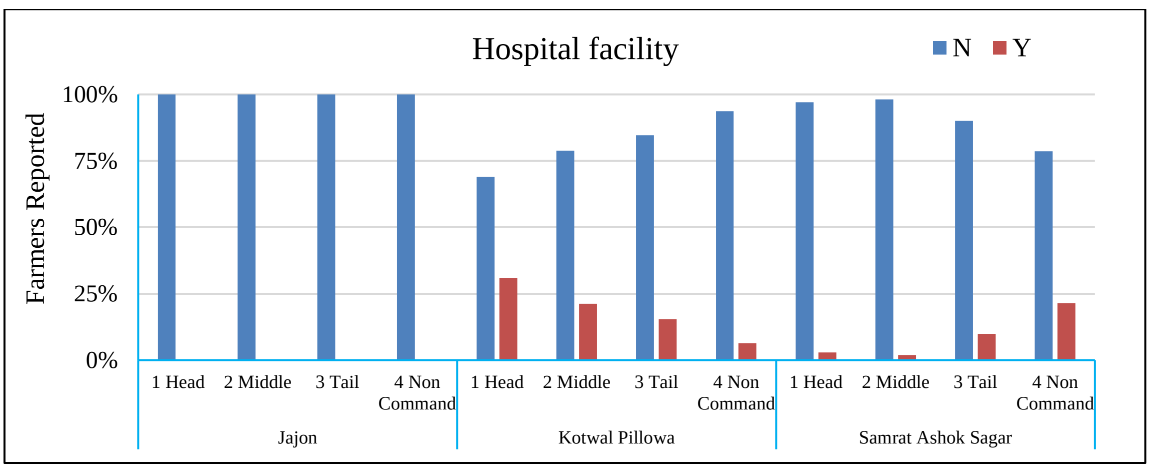


Figure 4.46: Hospital Facility

As shown in Figure 4.46, in Kotwal commands 31%, 21%, and 5% of farmers of the head, middle and tail reach respectively reported having good hospital facilities available in their or nearby villages. In Samrat Ashok Sagar command few farmers have reported good hospital facilities in villages that were reported lacking in the Jajone command area. The health facility needs to be strengthened in the rural area of these regions.

4.5.10 Health impacts

The survey questionnaire included questions related to the health aspects of the farmers of the command area like common diseases, symptoms of fever with chills/rigors, source of drinking water, filter water used for drinking, water emptied from containers, frequency of mosquito bite s before irrigation and after irrigation. The information derived from this survey gives an idea about the impact of irrigation projects on the increasing risk of water-borne and vector-borne diseases in the command area.

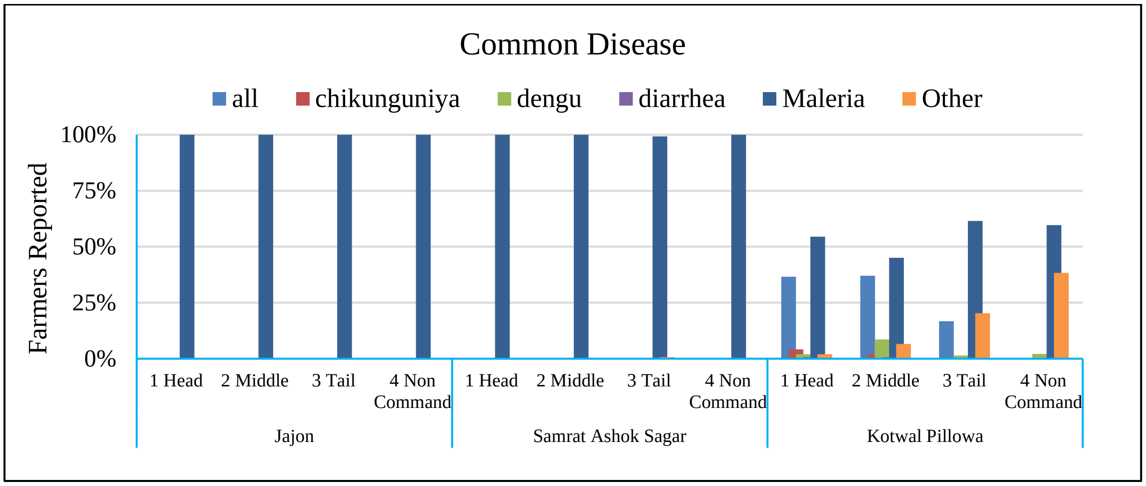


Figure 4.47: Common disease

As shown in Figure 4.47, the farmers of Jajon and Samrat Ashok Sagar Command have reported malaria as the most common disease in their area. In Kotwal-Pillowa around 60% of farmers reported malaria and 40% of farmers reported other diseases like dengue, diarrhea, chikungunya, etc. The water ponded in the canals and depression area due to irrigation has been seen as responsible for water and vector-borne diseases in the command areas of all three projects.

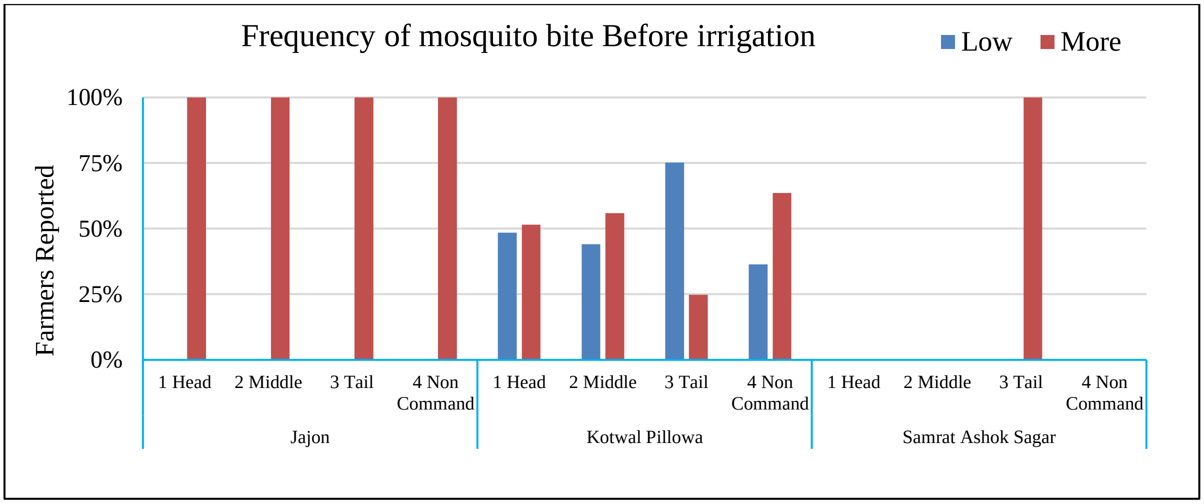


Figure 4.48: Frequency of mosquito bite before irrigation

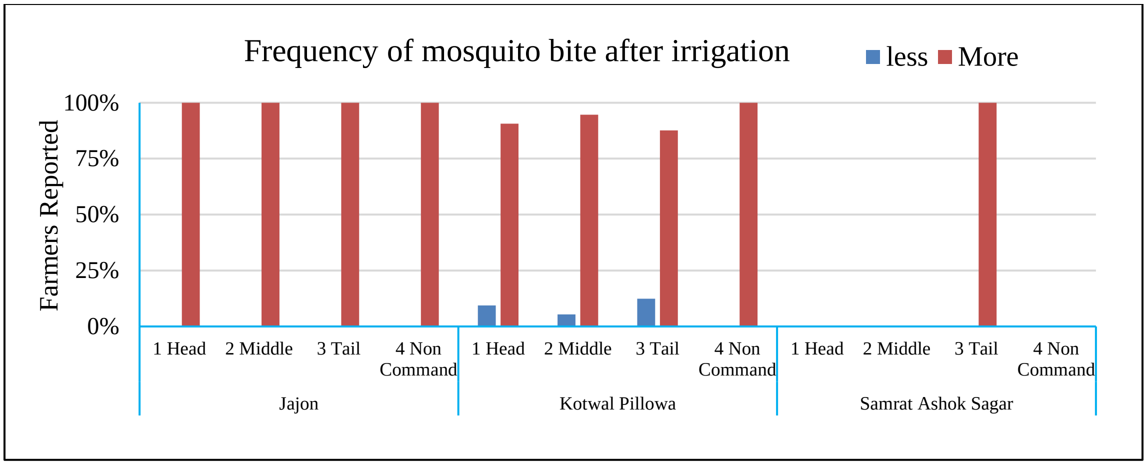


Figure 4.49: Frequency of mosquito bites after irrigation

In comparison to the frequency of mosquito bites before and after irrigation as shown in Figures 4.48 and 4.49, the farmers in Jajon and Samrat Ashok Sagar command have reported a very high frequency of mosquito bites before and after irrigation indicating a wide spread of malaria in their villages. However, in the Kotwal-Pillowa command, the frequency of mosquito bites was reported to be higher after irrigation as compared to the before irrigation period. Around 60% of farmers have reported this fact. The cases of mosquito bites and related diseases were found comparatively less in non-command areas.

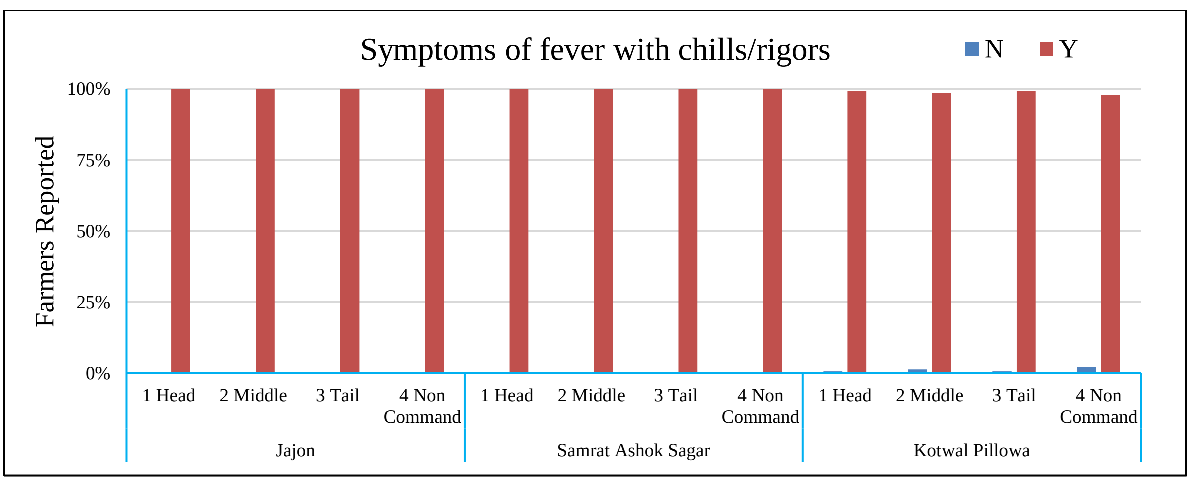


Figure 4.50: symptoms of fever with chills

As shown in Figure 4.50, almost all farmers in Jajon, Samrat Ashok Sagar, and Kotwal-Pillowa command farmers have reported of incidence of high fever with chills. This indicates the spread of water and water-borne diseases due to ponding water in the canal and other bodies during rabi seasons in command areas.

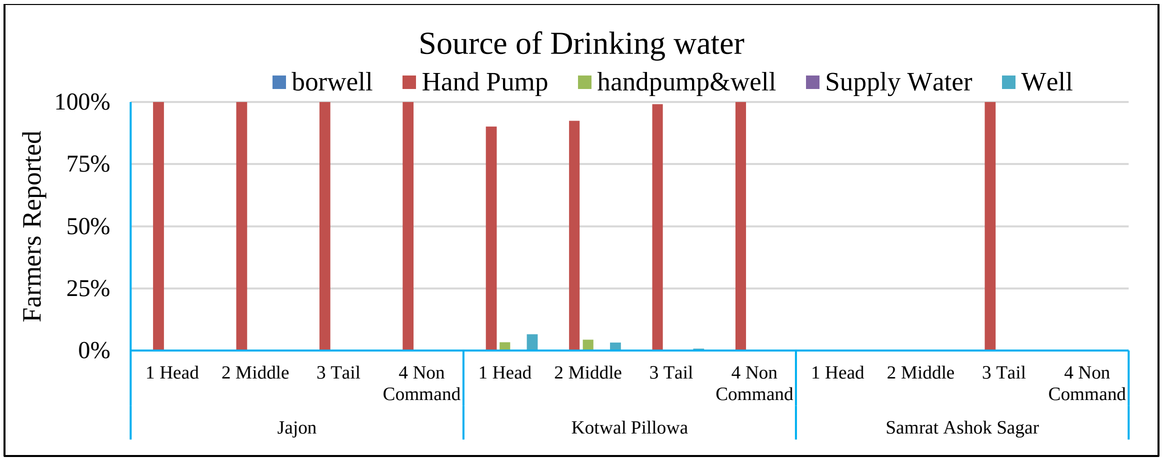


Figure 4.51: Source of Drinking Water

As shown in Figure 4.51, the majority of farmers in Jajon, Samrat Ashok Sagar, and Kotwal-Pillowa command have reported their source of drinking water is handpumps. Few large farmers have their borewells to get a drinking water supply. Several community water supply schemes are in progress to provide drinking water supply to these villages.

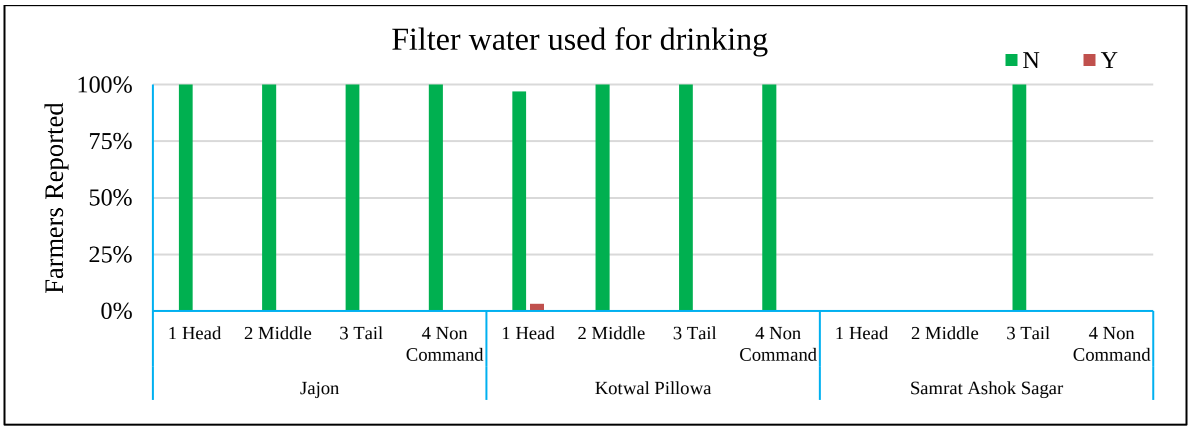


Figure 4.52: Filter water used for drinking

As shown in Figure 4.52, the majority of farmers living in villages falling in Jajon, Samrat Ashok Sagar, and Kotwal-Pillowa commands are not using filters or RO water filters for drinking water. The farmers living in cities or towns are seen using water filters to filter drinking water before consumption.

4.5.11 WUA issues in command area

The survey questionnaire included questions related to managerial and community participation aspects of the command area like whether the command area has a Water User Association (WUA), do farmers raise their issues in WUA meetings, do they feel that the problems are solved, whether the president of WUA handled the disputes successfully, do dam authority releases water as per the need of the crop, sowing of water resistance short duration variety during drought, do they have less production during drought years, do you feel ownership of the project and measures are required for further improvement.

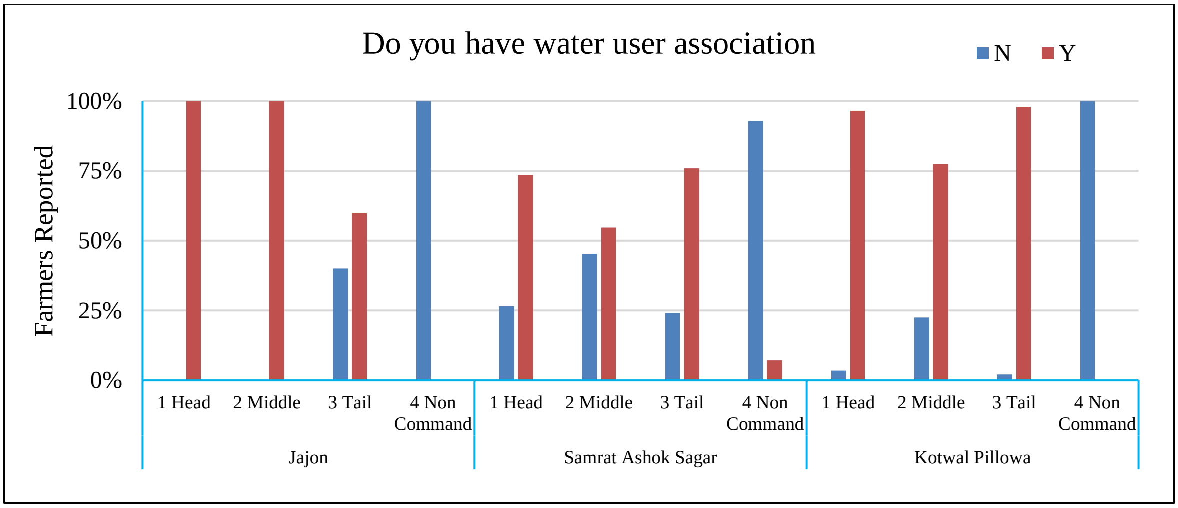


Figure 4.53: Do they have a water user association

As shown in Figure 4.53, all three irrigation projects, Jajon, Samrat Ashok Sagar, and Kotwal-Pillowa command have an elected WUA duly elected by the beneficiaries. The majority of farmers in the head, middle, and tail reach areas have reported having a water user association however in some pockets of Samrat Ashok Sagar such WUA are not formed.

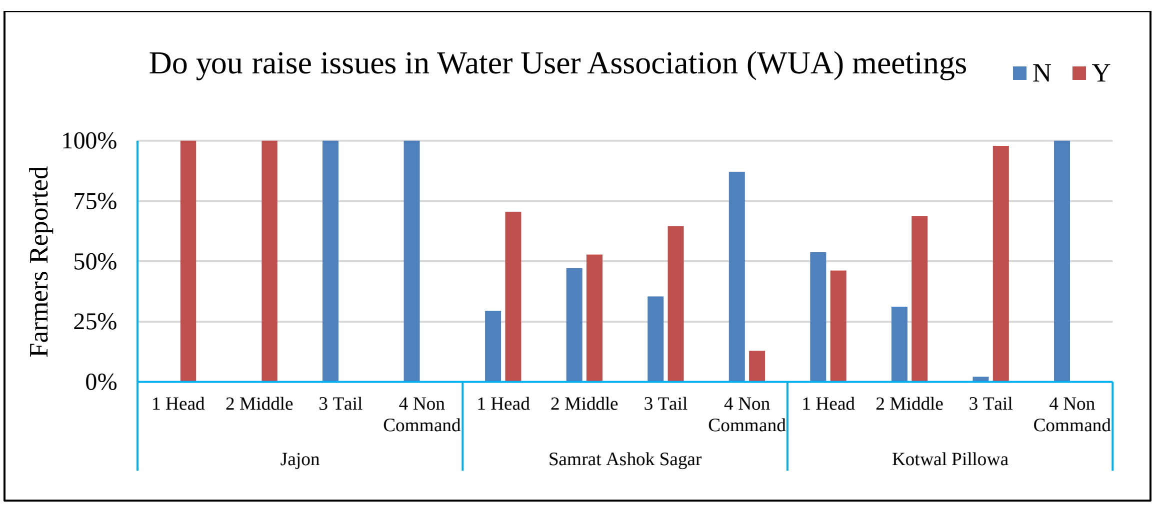


Figure 4.54: Do you raise issues in water user association meeting

As shown in Figure 4.54, in Jajon command 100% of farmers in head and middle reach have reported raising their issues during WUA meetings and farmers in the tail region are seen as reluctant. In Samrat Ashok Sagar command around 50 to 70% of farmers raise their issues and a similar situation was reported in the Kotwal-Pillowa command, especially by the farmers of the tail-end area.

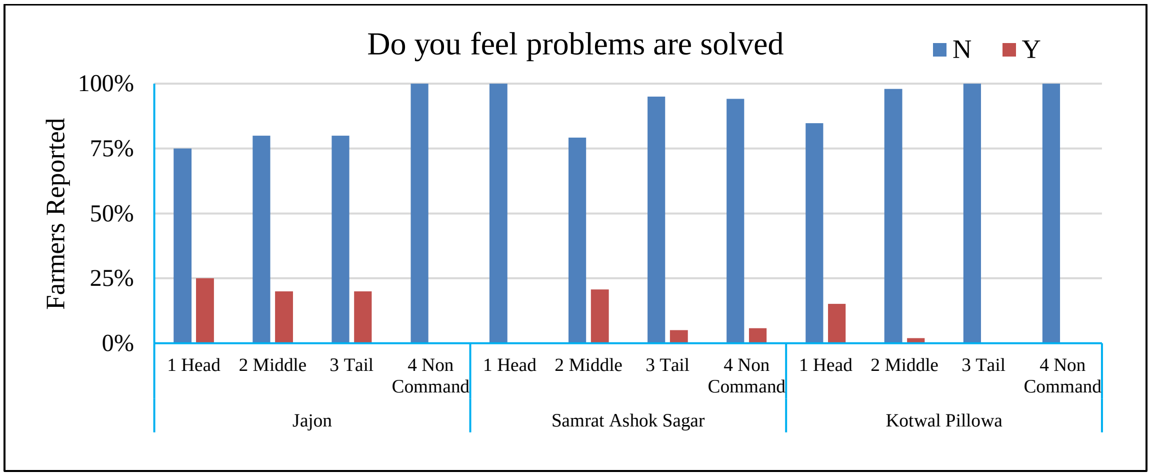


Figure 4.55: Problems solved in WUA meeting

As shown in Figure 4.55, surprisingly 80 to 85% of farmers in Jajon, Samrat Ashok Sagar, and kotwal commands have reported that their problems are not solved. However, 15% of farmers were seen as satisfied with WUA and they feel that their problems are solved by the association.

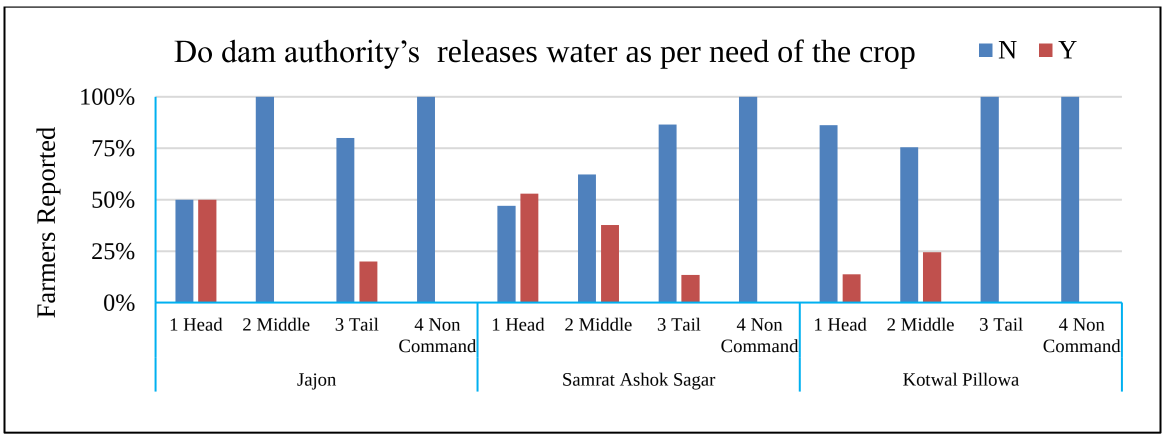


Figure 4.56: Dam authority releases water as per the need of the crop

This was a very important aspect of the survey, when asked about whether the dam authority releases water as per the need of the crop, 80 to 100% of farmers in Jajon command reported that water was not released as per the crop need which can be seen in Figure 4.56. A similar answer was reported by the farmers in the other two irrigation project commands. The dissatisfaction on this issue has been seen clearly in the tail reach of all three commands. This issue is of great concern to provide timely irrigation as per the need of the crop and the project authority has to develop a suitable mechanism to address this issue.

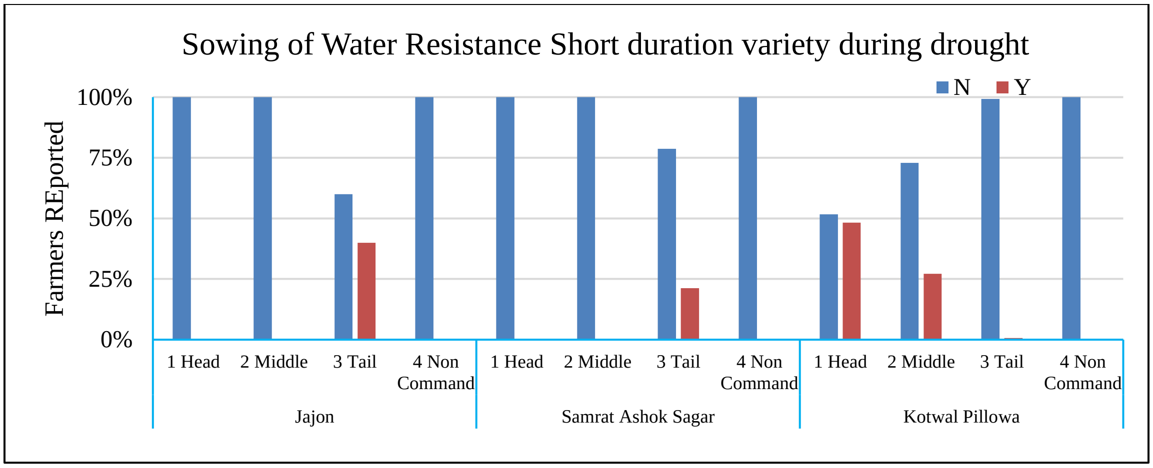


Figure 4.57: Sowing of Water Resistance Short duration variety during drought

As seen earlier, the recurrence of drought in the study area was observed as one drought after every 4 to 6 years in the case of all three selected dams. As shown in Figure 4.57, the majority of farmers in all three project commands and their head, middle and tail reach reported that they are not doing crop planning according to the drought situation. They do not opt for water-resistant and short-duration crops during droughts. However, 40% of farmers in the Jajon tail reach area, 20% of farmers in the Samrat Ashok Sagar command tail area, 50% in the head, and 30% in the middle reach of Kotwal-Pillowa command have reported sowing of water resistance short duration crop variety during drought periods. Thus awareness of growing the right crop at right time is very important to reap benefits even during the water scarcity period. This urges the need for continuous interaction for creating awareness among the farmers.

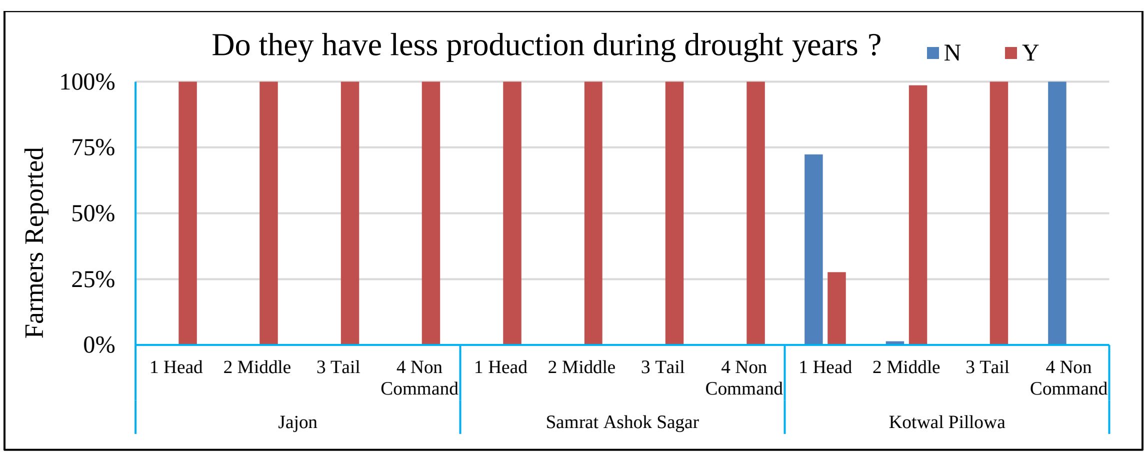


Figure 4.58: Reduced production during drought years

As shown in Figure 4.58 almost 100% of farmers in Jajon and Samrat Ashok Sagar command have reported a reduction in agricultural production during drought years. However, 70% of farmers in the head reach area of Kotwal-Pillowa command have reported that agriculture production has very little impact on droughts. This was seen due to water availability in the head-reach areas even during the severe drought years. The impact of drought on production was seen evident in the middle and tail reach of the Kotwal-Pillowa command.

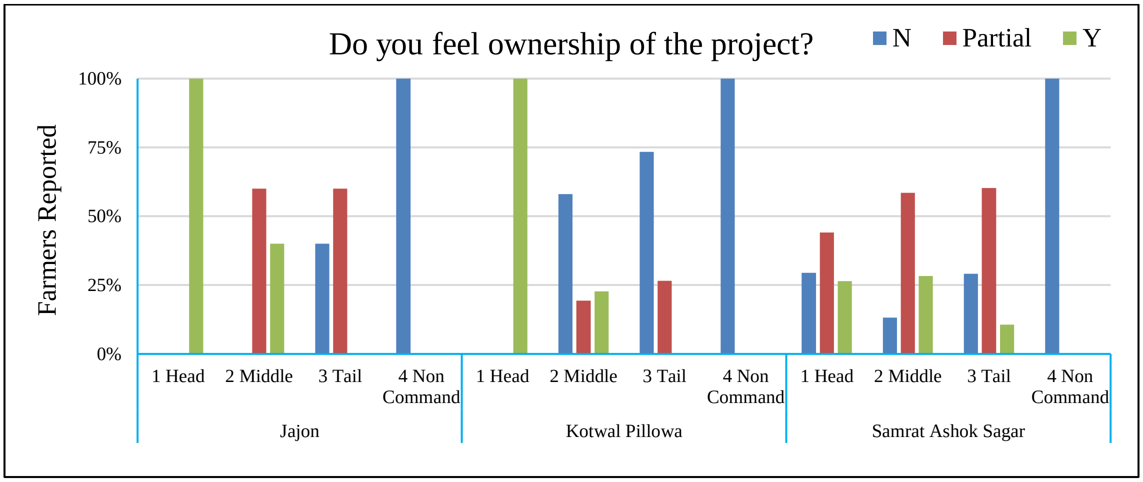


Figure 4.59: Feel ownership of the project

As shown in Figure 4.59, 100% of farmers in the head reach of Jajon and Kotwal-Pillowa command expressed the feeling of ownership of the irrigation project. This is a very important issue to adopt a participatory irrigation approach in the command area. Around 60% of farmers in Kotwal-Pillowa and Samrat Ashok Sagar dam felt partial ownership. However, 30 to 40% of farmers falling in the tail reach area of the command expressed no such feeling of ownership about the project. This fact may be due to the deficient irrigation supply in that area and the majority of farmers in the tail-reach region are using groundwater for irrigation.

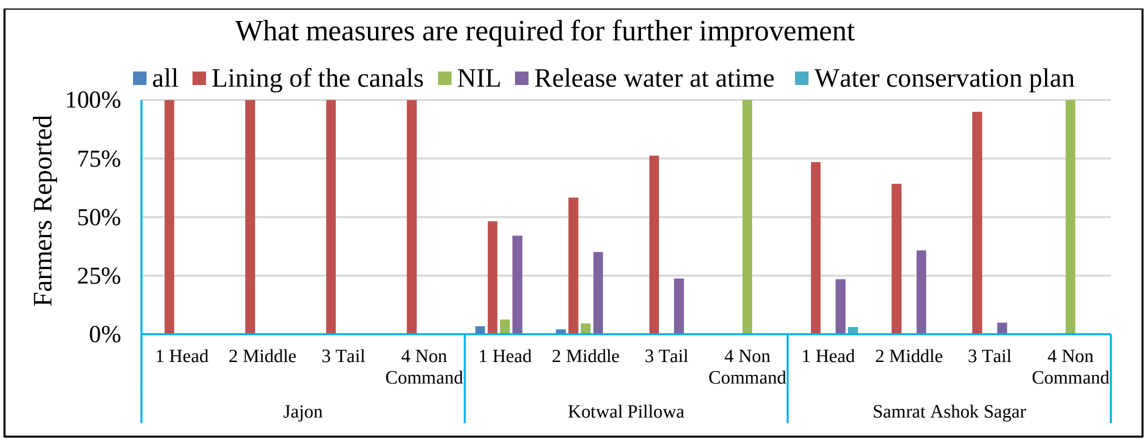


Figure 4.60: Measures required for further improvement

According to survey data, as shown in Figure 4.60, 100% of farmers in Jajon command, 50 to 60% of the farmer in Kotwal-Pillowa command, and 60 to 70% of farmers in Samrat Ashok Sagar command have expressed that the lining of the canal is the major issue to make optimal use of irrigation water.

4.6 Performance Evaluation of Irrigation Projects

In the present PDS, the performance evaluation analysis has been carried out for eight medium and minor irrigation projects namely Kotwal-Pilowa dam, Doraha dam, Naren Dam, Mala dam, Kaketo, Lilgi, Umrar, and Jajon dam. These dams are located in the major tributaries of the Ganga and Yamuna basins such as Betwa, Chambal, Dhasan, Ken, Son, tone, and Sindh.

The performance evaluation analysis of irrigation projects was carried out using nine comparative indicators suggested by International Water Management Institute (IWMI), Sri Lanka. These nine indicators are broadly categorized as agriculture, water use, or physical and economic performance evaluation of the irrigation project as suggested by Molden et al. (1998). The performance evaluation analysis aims to evaluate the irrigation project performance, assess the general health of the system, assess progress against strategic goals, assess the impact of interventions, diagnose constraints of the system, to better understand determinants of performance, compare performance with other system or with the same system over time and to improve system operations. It will help to identify bottlenecks, constraints, managerial laps, and other grey areas in the system. The ultimate goal of the whole exercise is to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system.

The present study involves the collection of primary and secondary data from field and Government departments respectively. The details of data collection, methods applied and indicators used are discussed in detail in Chapter Methodology. Primary data has been collected through field surveys and participator approach discussions to be held with beneficiary farmers and development agencies. It includes a collection of information from water user associations, farmers on the crop, production, agricultural practices, prices, etc., and informative discussion. Secondary data collection includes daily rainfall, meteorological data, dam details, crop type, area under different crops, total agricultural yields, prices of irrigated crops, area irrigated per crop per season or per year, crop types, production cost per season or year, and cropping pattern. These data have been collected from the Water Resources Department, Agricultural Department, Statistical Department, and Revenue Department. Climatic data of each irrigation project have been collected from the nearby weather stations, IMD Pune, and Data Centre MPWRD.

It has been observed that most of the minor and medium dams which are selected for the study have very little and inadequate data, in some cases, records are not traceable. The biggest problem was collecting release data for minor and medium dams. Hence obtaining data seems to be a great challenge. However, the data and information collected from WRD and other line departments such as Collectorate, Agricultural department, Revenue department, Statistical department, etc. have been almost completed through extensive surveys, field visits, and follow-ups with the line departments. The performance evaluation analysis report in the case of the Kotwal-Pillowa irrigation project has been elaborated in detail and summaries and outcomes of all other dams have been given in the following section. Salient fetures of all dams are given in *Annexure-II*.

4.6.1 CASE 1: Kotwal-Pillowa irrigation project

Irrigation development is one of the most commonly practiced strategies to increase agricultural production, food security, rural livelihood, and rural development. However, food security issues in developing nations have always been aggravated by the rapid population growth and the consequent demand for food (FAO, 1997). To tackle the situation India has achieved significant progress in creating many major, medium and minor irrigation projects after independence thereby increasing agricultural production in the country. Yet dissatisfaction with the performance of irrigation projects in the country is widespread. Despite their promises, irrigation projects typically perform far below their potential due to one or many reasons (Small and Svendsen, 1992). The low performance of the project may be due to inadequate management at the system and field levels (Cakmak et al., 2004). Therefore, it is important to evaluate the performance of the irrigation projects continuously to identify bottlenecks, constraints, managerial laps, and other grey areas in the system and to provide direction for improvement in water resources development and management strategies to reap its full benefits on a long-term basis. The performance evaluation of the irrigation project is an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. In the present study, the performance of the Kotwal-Pillowa complex irrigation project located in Madhya Pradesh has been evaluated using comparative indicators suggested by the International Water Management Institute (IWMI).

A number of studies have been conducted all over the world for performance evaluation of irrigation projects. International Water Management Institute, Sri Lanka in their Research Report No. 20 suggested the Indicators for comparing the performance of irrigated agricultural systems. Molden et al., (1998) compared the performance of eighteen irrigation systems located in eleven different countries through various indicators. Murray-Rust and Snellen (1993) conducted a research study on irrigation system performance assessment and diagnosis. Das et al., (1992) suggested performance evaluation parameters of irrigation canal systems should involve factors such as command area, canal network, control structures, cropping patterns, and weather conditions as well as human factors. Mohamed (1992) conducted a multi-objective performance evaluation of irrigation systems in less developed countries. Burt et al., (1997) emphasized standardizing the definitions and approaches to quantify various irrigation performance measures. Droogers et al., (1999) concluded that if irrigation performance indicators are used only at a local scale, a misleading picture can be given on the regional scale. Mishra et al., (2001) computed a performance ratio and used it as an indicator for assessing the degree of uniformity in flow deliveries along the length of the canal in the Right Bank Main Canal system of the Kangsabati project in West Bengal. Droogers and Bastiaanssen (2002) reported that irrigation performance and water accounting are useful tools to assess water use and related productivity. Ray et al., (2002) computed multi-temporal remote sensing data-based performance indices for the distributaries of the Mahi Right Bank Canal command in Gujarat, India.

Styles and Marino (2002) described the irrigation performance of sixteen international irrigation projects in less developed countries and found that the performance of many projects was poor due to technical, financial, managerial, social, and institutional causes. Bandara (2003) used *NOAA* satellite data to assess the performance of three large irrigation systems in Sri Lanka during the year 1999. Upadhyaya et al., (2004) identified constraints in water delivery from the canal and developed performance indicators. Bhatta et al., (2006) compared the performance of agency-managed and farmer-managed irrigation systems in Chitwan, Nepal. Singh et al., (2013) have carried out a case study to assess the performance of the Lift Irrigation Scheme Sirsa-Manjholi in the Solan area of the Shivalik Himalayas. Ingle et al., (2015) studied the performance of the Kalwande Minor Irrigation Scheme (KMIS) in the Ratnagiri district of Maharashtra and observed that the output values were lower than the recommended package of IWMI practices. Bos et al., (1994) Methodologies for assessing the performance of irrigation and drainage management.

The performance of the Kotwal-Pillowa irrigation project was evaluated using seven comparative indicators classified into two groups, agriculture, and water-use or physical performance suggested by the International Water Management Institute (IWMI) Sri Lanka.

Study Area: Kotwal-Pillowa Irrigation Project

The Kotwal-Pillowa joint project is a complex project having two separate dams Kotwal and Pillowa on two rivers on Asan and Sankh respectively falling in the Sindh sub-basin of the Chambal river in the Morena district of Madhya Pradesh. The Kotwal-Pillowa project is located at 26°28’11" E Longitude and 78°4’55" N Latitude. The location map of the Kotwal-Pillowa project is shown in Figure 4.61. Both Kotwal and Pillowa dams are interconnected by Jararua connecting channels carrying water from Kotwal to Pillowa. Kotwal dam is supplemented by the Gandhi Sagar dam on the Chambal river contributes a major part of irrigation and is also supplied by the Pagara dam located on the Asan river upstream of Kotwal. The gross command area of the Kotwal-Pillowa complex irrigation project is 121547 ha and the culturable command area is 120387 ha which falls in parts of Morena and Bhind districts. The network of Kotwal-Pillowa complex irrigation projects is shown in Figure 4.62. The details of dams such as catchment area, gross storage capacity, and command area are given in Table 4.7. The climate of the Bhind district is characterized by a hot summer and general dryness except during the southwestern monsoon.

Major crops grown in the command area during the rabi season are wheat, gram, mustard, lentil, pea, barley, and other oil crops.

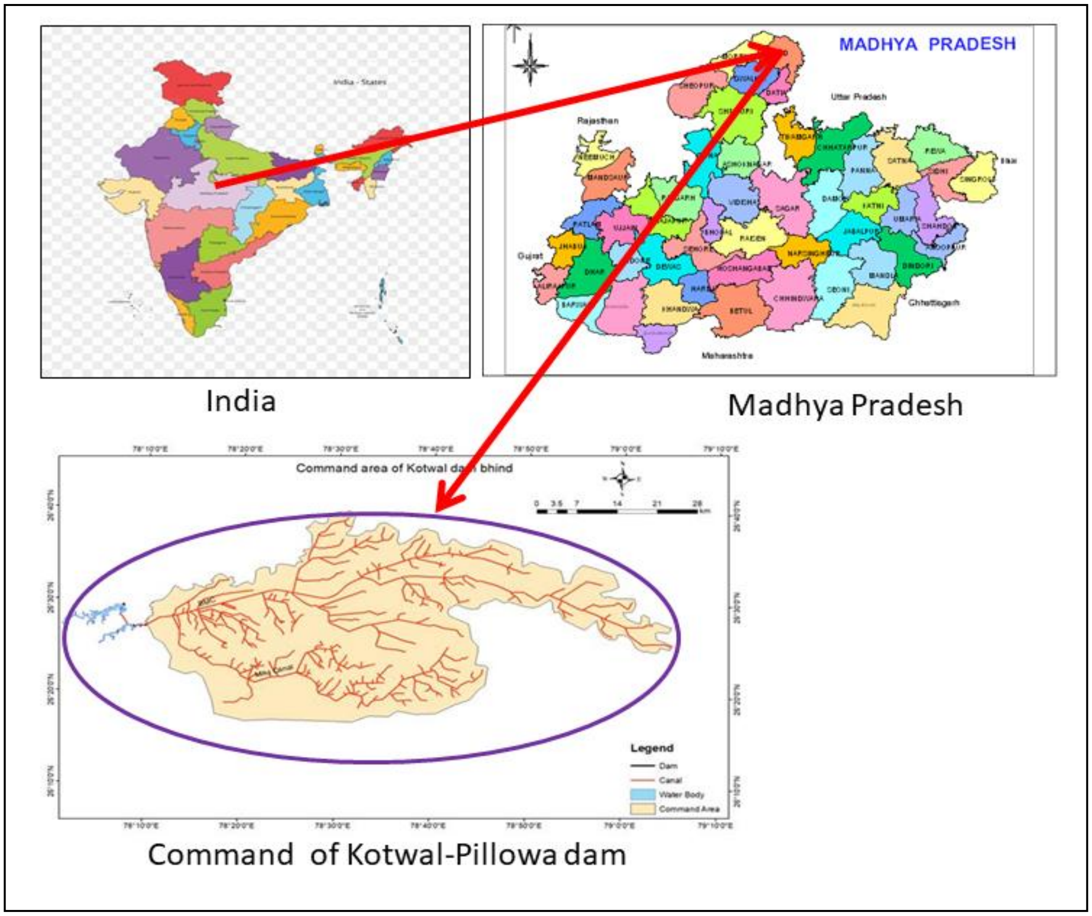


Figure 4.61: Location map of Kotwal-Pillowa project

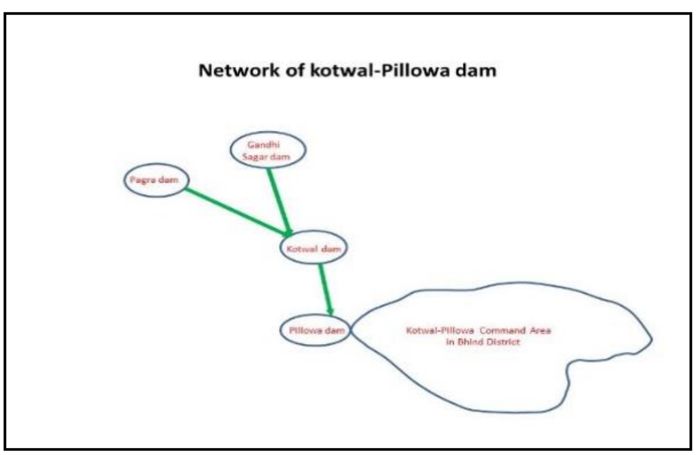


Figure 4.62: Network of Kotwal-Pillowa complex irrigation project

Table 4.7: Details of Kotwal-Pillowa complex irrigation project

Dams	Catchment Area (km^2)	Gross Storage Capacity (MCM)	Command area (ha)	Major Crops
Kotwal dam	1036	91.55	36830	Mustard Wheat Gram Lentil Pea, Barley, and other oil crops.
Pillowa dam	257.42	23.186		
Pagara dam		160.00		
Gandhi Sagar dam (on Chambal river)		556.00 (Diverted to Kotwal Dam)	83557	
Total		830.736	120387	

Data collection

The study involves significant data collection from field and concern departments such as the Crop area of each crop in command, the yield of each crop in the command area, the local price of each crop, the local price of the base crop, the value of base crop traded at the world price, command area, irrigated cropped area, total water supply, surface diversions, net groundwater draft, rainfall, irrigation supply, diverted irrigation supply, canal capacity to deliver water at system head. The present study has been carried out for four selected years 2005-06, 2009-10. 2013-14 and 2015-16. The long-term rainfall and meteorological data of Gwalior station were collected from the Indian Meteorology Department, Pune. Dam and command area-related data of selected years were collected from the Gohad and Bhind divisional offices of the Water Resources Department. Agricultural information was collected from the Agricultural department. Primary information such as sowing and harvesting of different crops, their duration, crop stage which needs irrigation, root zone depth of crop, etc. were collected from different sources including contacts with the local farmers and Water User Associations. The spatial information such as catchment area, water spread, command area, and canal network was digitized to prepare thematic maps using ARC GIS using 1:50000 scale Toposheet no. 54F/11; 12; 15; 16, 54G/5; 6; 9; 10, 54I/3 and 54J/2; 4; 6; 7; 10; 11; 15. The Bhind Main Canal (BMC) covers Bhind and a small part of Morena districts as shown in the command area map in Figure 4.63.

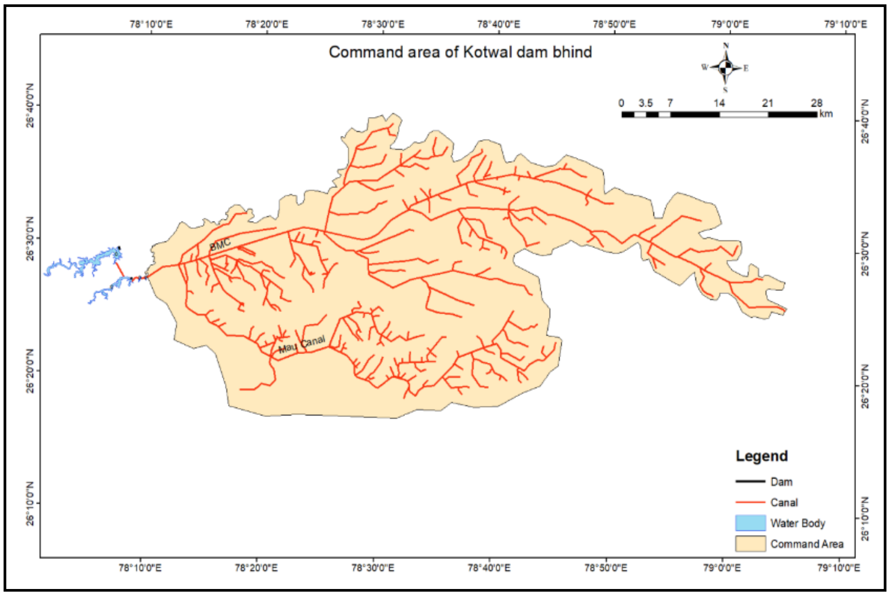


Figure 4.63: Command area map of Kotwal-Pillowa irrigation project

Comparative Performance Indicators

In the present study, the performance of the Kotwal-Pillowa irrigation project was evaluated using comparative indicators to evaluate its performance in terms of agricultural and water use performance as discussed in the previous section. The comparative indicators were analyzed for the Rabi seasons of years 2005-06, 2009-10, 2013-14, and 2015-16.

The Standardized Gross Value of Production (SGVP) is developed for cross-system comparison, as there are differences in local prices at different locations throughout the world. Agriculture performance was evaluated using four agriculture-based comparative indicators based on output per unit cropped area, command area, water consumed, and irrigation supply. Where Standardized Gross Value of Production (SGVP)is the output of the irrigated area in terms of the gross or net value of production measured at local or world prices. Irrigated cropped area is the sum of the areas under crops during the time of analysis. The command area is the design area to be irrigated. Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater. The volume of water consumed by ET is the actual evapotranspiration of crops. The volume of water consumed by ET (m^3) is the actual evapotranspiration of crops. The evapotranspiration was estimated using a modified Penman method using climatic data such as temperature, wind speed, relative humidity, and sunshine hours of Gwalior IMD station. For this purpose, the CROPWAT model program (FAO, 1992) was used. The actual crop water requirement (*ETc*) was calculated using the equation given by Doorenbos and Kassam (1986). *ETc* is the actual evapotranspiration or crop water requirement, K_c is the crop coefficient and ETo is the reference evapotranspiration. All agricultural performance indicators were compared with the Kalwande Minor Irrigation Scheme (KMIS) in the Ratnagiri district of Maharashtra(Ingle et al., 2015). The modified Crop factor (Kc) values for different crops in Madya Pradesh as per the Madhya Pradesh Irrigation Department Design Series Technical Circular (1990) Irrigation crop water requirement and irrigation requirement, TC- 25, GoMP are considered in the analysis and are given *Annexure-III.*

Water Use performance

The evaluation of the physical performance of the irrigation system was carried out using mainly three indicators they are Relative Water Supply (RWS), Relative Irrigation supply (RIS), and Water Delivery Capacity (WDC). They are meant to characterize the individual system for water supply and finances (Molden et al, 1998). Relative water supply and relative irrigation supply are used as the basic water supply indicator. Both RWS and RIS relate supply to demand and give some indication as to the condition of water abundance or scarcity, and how tightly supply and demand are matched in Kotwal-Pillowa irrigation projects. Water delivery capacity is meant to indicate the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands in Kotwal-Pillowa irrigation projects. Three types of indicators, relative water supply (RWS), relative irrigation supply (RIS), and water delivery capacity (WDC) were used for the evaluation of water use performance (Levine, 1982; Perry, 1996).

RWS indicates whether enough water is available in the dam to meet crop demand in the command area. The RWS relates the water made available for crops, including surface irrigation, groundwater pumped, and rainfall against the crop's needs. This indicator provides information about the relative abundance or scarcity of water. The RIS indicates whether crops are getting enough water and how canal irrigation supply and demand are matched. A value of RIS over one would suggest too much water is being supplied, possibly causing waterlogging and negatively impacting yields, and a value less than 1 indicates that crops are not getting enough water.

Both RWS and RIS relate supply to demand, and give some indication of water abundance or scarcity, and how tightly supply and demand are matched. If the irrigation system design constrains agricultural production then the water delivery capacity can suggest changes in irrigation infrastructure or cropping patterns to maximize cropping intensity. The water delivery capacity (WDC) is calculated based on the canal's capacity to deliver water at the system head. The present discharge capacity of the canal at the system head and peak consumptive demand is the crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system. WDC is meant to indicate the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands.

Results and Discussion

The performance of the Kotwal-Pillowa irrigation project was evaluated for its agricultural and water use performance using seven comparative indicators as suggested by IWMI. The performance evaluation was carried out for the Rabi season of the years 2005-06, 2009-10, 2013-14, and 2015-16. The information on diverted irrigation supply, irrigation supply, total water supply, water delivering capacity at a canal head during those selected years, and evapotranspiration was estimated using the CROPWAT 8.0 model and also given in Table 4.8. The diverted irrigation supply during 2013-14 and 2015-16 has increased as compared to the year 2005-06 and 2009-10. This has improved the total water supply in the command of Kotwal-Pillowa after 2013-14.

Table 4.8: Input parameters information for Kotwal-Pillowa irrigation projects

Years	Diverted irrigation supply (MCM)	Irrigation supply (MCM)	Volume ET (MCM)	Total water supply (MCM)	Capacity of canal Head (Cumec)
2005-06	157.5	157.5	577.0	157.8	44.15
2009-10	280.4	280.4	478.0	283.5	44.15
2013-14	614.9	614.9	192.8	630.9	44.15
2015-16	725.4	725.4	379.3	740.4	44.15

Estimation of Standardized Gross Value Production (SGVP)

SGVP values estimated for Rabi crops grown in the Kotwal-Pillowa irrigation project for the periods 2005-06, 2009-10, 2013-14, and 2015-16 have been shown in Table 4.9.

Table 4.9: Standardized SGVP

Years	Cropped area (ha)	Avg. Yield (ton/ha)	Production (Thousand ton)	SGVP (Cr. Rs)
2005-06	23133	1.21	33.5	31.28
2009-10	18959	1.25	31.2	46.65
2013-14	75802	1.59	146.1	342.77
2015-16	147639	1.79	339.2	618.28

In Kotwal-Pillowa command, the Mustard crop has been observed to grow in the majority of the command area, hence considered as a base crop for the calculation of SGVP. It is also the most tradable crop in the region. The Cropped area in Kotwal-Pillowa command has increased from 23133 ha in 2005-06 to 147630 ha in 2015-16. The average yield and production have also been found to increase during this period. Thus the SGVP value in the Kotwal-Pillowa command has been seen to increase from Rs. 31.28 Cr. in the year 2005-06 to Rs. 618.28 Cr. in the year 2015-16.

Performance evaluation of the irrigation projects

In this analysis SGVP values of the Kotwal-Pillowa irrigation project were used to evaluate seven 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. Year-wise comparative indicators evaluated for the years 2005-06, 2009-10, 2013-14, and 2015-16 are shown in Table 4.10 which can easily be compared with each other during various years.

Table 4.10: Evaluated comparative indicators for the Kotwal-Pillowa irrigation project

Year	SGVP (Lakh Rs)	Irrigated area (Thousand ha)	Command area (Thousand ha)	Effective Rainfall (mm/season)	Total ER (MCM)	Total water supply (cusec)	Diverted irrigation supply (MCM)	Volume ET (MCM)
2005-06	31.28	23.13	120.5	11.1	0.25	17176	157.54	57.78
2009-10	46.65	18.95	120.5	16.5	3.12	30570	280.40	47.86
2013-14	342.77	75.80	120.5	21.1	15.99	67042	614.93	192.84
2015-16	618.28	147.63	120.5	10.1	14.91	79095	725.49	379.35
Year	Total water supply DIS+TER (MCM)	CWR (mm/season)	Total CWR (MCM)	Irrigation supply (MCM)	IR (mm/season)	Total IR (MCM)	CCDWSH (cusec)	PCD (l/s/ha)
2005-06	157.80	249.81	57.78	157.54	244.92	56.65	44.15	0.35
2009-10	283.52	252.48	47.86	280.40	106.34	20.16	44.15	0.36
2013-14	630.93	254.41	192.84	614.93	233.96	177.34	44.15	0.35
2015-16	740.40	256.95	379.35	725.49	243.46	359.44	44.15	0.33
Year	PCD (cusec)	RWS	RIS	OPICA (Thou Rs/ha)	OPCA (Thou Rs/ha)	OPIS (Rs/m^3)	OPWC (Rs/m^3)	WDC
2005-06	8.10	2.73	2.78	13.52	2.59	1.99	5.41	5.45
2009-10	6.83	5.92	3.20	24.60	3.86	1.66	9.75	6.47
2013-14	26.53	3.27	3.47	45.22	28.42	5.57	17.77	1.66
2015-16	48.72	1.95	2.02	41.87	51.27	8.52	16.30	0.90

Evaluation of agriculture performance

Evaluation of agriculture performance involves the analysis of comparative indicators such as output per unit cropped area, output per unit of command area, output per unit of water consumed and output per unit of irrigation supply.

Output per unit cropped area

A comprehensive analysis of Table 4-65 indicated a significant rise in output per unit-cropped area during the Rabi season of the Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per unit cropped area in different years is shown graphically separately in Figure 4.64. It is seen that the Output per unit cropped area was 13523 Rs/ha in the year 2005-06 and increased to 45220 Rs/ha in the year 2013-14. However, with the same setup and infrastructure of the irrigation project, it was found to drop in the year 2015-16.

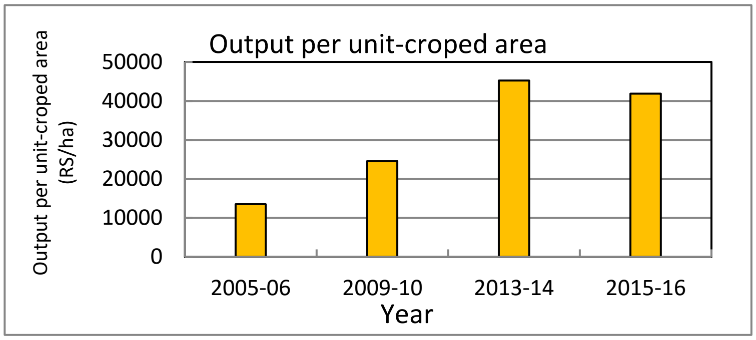


Figure 4.64: Outputs per unit cropped area

On the detailed examination, it was understood that the drop in indicator was due to a reduction in the base crop price at the world level in 2015-16 as compared to 2013-14. In the comparison of output per unit cropped area of Kotwal-Pillowa with Kalwandey minor irrigation scheme (KMIS) in Chiplun, Ratnagiri districts of Maharashtra and other irrigation schemes. It was found quite low in the case of the Kotwal-Pillowa project. It suggests the need for improvement to increase production, reduction of cost of cultivation providing proper support price to the produce.

Output per unit Command Area

Analysis indicated a significant rise in output per unit-command area during the Rabi season of the Kotwal-Pillowa irrigation project during the period from 2005-6 to 2016-17. The output per unit command area in different years is shown graphically separately in Figure 4.65. The production rate obtained varied between 2594 to 51272 Rs/ha during the Rabi season and the output per ha has been found to increase. The output per unit command area is compared for the last two years (i.e. 2013-14 and 2015-16). It is observed that the output per unit command area has increased by 28425 Rs/ha in the year 2013-14 and 51272 Rs/ha in the year 2015-16. This indicates that there is a need to develop a command area and increase the cropped area in the Kotwal-Pillowa project.

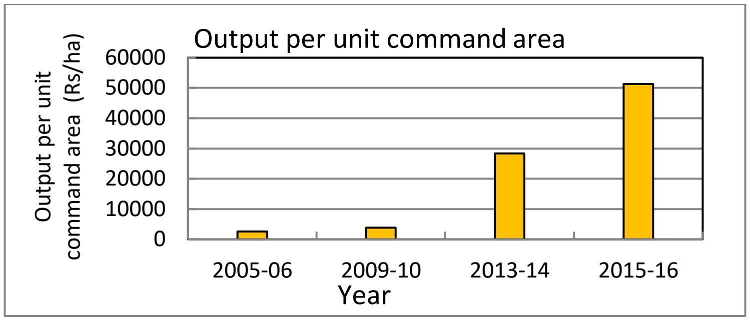


Figure 4.65: Outputs per unit command area

Output per unit of water consumed

The analysis of results indicated a significant rise in output per unit water consumed during the Rabi season of the Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per unit water consumed in different years is shown graphically separately in Figure 4.66.

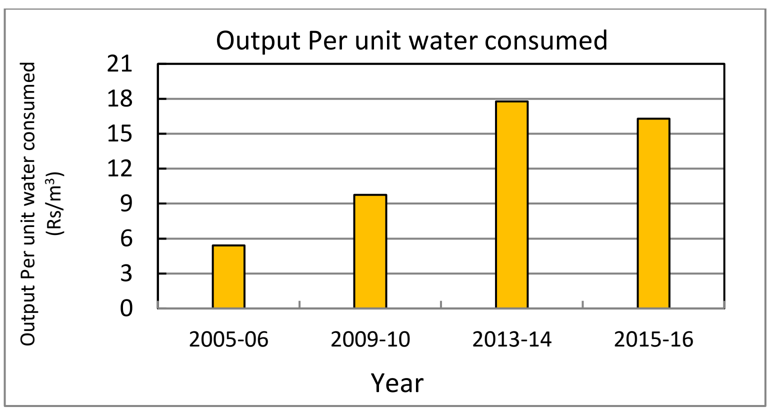


Figure 4.66: Output per unit of water consumed

From the analysis, it was observed that the Output per unit of water consumed was 5 Rs/m^3 in the year 2005-06 and increased to 17 Rs/m^3 and 18 Rs/m^3 during the year 2013-14 and 2015-16 respectively. The Output per unit of water consumed in the year 2013-14 was higher as compared to 2015-16 which may be due to less water consumed and high gross returns.

Output per unit irrigation supply (OPUIS)

The analysis of Table 16 indicated a significant rise in output per unit of irrigation supply during the Rabi season of the Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per irrigation supply in different years is shown graphically separately in Figure 4.67. The result shows the output per unit of irrigation supply varied between 1 to 7 Rs/m^3 indicating significant variation during the study periods. It was higher for the year 2015-16 due to less water consumed and high gross returns. The increase in the Standardized Gross Value Production (SGVP) per unit of irrigation supply can be achieved through orchard medical crops and vegetables.

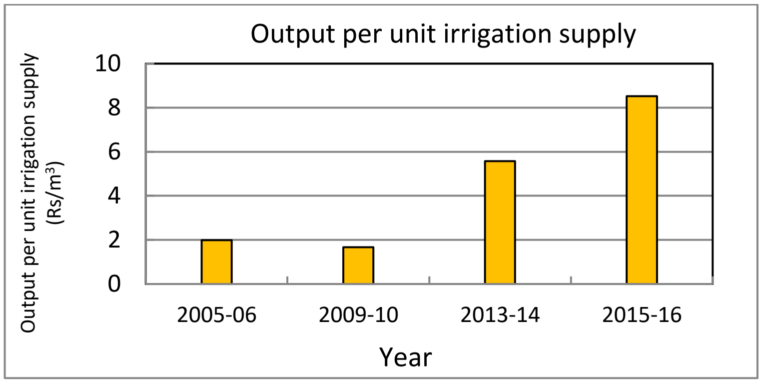


Figure 4.67: Outputs per unit of irrigation supplies

Evaluation of Water use performance

Evaluation of Water use performance involves the analysis of three types of indicators, relative water supply (RWS), relative irrigation supply (RIS), and water delivery capacity (WDC).

Relative water supply (RWS)

The analysis of Table 16 indicated a significant rise in Relative water supply during the Rabi season in the year 2009-10. However, it was found quite low during other years. The year-wise Relative water supply (RWS) is shown in Figure 4.68.

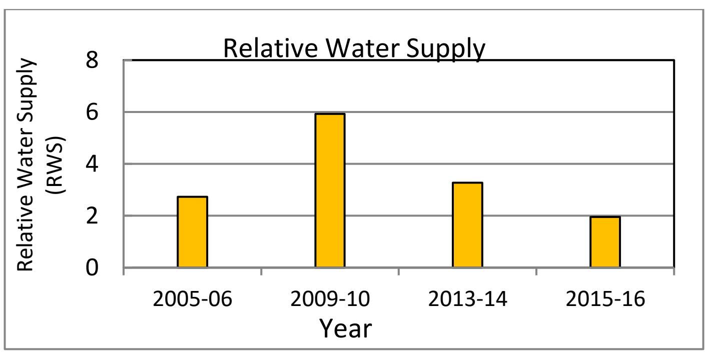


Figure 4.68: Relative water supplies

The relative water supply indicators during the Rabi season in the years 2005-06, 2009-10, 2013-14, and 2015-16 were found as 2.73, 5.92, 3.27, and 1.95 respectively. A value of more than 1.0 indicates that the total water supply is enough to meet the crop demand. Excess water supply was seen during the year 2009-10 and the relative water supply was better in the year 2015-16 as compared to other years during the study period. The relative water supply value of 1.91 was observed for Hayrabolu Irrigation Scheme in Turkey, 3.13 to 5.96 for Takez basin, Northern Ethiopia for the years 1998 to 2002, 1.14 for the tail reach of Patna main canal command, Bihar, and 1.41 to 4.04 for different irrigation schemes in Turkey for the year 2001 and 2.49 Kalwande minor irrigation scheme. In comparison, it could be concluded that the Kotwal-Pillowa command is getting sufficient irrigation water.

Relative irrigation supply (RIS)

The analysis of Table 16 indicated a significant rise in Relative irrigation supply during the Rabi season in the year 2009-10. However, it was found quite low during other years. The year-wise Relative irrigation supply (RIS) is shown in Figure 4.69.

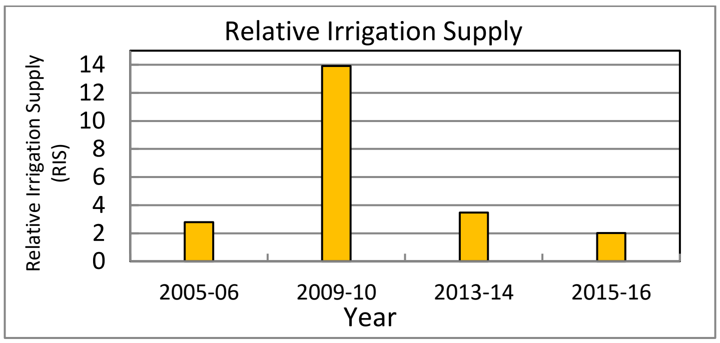


Figure 4.69: Relative irrigation supplies

The relative irrigation supply indicator during the Rabi season in the years 2005-06, 2009-10, 2013-14, and 2015-16 was found as 2.78, 13.90, 3.4, and 2.01 respectively. A value of more than 1.0 indicates that the irrigation supply by the canal is enough to meet the irrigation demand. Excess water supply was seen during the year 2009-10 and the Relative irrigation supply is better in the year 2015-16 as compared to during the study period. others irrigation projects the relative irrigation supply value was found between 0.41 to 4.81 for eleven different countries, 1.55 for the Hayrabolu Irrigation Scheme in Turkey, 1.4 and 0.77 for Nura Era and Wonji estate of Ethiopia, and 3.33 to 6.68 for Takez basin and the RIS Kalwande minor irrigation scheme was 1.27. This indicates that the Kotwal-Pillowa command is getting sufficient irrigation water.

Water delivery capacity (WDC)

The year-wise water delivery capacity for the Rabi season of the Kotwal-Pillowa irrigation project from the year 2005-6 to 2016-17 has been shown separately in Figure 4.70.

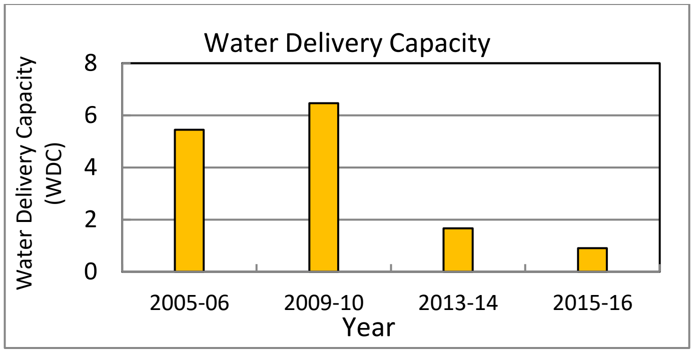


Figure 4.70: Water delivery capacities

Water delivery capacity indicator during Rabi-season in years 2005-06, 2009-10, 2013-14, and 2015-16. It is indicated that water delivery capacity in the year 2013-14 was better as compared to other seasons. Higher value in the year 2009-10 indicated that its capacity has a lesser constraint to meet crop water demands.

Major Conclusions of the analysis

The performance evaluation of the Kotwal-Pillowa, a complex irrigation project of Madhya Pradesh has been carried out for selected years 2005-06, 2009-10, 2013-14, and 2015-16 using comparative indicators suggested by International Water Management Institute (IWMI). This has been found very helpful to understand, how the improvement in diverted irrigation supply, increase in command area and other management practices have helped to improve the performance agricultural and physical performance of the project.

The Kotwal-Pillowa complex irrigation project is supplemented by the Gandhi Sagar dam on the Chambal River and the Pagara dam providing irrigation 1.21 lakh ha area in Morena and Bhind districts. In the comparison of the recent performance of the irrigation project to its past, it was observed that the output per unit cropped area was 13523 Rs/ha in the year 2005-06 and it increased up to 45220 Rs/ha in the year 2013-14. The output per unit command area was seen to increase from 28425 Rs/ha in the year 2013-14 to 51272 Rs/ha in the year 2015-16.

Though the year 2015-16 was a dry year, output per unit of irrigation supply was better i.e. 6.53 Rs/m^3, this was because of a high gross return due to adaptation of proper water management practices, and crop selection like vegetable, cash crop, and more horticulture. The Relative Water Supply (RWS) index should be nearly 1.0 and it was 1.95 in the year 2015-16. The RWS of the Kotwal-Pillowa project was found better as compared to other irrigation projects in India and worldwide. Similar results were also found in the case of the Relative Irrigation Supply (RIS) index and the Kotwal-Pillowa project has been found to perform well.

The Water Delivery Capacity index analysis indicated that the dam's infrastructure is capable of delivering water to meet peak water demand. Thus it could be concluded that the performance of the Kotwal-Pillowa irrigation project has been improved significantly in terms of its agricultural, water use based performance in the recent period especially after 2013-14, which is due to additional water supply from the Gandhi Sagar dam on Chambal river, increased cropped area and adoption of appropriate managerial practices. The performance evaluation is a simple method as comparative indicators are very easy to calculate by using field data and are useful to assess the progress of irrigation projects against strategic goals and formulate strategies to improve system operations.

4.6.2 CASE 2: Kaketo irrigation project

The Kaketo is a medium irrigation project situated at 25°53'50" N Latitude and 77°41'50" E Longitude which falls in Pohari Tehsil of Shivpuri district. It is constructed on the Parvati river in the Sindh basin and its command comes under the Shivpuri district. Its Gross storage Capacity at full reservoir level (FRL) is 79.3 MCM and the command area is 3271 ha shown in Figure 4.71.

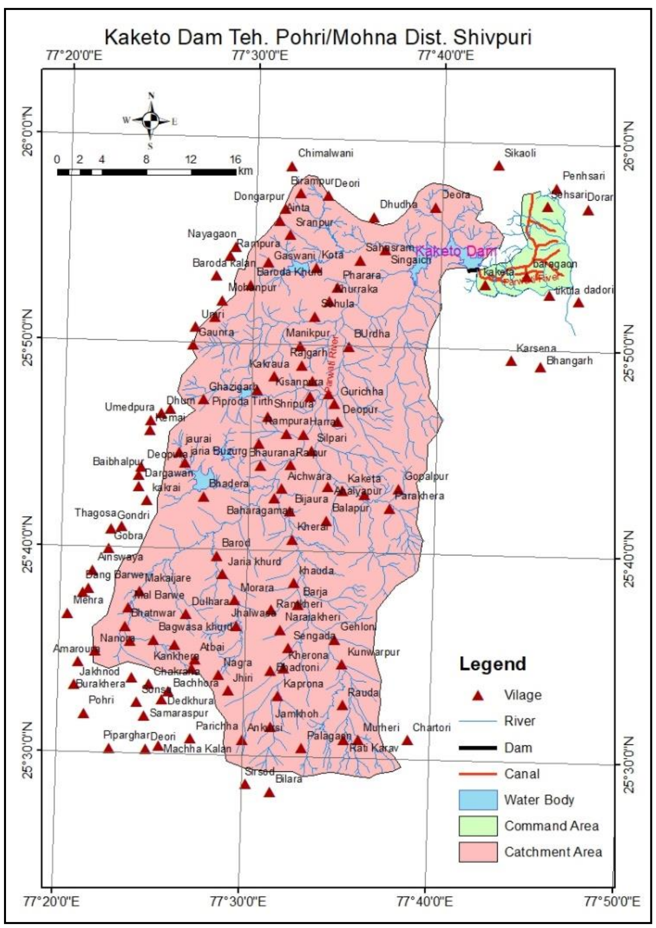


Figure 4.71: Command area map of Kaketo irrigation project

The performance evaluation of the Kaketo irrigation project has been carried out for Rabi seasons by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of four years 2014-15, 2015-16, 2016-17, and 2018-19. Evaluated comparative indicators for the Kaketo irrigation project are shown in Table 4.11 and a graphical comparison has been shown in Figure 4.72. The analysis could not be carried out for the year 2017-18 due to the non-availability of data for that year.

Table 4.11: Evaluated comparative indicators: Kaketo irrigation project

Year	SGVP (crore Rs)	Irrigated area (ha)	Command area (ha)	Volume ET (MCM)	Total ER (MCM)	Rainfall (Seasonal) mm	Total Rainfall (Seasonal) (MCM)	Net Removal Ground Water (MCM)	Water Supply from Canal (MCM)	Diverted irrigation supply (DIS) MCM
2014-15	9.66	2644	2833	4.87	1.16	187.60	4.96	0.3312	33.31	33.64
2015-16	10.06	2662	2833	4.88	3.41	165.90	4.42	0.3312	29.37	29.70
2016-17	7.99	2600	2833	5.74	3.96	52.83	1.37	0.3312	24.89	25.22
2017-18	-	-	-	-	-	-	-	-	-	-
2018-19	12.68	2600	2833	5.96	4.32	50.10	1.30	0.3312	11.34	11.67

Year	Total water supply (MCM)	CWR (mm/season)	Total CWR (MCM)	IR (mm/season)	Total IR (MCM)	CCDWH (cumec)	PKD (l/s/ha)	PKD (cumec)	Cost of Irrigation infrastructure (Crore Rs)	Revenue from Irrigation (Crore Rs)
2014-15	38.60	184.32	4.87	157.82	4.17	14.15	0.21	0.56	143.39	0.07
2015-16	34.12	183.43	4.88	64.45	1.72	14.15	0.25	0.67	157.73	0.07
2016-17	26.59	220.76	5.74	48.89	1.27	14.15	0.3	0.78	173.50	0.07
2017-18	-	-	-	-	-	-	-	-	-	-
2018-19	12.97	229.16	5.96	40.51	1.05	14.15	0.26	0.68	209.93	0.07

Year	Total O&M Expenditure (crore Rs)	OPIA (Rs/ha)	OPCA (Rs/ha)	OPIS (Rs/m^3)	OPWC (Rs/m^3)	RWS	RIS	WDC	GRI %	FSS %
2014-15	0.05	36519	34083	2.87	19.81	7.92	8.06	25.48	7	143
2015-16	0.05	37791	35510	3.39	20.60	6.99	17.31	21.26	6	144
2016-17	0.05	30746	28217	3.17	13.93	4.63	19.84	18.14	5	140
2017-18	-	-	-	-	-	-	-	-	-	-
2018-19	0.05	48775	44763	10.87	21.28	2.18	11.08	20.93	6	140

Table 4-11 and Figure 4.72 shows all nine comparative indicators derived for the Kaketo irrigation project for the Rabi seasons of years 2014-15, 2015-16, 2016-17, and 2018-19. The major crop grown in the command was wheat, gram, and mustard in the command area of Kaketo dam. The output per unit cropped area was observed at 36519 Rs/ha in the year 2014-15 and it increased to 48775 Rs/ha in the year 2018-19 indicating an increase in crop productivity in the command area.

The output per unit command area was seen to increase from 34083 Rs/ha in the year 2014-15 to 44763 Rs/ha in the year 2018-19 indicating an improvement in land productivity in the command of Kaketo.

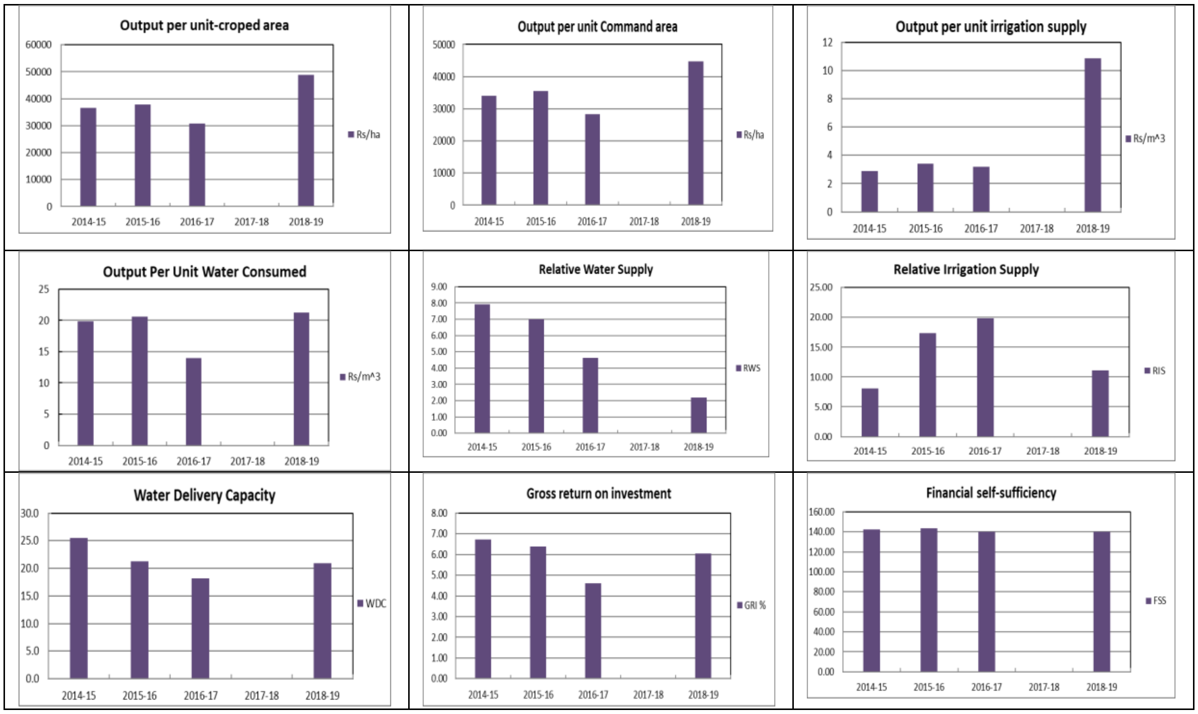


Figure 4.72: Performance evaluations of irrigation projects of Kaketo dam

As compared to the year 2018-19, the output per unit of irrigation supplies was better in another year of assessment, this was because of a high gross return due to the adaptation of proper water management practices and more area cultivation with orchards, industrial crops, vegetable and more horticulture in the Kaketo command. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed has been found to vary with time. The value of water consumed in the year 2016-17 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future. The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 2.18 to 7.92 and RIS values were seen ranging from 8.06 to 19.84. These irrigation indicators are ideally expected to be near 1.50. High values of RWS and RIS indicate abundant water availability in comparison to demand in the Kaketo command. Water Delivers Capacity (WDC) index indicates that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Kaketo dam has a very high capacity and water is being used for irrigation and to supply Pasari dam for irrigation purposes and Tigra dam for domestic water supply to Gwalior city. The Kaketo irrigation project has been seen as a good return in terms of investment and financially self-sufficient as indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

4.6.3 CASE 3: Doraha dam

A Doraha dam is a medium irrigation project situated at 23°23'57" N Latitude and 77°10'59" E Longitude which falls in Sehore Tehsil of Sihore district. It is located on a local river Utabli in the Chambal basin and its command area comes under the Sehore district. Its catchment area is 49.21 sq km, its Gross storage Capacity at full reservoir level (FRL) is 15.53 MCM and its command area is 2794 ha as shown in Figure 4.73.

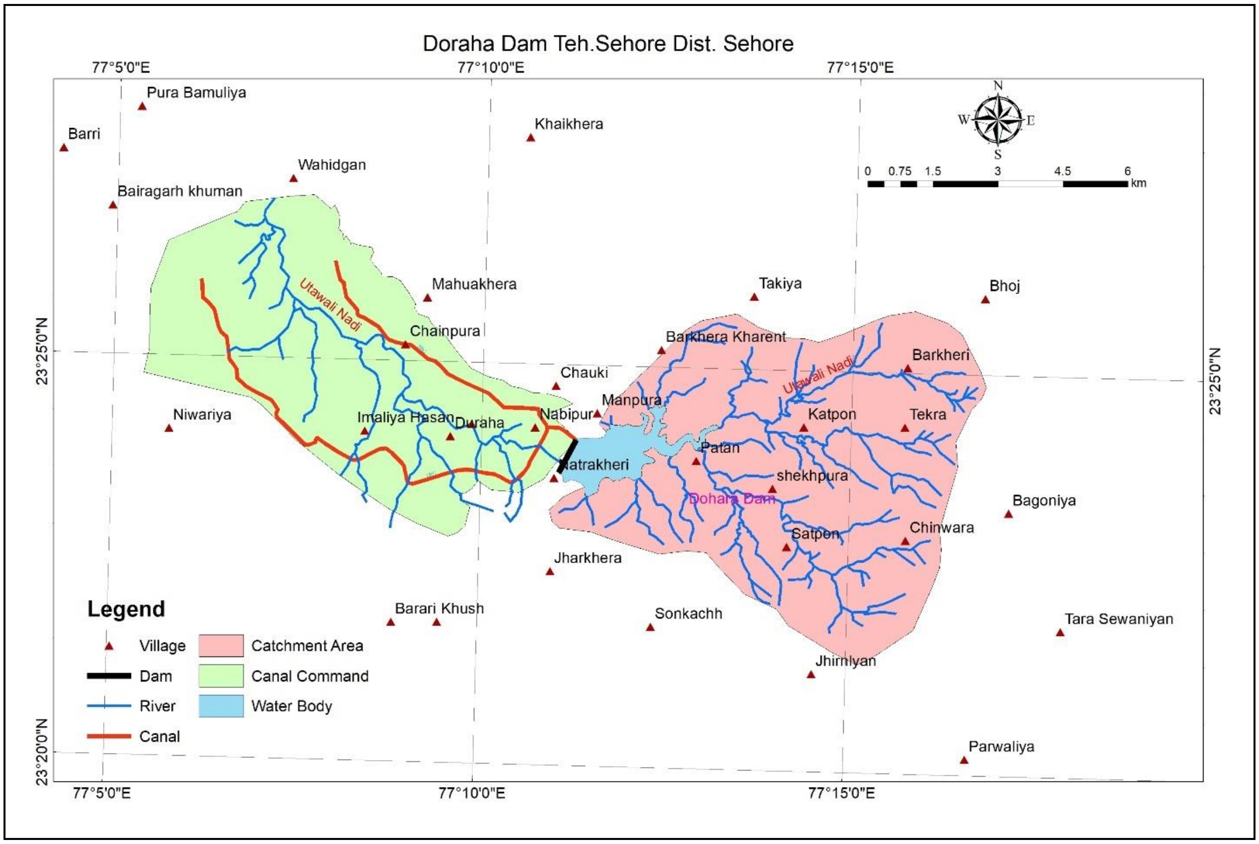


Figure 4.73: Doraha Dam

The performance evaluation of the Doraha irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Kaketo irrigation project are shown in Table 4.12 and a graphical comparison has been shown in Figure 4.74.

Table 4.12: Evaluated comparative indicators: Doraha irrigation project

Year	SGVP (crore Rs)	Irrigated area (ha)	Command area (ha)	Volume ET (MCM)	Total ER (MCM)	Rainfall (Seasonal) mm	Total Rainfall (Seasonal) (MCM)	Net Removal Ground Water (MCM)	Water Supply from Canal (MCM)	Diverted irrigation supply (DIS) (MCM)
2014-15	14.83	2826	2863	7.20	2.49	95.3	2.70	0.76	8.93	9.68
2015-16	14.27	2794	2863	8.68	1.89	92.4	2.59	0.76	15.55	16.30
2016-17	10.39	2213	2863	7.27	1.25	60.5	1.34	0.76	15.55	16.30
2017-18	5.96	950	2863	3.22	0.64	74.6	0.71	0.76	2.65	3.40
2018-19	16.50	2533	2863	8.58	1.84	80.7	2.05	0.76	10.06	10.81
Year	**Total water Supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR (MCM)**	**CCD WH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore)**	**Revenue from Irrigation (Crore)**
2014-15	12.37	254.54	7.20	185.18	5.24	3.54	0.34	0.96	120.93	0.08
2015-16	18.88	310.54	8.68	228.17	6.38	3.54	0.45	1.26	133.02	0.08
2016-17	17.64	328.32	7.27	283.44	6.28	3.54	0.46	1.02	146.32	0.07
2017-18	4.11	338.42	3.22	296.78	2.82	3.54	0.45	0.43	160.96	0.03
2018-19	12.85	338.43	8.58	262.48	6.65	3.54	0.42	1.06	177.05	0.070
Year	**Total O&M Expenditure (crore Rs)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0.06	52480	51802	15.33	20.62	1.72	1.85	3.68	12	151
2015-16	0.06	51070	49840	8.76	16.45	2.18	2.56	2.82	11	149
2016-17	0.06	46952	36292	6.38	14.30	2.43	2.60	3.48	7	118
2017-18	0.06	62777	20831	17.58	18.55	1.28	1.20	8.28	4	51
2018-19	0.06	65132	57624	15.27	19.25	1.50	1.62	3.33	9	135

Table 4-12 and Figure 4.74 shows all nine comparative indicators derived for the Doraha irrigation project for the rabi seasons of years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. The major crops grown in the command were wheat and gram. The output per unit cropped area of the project was 46952 Rs/ha in the year 2016-17 and it was increased to 65132 Rs/ha in the year 2018-19 indicating an increase in crop productivity in the command area. The output per unit command area was seen to decrease from 51802 Rs/ha in the year 2014-15, 20831 Rs/ha in the year 2017-18 and it was then again increased to 57626 Rs/ha in the year 2018-19 indicating reduction in land productivity for some years and improvement therein in later years.

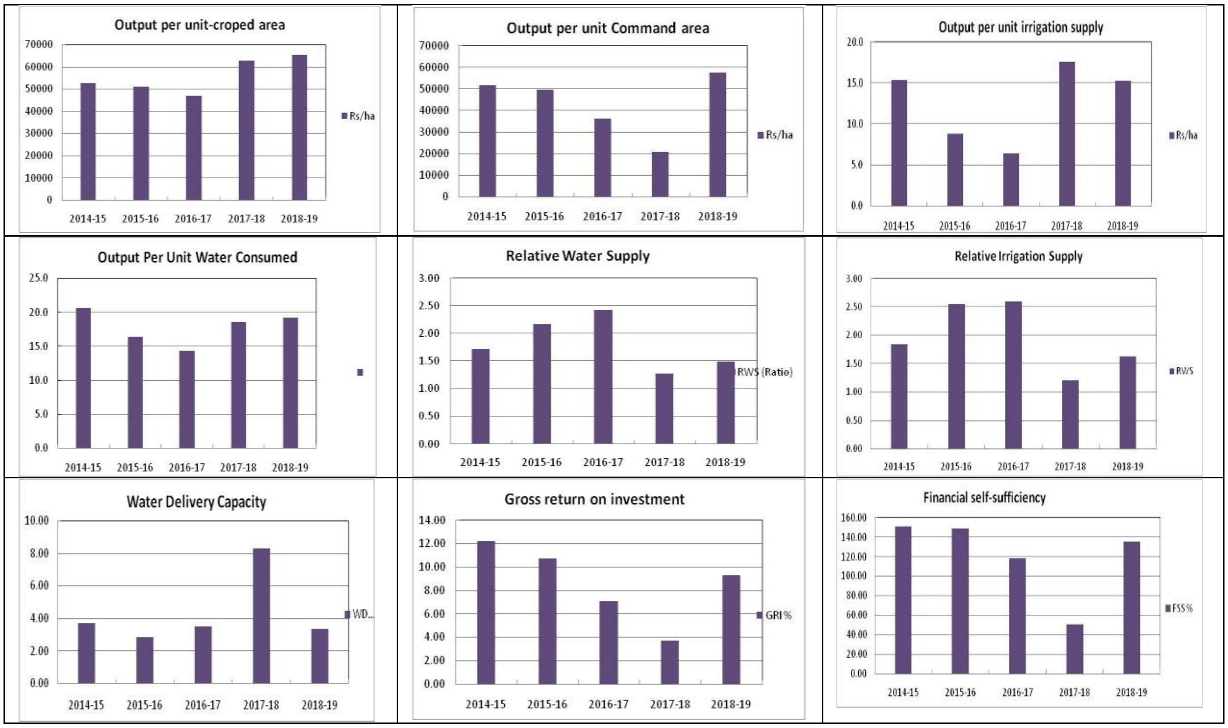


Figure 4.74:Performance evaluations of irrigation projects of Doraha dam

The output per unit of irrigation supplies was observed better in all years of assessment except years 2017-18, this was because of a high gross return due to the adaptation of proper water management practices during better years. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed per has been found to vary with time. The value of water consumed in the year 2016-17 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future. The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 1.28 to 2.43 and RIS values were seen ranging from 1.20 to 2.60. These irrigation indicators are ideally expected to be near 1.50. Water Delivers Capacity (WDC) index indicates that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Doraha dam has a good water delivery capacity. It was seen that water delivery capacity values ranged from 2.85 to 8.28. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

4.6.4 CASE 4: Jajon dam

A Jajon dam is a minor irrigation project situated at 23°55'00" N Latitude and 78°10'00" E Longitude which falls in Basoda Tehsil of Vidisha district. It is located on a local nalla in the

Betwa basin and its command area comes under the Vidisha district. Its catchment area is 17.35 sq km, its Gross storage Capacity at full reservoir level (FRL) is 7.43 MCM and its command area is 1296 ha shown in Figure 4.75.

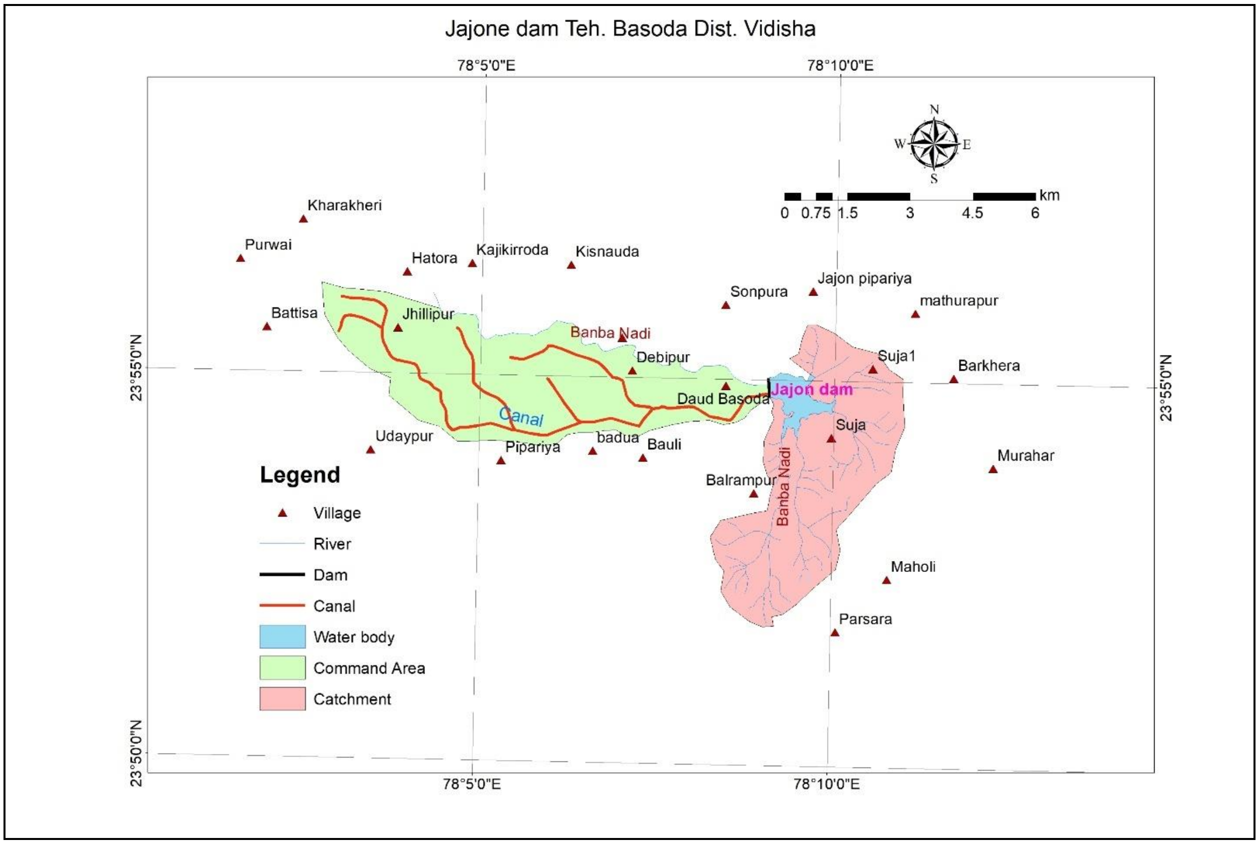


Figure 4.75: Jajone Dam

The performance evaluation of the Jajon irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Jajon irrigation project are shown in Table 4.13 and a graphical comparison has been shown in Figure 4.76.

Table 4-13 and Figure 4.76 shows all nine comparative indicators derived for the Jajon irrigation project for the rabi seasons of years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. The major crops grown in the command were wheat and gram. The output per unit cropped area was 49708 Rs/ha in the year 2015-16 and it increased to 62525 Rs/ha in the year 2017-18 indicating the increase in crop productivity in the command area. The output per unit command area was also seen to increase from 34600 Rs/ha in the year 2015-16, and it was increased to 46691 Rs/ha in the year 2016-17 indicating an improvement in crop and land productivity of the Jajon irrigation project.

Table 4.13: Evaluated comparative indicators: Jajon irrigation project

Year	SGVP (crore Rs)	Irrigated area (ha)	Command area (ha)	Volume ET (MCM)	Total ER (MCM)	Rainfall (Seasonal) mm	Total Rainfall (Seasonal) (MCM)	Net Removal Ground Water (MCM)	Water Supply from Canal (MCM)	Diverted irrigation supply (DIS) (MCM)
2014-15	6.24	1187	1746	4.03	1.27	126.00	1.50	0.68	6.89	7.57
2015-16	6.04	1215	1746	3.46	0.86	104.40	1.27	0.68	6.89	7.57
2016-17	8.15	1303	1746	4.05	0.00	0.00	0.00	0.68	6.89	7.57
2017-18	7.32	1226	1746	4.20	0.02	1.40	0.02	0.68	6.89	7.57
2018-19	-	-	-	-	-	-	-	-	-	-
Year	**Total water supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR (MCM)**	**CCDWH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore Rs)**	**Revenue from Irrigation (Crore Rs)**
2014-15	9.07	339.88	4.03	228.25	2.71	1.019	0.44	0.52	19.88	0.03
2015-16	8.84	284.50	3.46	205.34	2.50	1.019	0.45	0.55	21.87	0.03
2016-17	7.57	310.82	4.05	310.82	4.05	1.019	0.46	0.60	24.06	0.04
2017-18	7.59	342.61	4.20	341.11	4.18	1.019	0.46	0.56	26.47	0.03
2018-19	-	-	-	-	-	-	-	-	-	-
Year	**Total O&M Expenditure (crore Rs)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS (Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0.03	52590	35754	8.24	15.47	2.25	2.80	1.95	31	104
2015-16	0.03	49708	34600	7.98	17.47	2.56	3.03	1.86	28	106
2016-17	0.03	62525	46691	10.76	20.12	1.87	1.87	1.70	34	114
2017-18	0.03	59675	41912	9.66	17.42	1.81	1.81	1.81	28	107
2018-19	-	-	-	-	-	-	-	-	-	-

The output per unit of irrigation supplies was observed better in all years of the assessment period except the year 2016-17, this was because of a high gross return due to the adaptation of proper water management practices and more area cultivated with orchards, industrial crops, vegetable, and more horticulture during those good years. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed per has been found to vary with time. The value of water consumed in the year 2014-15 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future. The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 1.81 to 2.56 and RIS values were seen ranging from 1.81 to 3.03.

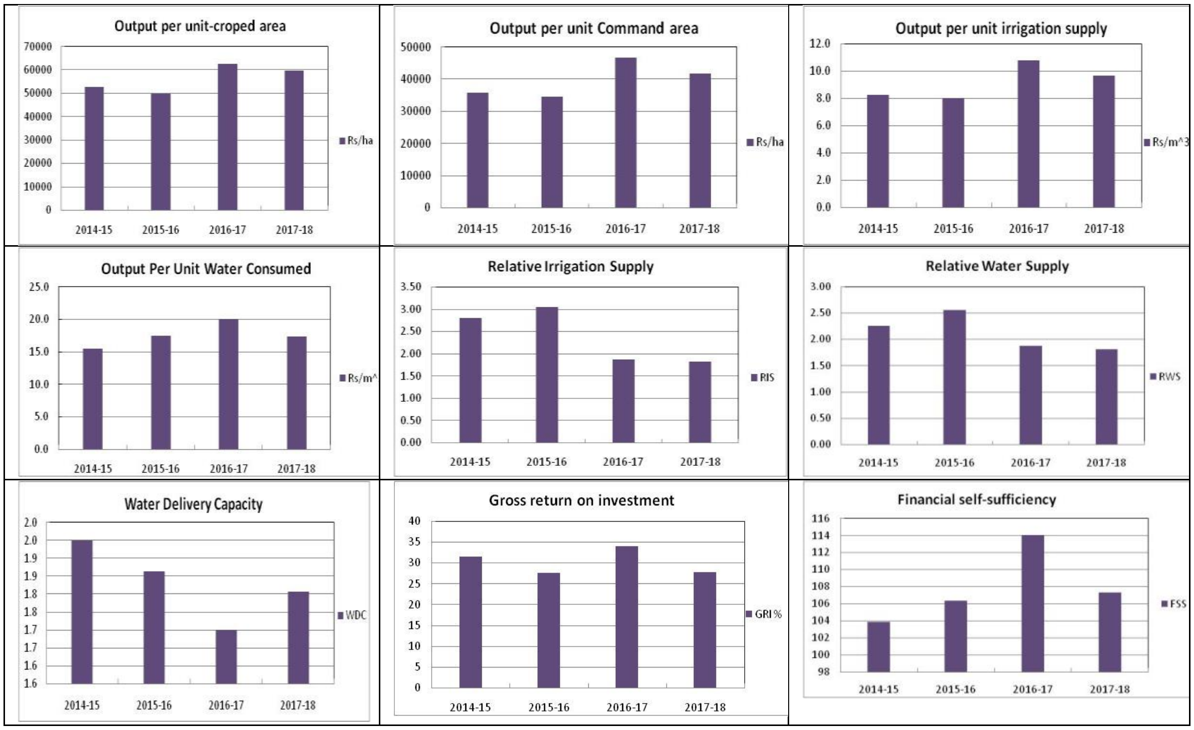


Figure 4.76: Performance evaluations of irrigation projects of Jajon dam

These irrigation indicators are ideally expected to be near 1.50. The water Delivers Capacity (WDC) index value is one it was indicated that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Jajon dam has a very good water delivery capacity. It was seen water deliver capacity values from 1.70 to 1.95. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

4.6.5 CASE 5: Lilgi dam

A Lilgi dam is a minor irrigation project situated at 24°15'43" N Latitude and 80°44'13" E Longitude which falls in Maiher Tehsil of Satna district. It is located on a local nallah in the Ton river basin and its command area comes under the Maihar tehsil. Its catchment area is 11.20 sq. km, its Gross storage Capacity at full reservoir level (FRL) is 2.20 MCM and the command area is 1024 ha. Water from this dam is supplied for irrigation and Maihar Mata temple premises. The command area of the Lilgi irrigation project is shown in Figure 4.77.

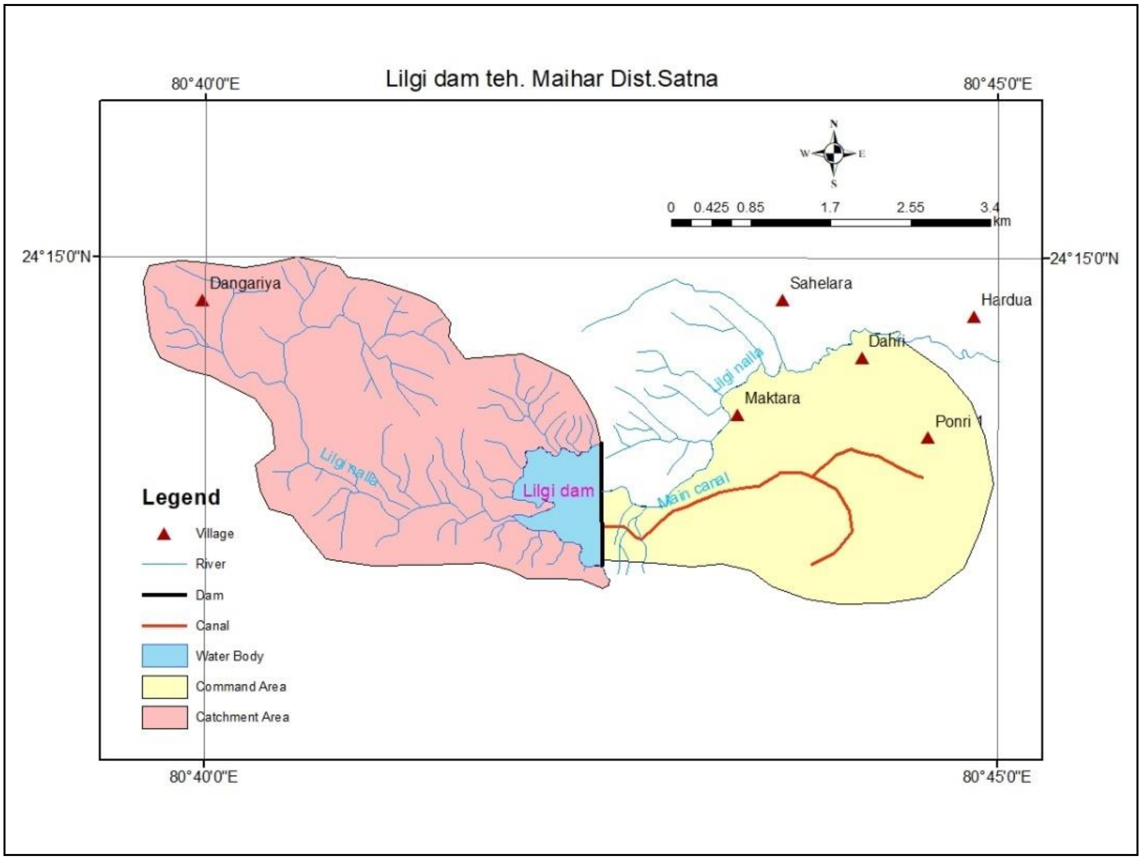


Figure 4.77: Command Area map of Lilgi Irrigation Project

The performance evaluation of the Lilgi irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Lilgi irrigation project are shown in Table 4.14 and a graphical comparison has been shown in Figure 4.78.

Table 4-14 and Figure 4.78 shows all nine comparative indicators derived for the Lilgi irrigation project for the rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. The major crop grown in the command area of the Lilgi dam were wheat and gram. The output per unit cropped area was 50559 Rs/ha in the year 2015-16 and it increased to 77148 Rs/ha in the year 2018-19 indicating an increase in crop productivity in the command area. The output per unit command area was seen to increase from 4967 Rs/ha in the year 2014-15, and it was increased to 14149 Rs/ha in the year 2018-19 indicating an improvement in land productivity in the command of Lilgi dam.

Table 4.14: Evaluated comparative indicators: Lilgi irrigation project

Year	**SGVP (crore Rs)**	**Irrigated area (ha)**	**Command area (ha)**	**Volume ET (MCM)**	**Total ER (MCM)**	**Rainfall (Seasonal) mm**	**Total Rainfall (Seasonal) (MCM)**	**Net Removal Ground Water (MCM)**	**Water Supply from Canal (MCM)**	**Diverted irrigation supply (DIS) (MCM)**
2014-15	0.26	48	518	0.12	0.07	185.40	0.09	0.14	0.34	0.48
2015-16	0.37	74	518	0.18	0.08	166.20	0.12	0.14	0.60	0.74
2016-17	0.51	81	518	0.21	0.04	61.90	0.05	0.14	0.50	0.64
2017-18	0.58	91	518	0.35	0.01	7.40	0.01	0.14	0.55	0.69
2018-19	0.73	95	518	0.27	0.05	64.63	0.06	0.14	0.65	0.79
Year	**Total water supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR (MCM)**	**CCDWH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore)**	**Revenue from Irrigation (Crore)**
2014-15	0.57	250.71	0.12	98.35	0.05	0.15	0.21	0.01	2.13	0.0013
2015-16	0.86	246.22	0.18	128.47	0.10	0.15	0.27	0.02	2.35	0.0020
2016-17	0.69	256.07	0.21	201.62	0.16	0.15	0.33	0.03	2.58	0.0022
2017-18	0.69	387.14	0.35	298.55	0.27	0.15	0.40	0.04	2.84	0.0025
2018-19	0.85	286.43	0.27	231.32	0.22	0.15	0.31	0.03	3.12	0.0026
Year	**Total O&M Expenditure (crore Rs)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS (Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0.01	53607	4967	5.40	21.38	4.70	10.10	14.88	12	14
2015-16	0.01	50559	7223	5.08	20.53	4.72	7.75	7.51	16	22
2016-17	0.01	62482	9770	7.95	24.40	3.31	3.90	5.61	20	24
2017-18	0.01	63493	11154	8.41	16.40	1.97	2.53	4.12	20	27
2018-19	0.01	77148	14149	9.32	26.93	3.12	3.58	5.09	23	28

As compared to the year 2018-19, the output per unit of irrigation supplies was better in another year of assessment; this was because of a high gross return due to the adaptation of proper water management practices and more area cultivated with orchards, industrial crops, vegetable, and more horticulture. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed per has been found to vary with time. The value of water consumed in the year 2017-18 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future. The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 2 to 5 and RIS values were seen ranging from 3 to 10. These irrigation indicators are ideally expected to be near 1.50. High values of RWS and RIS indicate abundant water availability in comparison to demand in the Lilgi command.

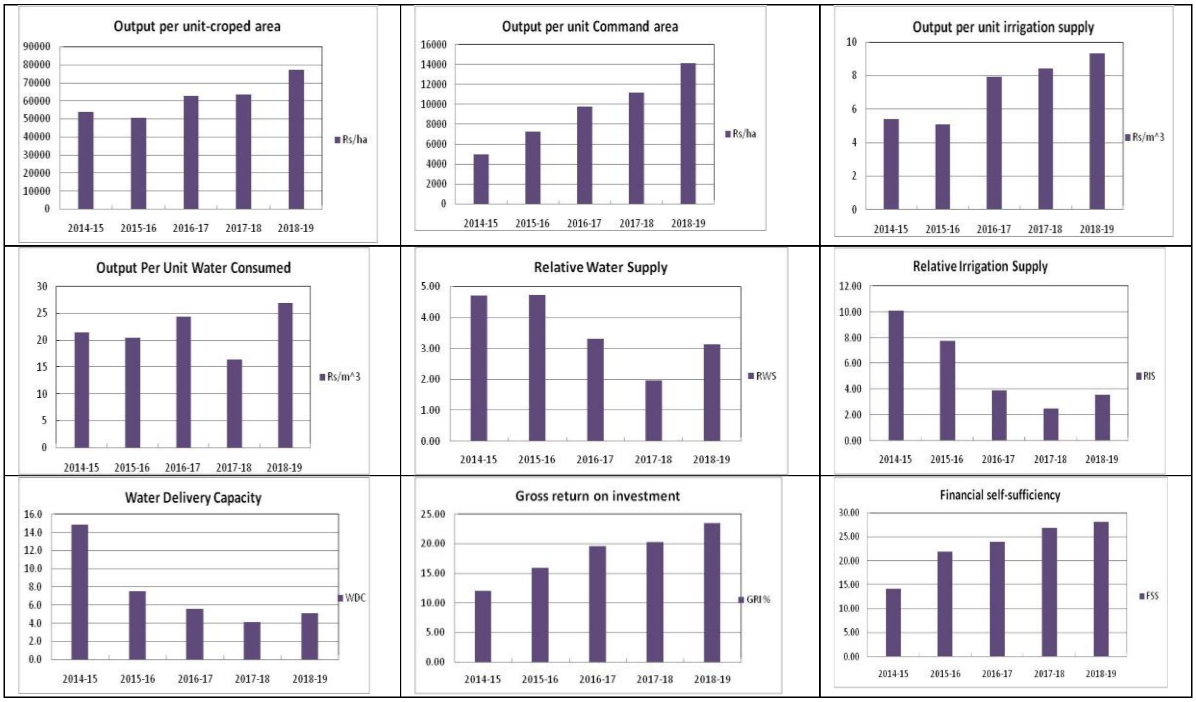


Figure 4.78: Performance evaluations of irrigation projects of Lilgi dam

The water Delivers Capacity (WDC) index value is one it was indicated that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Lilgi dam has a high water delivery capacity as the water is being used for irrigation and to Maiher Temple. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

4.6.6 CASE 6: Mala tank

A Mala tank is a medium irrigation project situated at 23°19'59"N Latitude and 79°42'00"E Longitude which falls in Jabera Tehsil of Damoh district. It is located on a Mala river in the Ken river basin and its command area comes under the Jabera tehsil. Its catchment area is 161.3 sq. km, its Gross storage Capacity at full reservoir level (FRL) is 16.76 MCM and its command area is 2750 ha as shown in Figure 4.79.

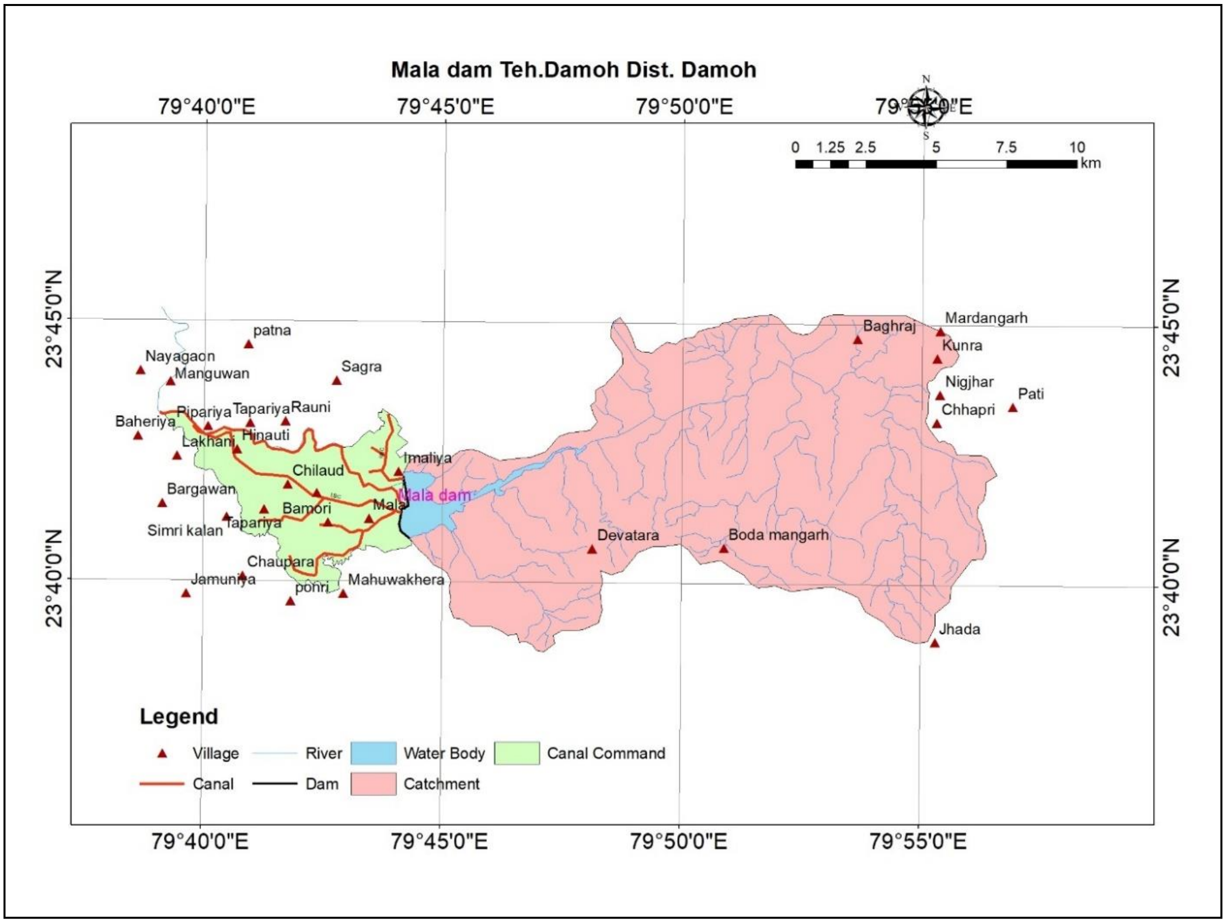


Figure 4.79: Command Area map of Mala Irrigation Project

The performance evaluation of the Mala tank irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Mala tank irrigation project are shown in Table 4.15 and a graphical comparison has been shown in Figure 4.80.

Table 4.15 and Figure 4.80 shows all nine comparative indicators derived for the Mala tank irrigation project for the rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. The major crops grown are wheat, gram, and lentil in the command area of Mala tank. The output per unit cropped area was 33591 Rs/ha in the year 2014-15 and it increased to 45757 Rs/ha in the year 2018-19, agriculture practice was good in the command area and crop productivity increased. The output per unit command area was seen to increase from 30633 Rs/ha in the year 2014-15 to 43776 Rs/ha in the year 2018-19, it was increased land productivity.

Table 4.15: Evaluated comparative indicators: Mala tank irrigation project

Year	SGVP (crore Rs)	Irrigated area (ha)	Command area (ha)	Volume ET (MCM)	Total ER MCM	Rainfall (Seasonal) mm	Total Rainfall (Seasonal) (MCM)	Net Removal Ground Water (MCM)	Water Supply from Canal (MCM)	Diverted irrigation supply (DIS) (MCM)
2014-15	10.26	3055	3350	7.68	3.83	138.10	4.22	0.82	11.51	12.33
2015-16	13.14	3276	3350	7.98	2.66	118.60	3.89	0.82	12.91	13.73
2016-17	11.01	3205	3350	8.20	1.80	66.00	2.12	0.82	16.38	17.20
2017-18	10.97	3205	3350	12.96	0.67	22.00	0.71	0.82	15.88	16.70
2018-19	14.67	3205	3350	9.11	1.45	56.50	1.81	0.82	16.87	17.69
Year	**Total water supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR MCM**	**CCDWH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore)**	**Revenue from Irrigation (Crore)**
2014-15	16.55	251.34	7.68	137.87	4.21	2.42	0.27	0.82	209.93	0.0840
2015-16	17.62	243.64	7.98	145.46	4.77	2.42	0.32	1.05	230.93	0.0901
2016-17	19.32	256.01	8.20	195.69	6.27	2.42	0.34	1.09	254.02	0.0881
2017-18	17.41	404.21	12.96	272.66	8.74	2.42	0.38	1.22	279.42	0.0881
2018-19	19.50	284.20	9.11	238.06	7.63	2.42	0.35	1.12	307.36	0.0881
Year	**Total O&M Expenditure (crore)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS (Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0.06	33591	30633	8.32	13.36	2.16	2.93	2.93	5	139
2015-16	0.06	40103	39218	9.57	16.46	2.21	2.88	2.30	6	149
2016-17	0.06	34348	32862	6.40	13.42	2.35	2.74	2.22	4	146
2017-18	0.06	34227	32746	6.57	8.47	1.34	1.91	1.98	4	146
2018-19	0.06	45757	43776	8.29	16.10	2.14	2.32	2.15	5	146

Though in all selected years the output per unit of irrigation supply as compared to 2015-16 was better, this was because of a high gross return due to the adaptation of proper water management practices and much more area cultivated with orchards, industrial crops, vegetable, and more horticulture is needed. It is determined by considering reference crop ET for rabi crops. The daily ETo values were estimated using the FAO Penman-Monteith method because the value of SGVP increased yearly. The output per unit of water consumed per m^3 is increasing and decreasing in the selected year. The value of water consumed per m^3 in the year 2017-18 was low as compared to others years due to the high water consumed. The relative water supply and relative irrigation supply were good in all selected years of Mala tank command because the year 2017-18 was not a good performance.

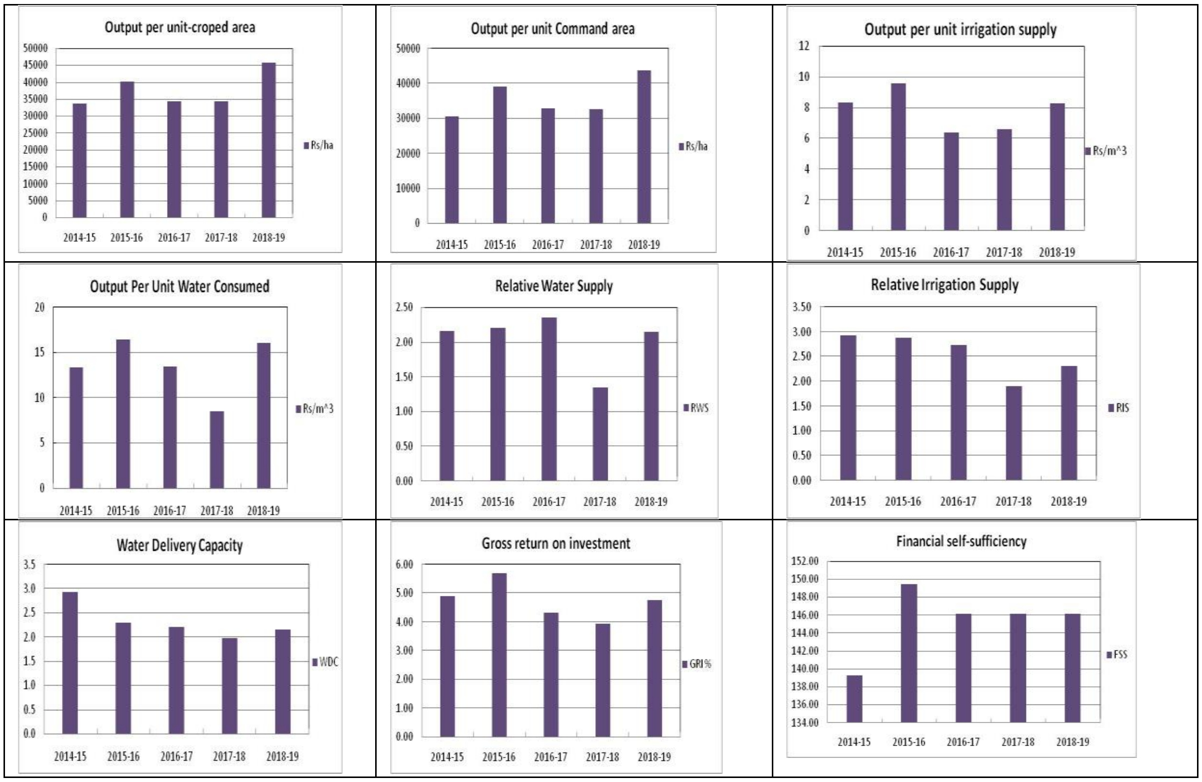


Figure 4.80: Performance evaluations of irrigation projects of Mala tank

These irrigation indicators should be nearly 1.50 and it was 1.00 to 3.00 in all selected years of the Mala tank. The water Delivery Capacity (WDC) index value is 1 and it was indicated that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

4.6.7 CASE 7: Naren dam

A Naren tank is a medium irrigation project situated at 24°01'42"N Latitude and 77°45'37"E Longitude which falls in Sironj Tehsil of Vidisha district. It is located on a Local nallah in the Betwa river basin and its command area comes under the Vidisha district. Its catchment area is 61.44 sq. km, its Gross storage Capacity at full reservoir level (FRL) is 18.82 MCM and its command area is 3450 ha as shown in Figure 4.81.

The performance evaluation of the Naren irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Naren irrigation project are shown in Table 4.16 and a graphical comparison has been shown in Figure 4.82.

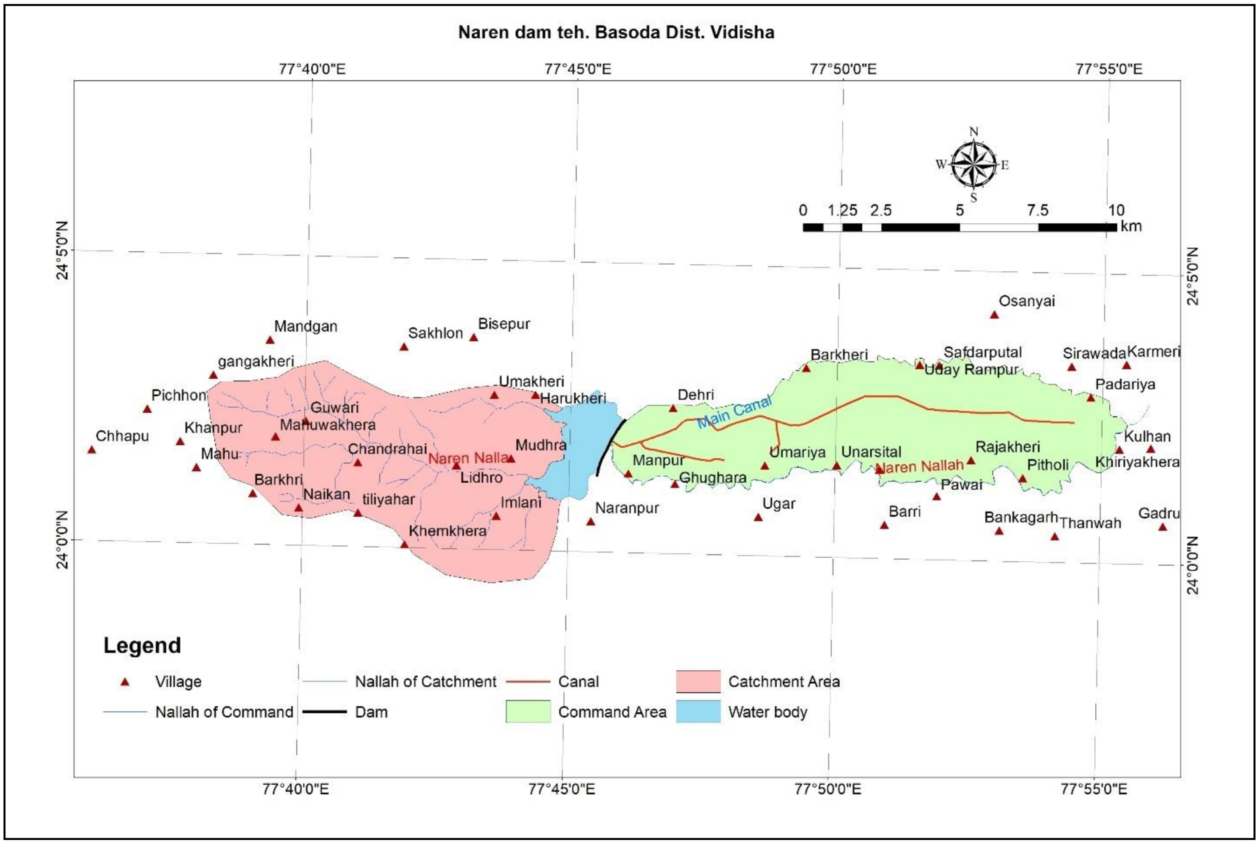


Figure 4.81: Command Area map of Naren Irrigation Project

Table 4.16 and Figure 4.82 shows all nine comparative indicators derived for the Naren irrigation project for the rabi seasons of five years 2014-15, 2015-16, 2016-17, 2017-18, and 2018-19. The major crops grown are wheat, gram, and lentil in the command area of Naren dam. The average annual rainfall of the Vidisha station which is the nearest station is 1077 mm. The output per unit cropped area was 50638 Rs/ha in the year 2015-16 and it increased to 65927 Rs/ha in the year 2018-19, it was indicated crop productivity. The output per unit command area was seen to increase from 46356 Rs/ha in the year 2014-15 to 52017 Rs/ha in the year 2018-19, but land productivity was good in the year 2016-17. Though the year 2018-19 output per unit of irrigation supply was better i.e. 20 Rs/m3, this was because of a high gross return due to adaptation of proper water management practices and crop selection like vegetable, cash crop, and more horticulture. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed per has been found to vary with time. The value of water consumed in the year 2017-18 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future.

Table 4.16: Evaluated comparative indicators: Naren irrigation project

Year	**SGVP (crore Rs)**	**Irrigated area (ha)**	**Command area(ha)**	**Volume ET (MCM)**	**Total ER (MCM)**	**Rainfall (Seasonal) mm**	**Total Rainfall (Seasonal) (MCM)**	**Net Removal Ground Water (MCM)**	**Water Supply from Canal (MCM)**	**Diverted irrigation supply (DIS) (MCM)**
2014-15	16.46	3108	3550	9.95	3.18	118.00	3.67	1.37	8.75	10.12
2015-16	17.75	3506	3550	10.60	2.45	98.00	3.44	1.37	11.85	13.22
2016-17	21.86	3501	3550	11.17	0.00	0.00	0.00	1.37	18.31	19.68
2017-18	17.85	2836	3550	11.61	0.00	0.00	0.00	1.37	10.09	11.46
2018-19	18.47	2801	3550	8.72	0.89	46.45	1.30	1.37	8.09	9.46

Year	**Total water supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR (MCM)**	**CCDWH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore)**	**Revenue from Irrigation (Crore)**
2014-15	13.79	320.01	9.95	219.74	6.83	4.21	0.29	0.90	101.26	0.0855
2015-16	16.65	302.28	10.60	218.63	7.67	4.21	0.45	1.58	111.39	0.0964
2016-17	19.68	319.16	11.17	319.16	11.17	4.21	0.46	1.61	122.53	0.0963
2017-18	11.46	409.21	11.61	316.39	8.97	4.21	0.47	1.33	134.78	0.0780
2018-19	10.76	311.44	8.72	280.21	7.85	4.21	0.43	1.20	148.26	0.0770

Year	**Total O&M Expenditure (crore)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS (Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0.06	52948	46356	16.26	16.55	1.39	1.48	4.67	16	134
2015-16	0.06	50638	50011	13.43	16.75	1.57	1.72	2.67	16	151
2016-17	0.06	62439	61577	11.11	19.56	1.76	1.76	2.62	18	151
2017-18	0.06	62946	50286	15.58	15.38	0.99	1.28	3.16	13	122
2018-19	0.06	65927	52017	19.52	21.17	1.23	1.21	3.50	12	121

The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 0.99 to 1.76 and RIS values were seen ranging from 1.21 to 1.76. These irrigation indicators are ideally expected to be near 1.50, but demand was not fulfilled because of water scarcity in the year 2016-17. The water Delivery Capacity (WDC) index is 1 and it was indicated that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Naren dam has a good water delivery capacity. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

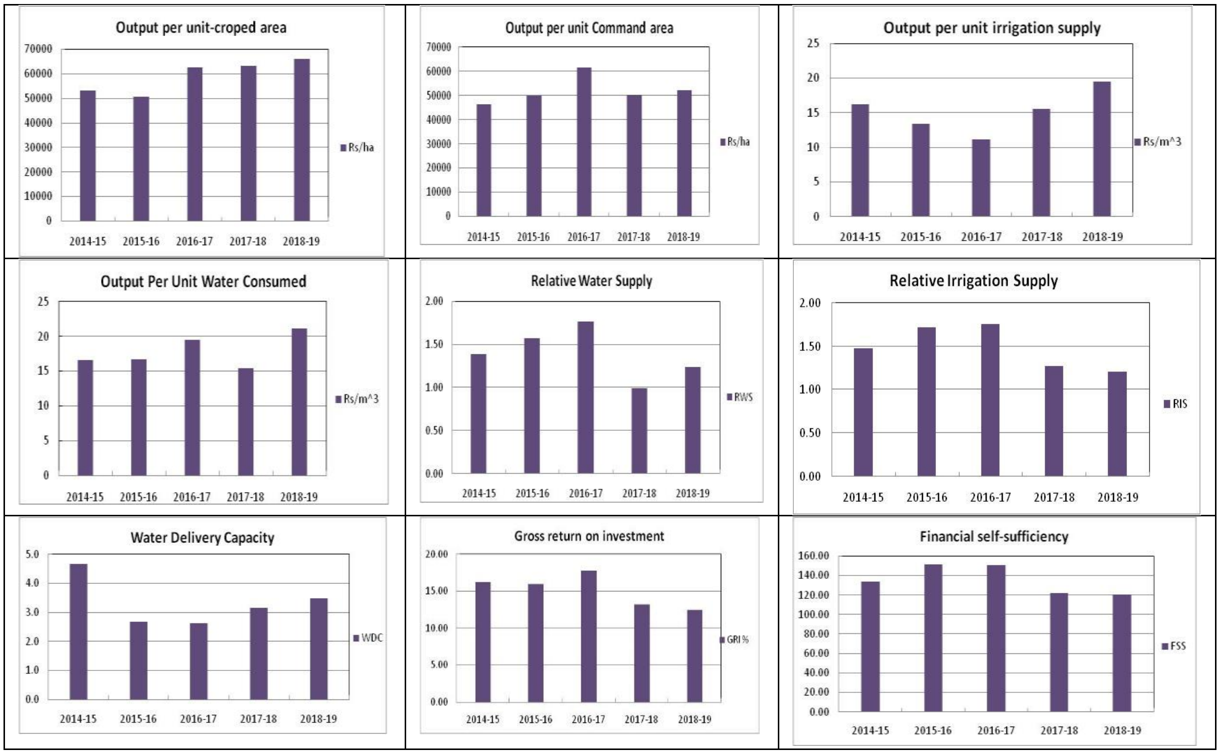


Figure 4.82: Performance evaluations of irrigation projects of Naren dam

4.6.8 CASE 8: Umrar dam

A Umrar is a medium irrigation project situated at 23°29'34" N Latitude and 80°49'32"E Longitude which falls in Bandhavgarh Tehsil of Umaria district. It is located on a Local river Umrar in the Son river basin and its command area comes under the Umaria district as shown in Figure 4.83. The performance evaluation of the Umrar irrigation project has been carried out by estimating SGVP values and using nine comparative indicators. Year-wise comparative indicators were evaluated for Rabi seasons of three years 2016-17, 2017-18, and 2018-19. Evaluated comparative indicators for the Umrar irrigation project are shown in Table 4.17 and a graphical comparison has been shown in Figure 4.84.

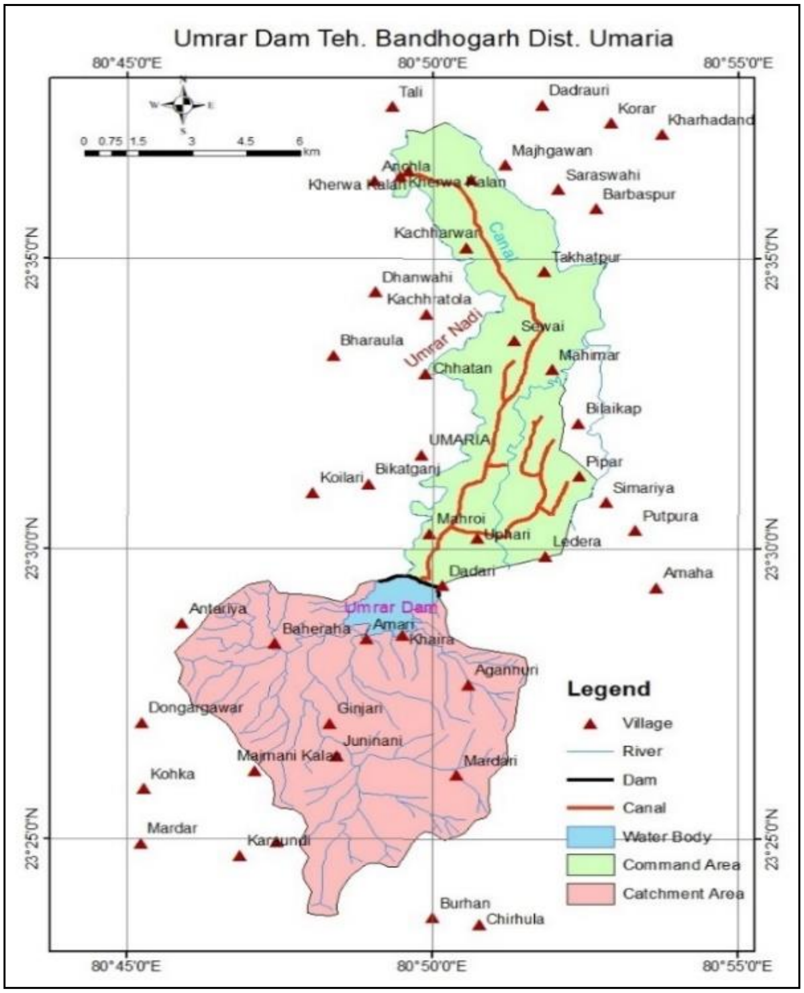


Figure 4.83: Command Area Map of Umrar Dam

Table 4.17 and Figure 4.84 shows all nine comparative indicators derived for the Umrar irrigation project for the rabi seasons for three years 2016-17, 2017-18, and 2018-19. The major crops grown are wheat, gram, and lentil in the command area of Umrar dam. The output per unit cropped area was 62335 Rs/ha in the year 2015-16 and it increased to 65072 Rs/ha in the year 2018-19, which was indicated by crop productivity. The output per unit command area was seen to increase from 33425 Rs/ha in the year 2017-18 to 52046 Rs/ha in the year 2018-19, which was indicated by land productivity. Though the year 2017-18 output per unit of irrigation supply was better i.e. 7.54 Rs/m3, this was because of a high gross return due to adaptation of proper water management practices and crop selection like vegetable, cash crop, and more horticulture. In the analysis, the daily ETo values were estimated using the FAO Penman-Monteith method. The output per unit of water consumed per has been found to vary with time. The value of water consumed in the year 2017-18 was seen low as compared to other years, the reason behind this can be identified and investigated to formulate strategies for the future.

Table 4.17: Evaluated comparative indicators: Umrar irrigation project

Year	SGVP (crore Rs)	Irrigated area (ha)	Command area(ha)	Volume ET (MCM)	Total ER (MCM)	Rainfall (Seasonal) mm	Total Rainfall (Seasonal) (MCM)	Net Removal Ground Water (MCM)	Water Supply from Canal (MCM)	Diverted irrigation supply (DIS) (MCM)
2014-15	0	0	0	0	0	0	0	0	0	0
2015-16	0	0	0	0	0	0	0	0	0	0
2016-17	11.53	1850	2313	4.84	1.18	88.60	1.64	0.77	15.87	16.64
2017-18	7.73	1205	2313	4.44	0.29	24.80	0.30	0.77	9.49	10.26
2018-19	12.04	1850	2313	5.71	1.28	93.34	1.73	0.77	16.49	17.26
Year	**Total water supply (MCM)**	**CWR (mm/season)**	**Total CWR (MCM)**	**IR (mm/season)**	**Total IR (MCM)**	**CCDWH (cumec)**	**PKD (l/s/ha)**	**PKD (cumec)**	**Cost of Irrigation infrastructure (Crore)**	**Revenue from Irrigation (Crore)**
2014-15	0	0	0	0	0	0	0	0	0	0
2015-16	0	0	0	0	0	0	0	0	0	0
2016-17	18.28	261.64	4.84	182.35	3.37	2.26	0.26	0.48	77.28	0.0168
2017-18	10.55	368.36	4.44	283.69	3.42	2.26	0.37	0.45	85.01	0.0340
2018-19	18.98	308.67	5.71	235.16	4.35	2.26	0.29	0.54	93.51	0.0192
Year	**Total O&M Expenditure (crore)**	**OPIA (Rs/ha)**	**OPCA (Rs/ha)**	**OPIS (Rs/m^3)**	**OPWC (Rs/m^3)**	**RWS**	**RIS**	**WDC**	**GRI %**	**FSS %**
2014-15	0	0	0	0	0	0	0	0	0	0
2015-16	0	0	0	0	0	0	0	0	0	0
2016-17	0.02	62335	49857	6.93	23.83	3.78	4.93	4.70	15	107
2017-18	0.02	64159	33425	7.54	17.42	2.38	3.00	5.07	9	146
2018-19	0.02	65072	52046	6.98	21.08	3.32	3.97	4.21	13	82

The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand. The RWS values were seen ranging from 2.38 to 3.78 and RIS values were seen ranging from 3.00 to 4.93. These irrigation indicators are ideally expected to be near 1.50. High values of RWS and RIS indicate abundant water availability in comparison to demand in the Umrar dam command. The water Delivers Capacity (WDC) index value is one it was indicated that the dam's infrastructure is capable of delivering water to meet peak consumptive water demand. The Umrar dam has a good water delivery capacity. The financial-based indicators like Gross Retune Investment and Financial Self-Sufficiency were found reasonable.

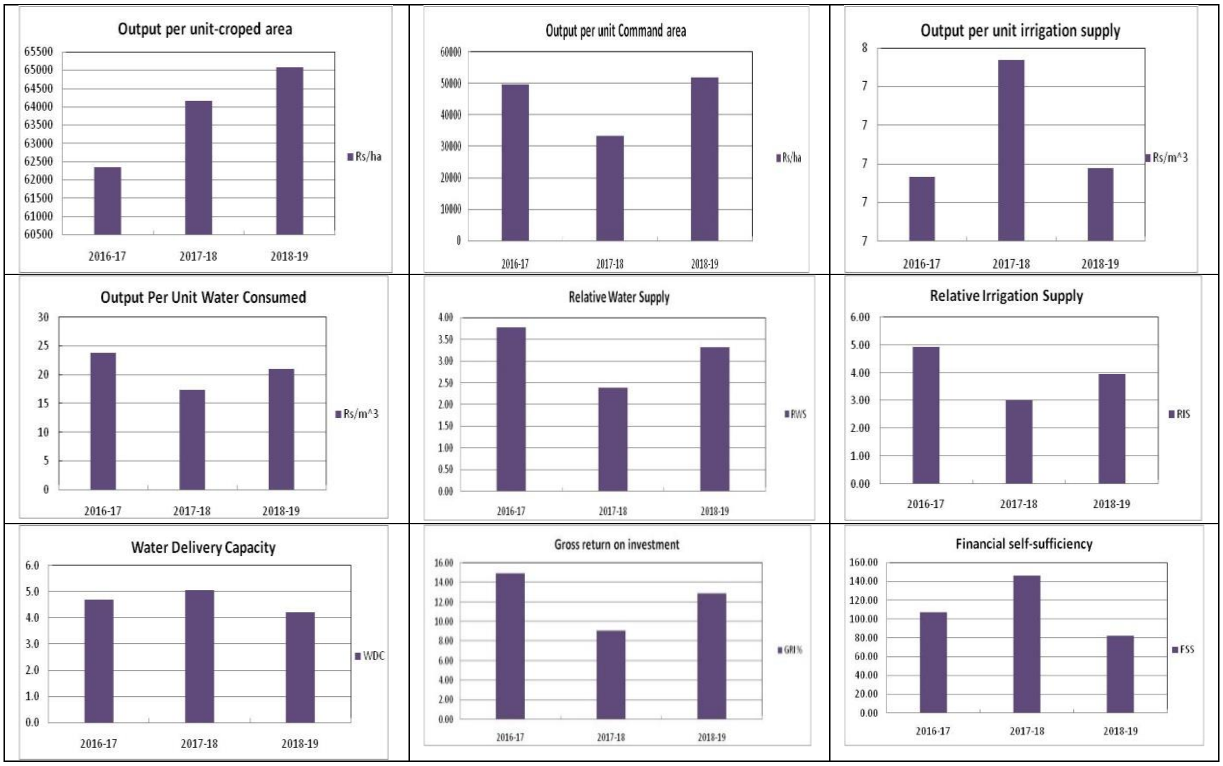


Figure 4.84: Performance evaluations of irrigation projects of Umrar dam

4.6.9 Cross-system comparison and performance evaluation of dams

After analyzing the performance evaluation of individual dams with their past performance, the performance has been evaluated using a cross-system comparison of indicators. The results of all irrigation projects are shown in Table 4.18 and a comparison has been made to understand the extent of performance indicators, best performers, and possible reasons for good or bad performance. The cross-system comparison also helps to set the benchmark for each indicator to compare the performance of irrigation projects. All irrigation projects were also compared on a temporal scale to see the improvement or degradation in performance.

Table 4.18: Cross-System Comparison of all selected irrigation project

System	year	OPICA (Rs/ha)	OPCA (Rs/ha)	OPWC (Rs/m^3)	OPIS (Rs/m^3)	RWS (Ratio)	RIS (Ratio)	WDC (Ratio)	GRI %	FSS %
Doraha dam	2014-15	52480	51802	15.33	20.62	1.72	1.85	3.68	12.26	150.80
	2015-16	51070	49840	8.76	16.45	2.18	2.56	2.82	10.73	149.10
	2016-17	46952	36292	6.38	14.30	2.43	2.60	3.48	7.10	118.09
	2017-18	62777	20831	17.58	18.55	1.28	1.20	8.28	3.71	50.69
	2018-19	65132	57624	15.27	19.25	1.50	1.62	3.33	9.32	135.17
Jajon dam	2014-15	52590	35754	8.24	15.47	2.25	2.80	1.95	31.39	103.87
	2015-16	49708	34600	7.98	17.47	2.56	3.03	1.86	27.62	106.34
	2016-17	62525	46691	10.76	20.12	1.87	1.87	1.70	33.88	114.09
	2017-18	59675	41912	9.66	17.42	1.81	1.81	1.81	27.65	107.30
	2018-19	0	0	0	0	0	0	0	0	0
Kaketo dam	2014-15	36519	34083	2.87	19.81	7.92	8.06	25.48	6.73	142.59
	2015-16	37791	35510	3.39	20.60	6.99	17.31	21.26	6.38	143.56
	2016-17	30746	28217	3.17	13.93	4.63	19.84	18.14	4.61	140.21
	2017-18	0	0	0	0	0	0	0	0	0
	2018-19	48775	44763	10.87	21.28	2.18	11.08	20.93	6.04	140.21
Lilgi dam	2014-15	53607	4967	5.40	21.38	4.70	10.10	14.88	12.06	14.16
	2015-16	50559	7223	5.08	20.53	4.72	7.75	7.51	15.94	21.83
	2016-17	62482	9770	7.95	24.40	3.31	3.90	5.61	19.60	23.89
	2017-18	63493	11154	8.41	16.40	1.97	2.53	4.12	20.34	26.84
	2018-19	77148	14149	9.32	26.93	3.12	3.58	5.09	23.45	28.02
Mala dam	2014-15	33591	30633	8.32	13.36	2.16	2.93	2.93	4.89	139.32
	2015-16	40103	39218	9.57	16.46	2.21	2.88	2.30	5.69	149.40
	2016-17	34348	32862	6.40	13.42	2.35	2.74	2.22	4.33	146.17
	2017-18	34227	32746	6.57	8.47	1.34	1.91	1.98	3.93	146.17
	2018-19	45757	43776	8.29	16.10	2.14	2.32	2.15	4.77	146.17
Naren dam	2014-15	52948	46356	16.26	16.55	1.39	1.48	4.67	16.25	133.76
	2015-16	50638	50011	13.43	16.75	1.57	1.72	2.67	15.94	150.88
	2016-17	62439	61577	11.11	19.56	1.76	1.76	2.62	17.84	150.67
	2017-18	62946	50286	15.58	15.38	0.99	1.28	3.16	13.24	122.05
	2018-19	65927	52017	19.52	21.17	1.23	1.21	3.50	12.46	120.54
Umrar dam	2014-15	0	0	0	0	0	0	0	0	0
	2015-16	0	0	0	0	0	0	0	0	0
	2016-17	62335	49857	6.93	23.83	3.78	4.93	4.70	14.92	107.08
	2017-18	64159	33425	7.54	17.42	2.38	3.00	5.07	9.09	146.18
	2018-19	65072	52046	6.98	21.08	3.32	3.97	4.21	12.87	82.29

The cross-system comparison has been carried out for individual comparative indicators of all selected irrigation projects and results are discussed and elaborated through graphs as given below.

Output per Unit Irrigated Cropped Area (OPICA)

Output per Unit Irrigated Cropped Area of all dams has been shown in Figure 4.85 and results are summarized below.

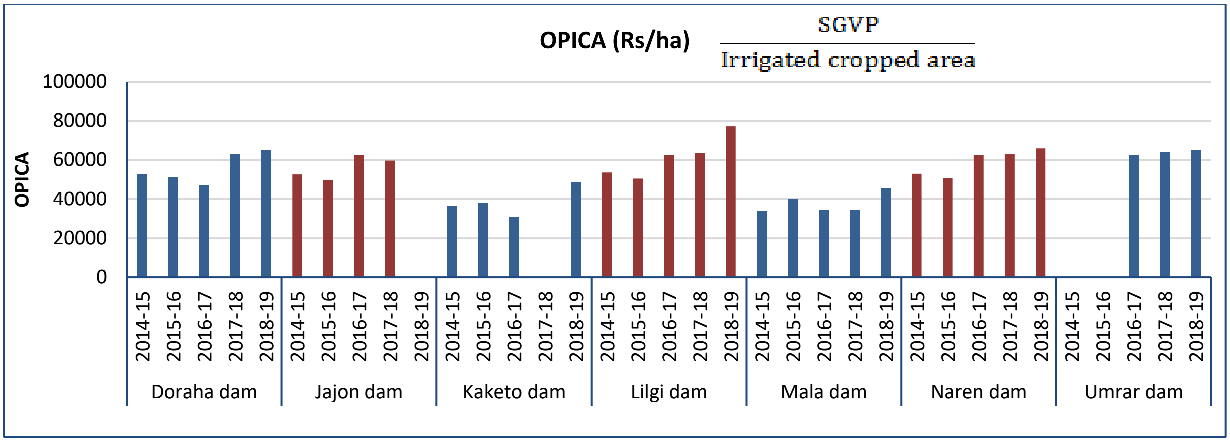


Figure 4.85: Output per Unit Irrigated Cropped Area of all dams

- OPICA indicates the Crop productivity and value were found ranging from Rs 45775 to 77148.
- OPICA was found better in recent years 2017-18 and 2018-19 for all Dams
- OPICA was found to better and improved with time in all the dams except Mala Tank and Kaketo
- We have to check the types of crop grown and cropping intensity when these values were low or high

Output per Unit Command Area (OPCA)

Output per Unit Command Area of all dams has been shown in Figure 4.86 and results are summarized below.

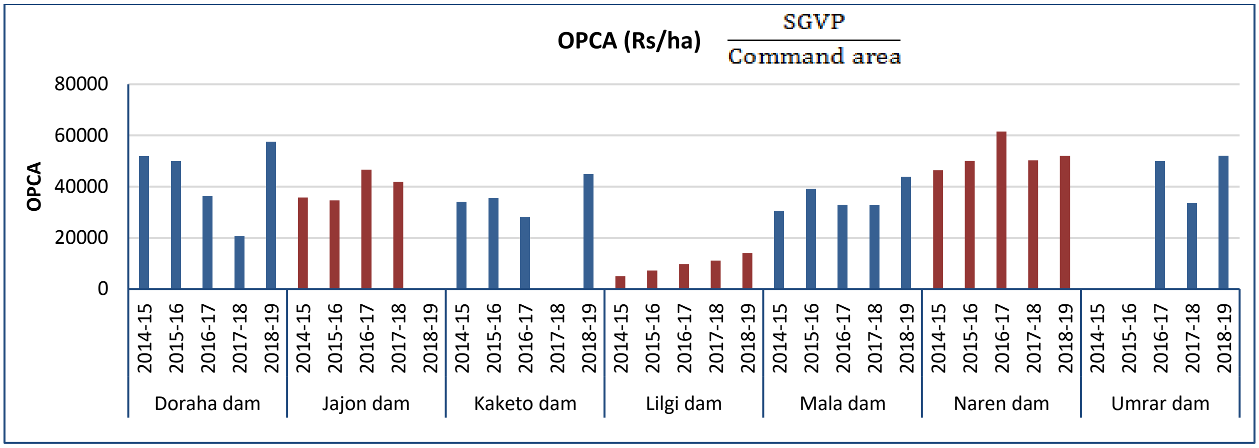


Figure 4.86: Output per Unit Command Area of all dams

- OPCA indicates land productivity based on the type of crops grown and cropping intensity.
- OPCA values found ranged from Rs. 4966 (Lilgi) to Rs 61577 (Naren Dam).
- Low values indicated that the full command area has not been covered under crop and the reasons behind this need to be investigated.
- Planning should be made to keep this value as high as possible as found in the case of in Naren dam in the year 2016-17 and the Doraha dam in the year 2018-19

Output per unit water consumed (OPWC)

Output per Unit of Water consumed by all dams has been shown in Figure 4.87 and the results are summarized below.

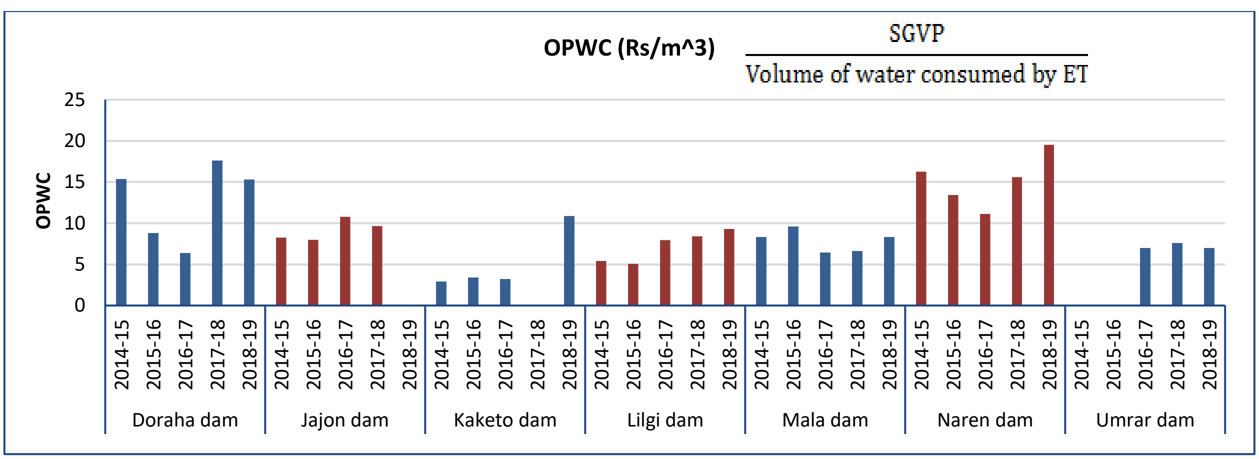


Figure 4.87: Output per unit water consumed (OPWC) of All Dam

- OPWC indicates the water productivity and its values ranging from 2.87 (Kaketo) to 19.52 (Naren) and shows a high variation within the systems.
- Naren dam has done better in terms of OPWC

- Low OPWC values in dams may be due to high water requirement crops.
- The rice-based system may have a low value as compared to the wheat-based system.
- High return crops like pulses, oil seeds, orchids, and industrial crops be recommended.

Output per unit Irrigation Supply (OPIS)

Output per Unit Irrigation Supply of all dams has been shown in Figure 4.88 and the results are summarized below.

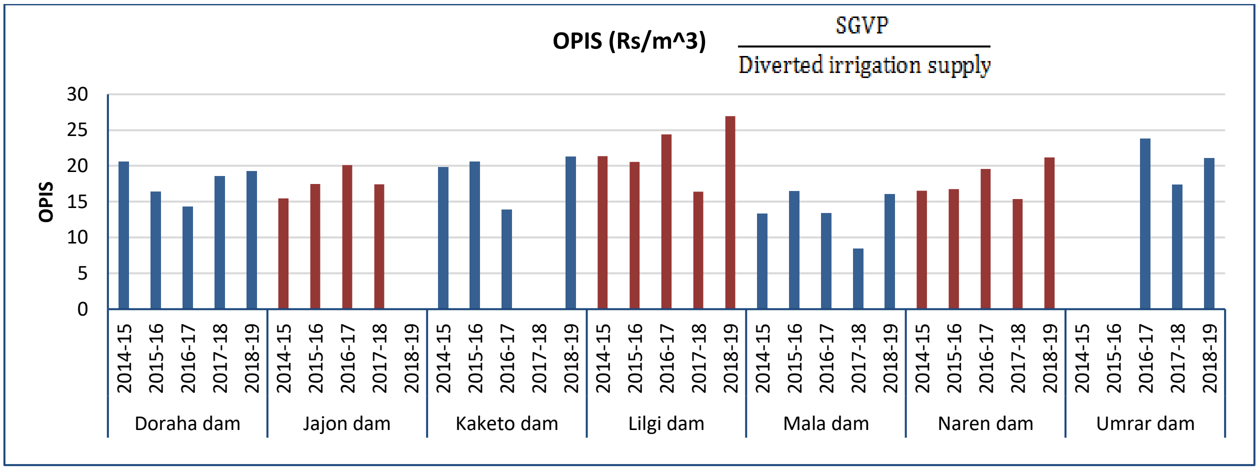


Figure 4.88: Output per unit Irrigation Supply (OPIS)

- OPIS also indicates Water Productivity and varies from 8.47 (Mala tank) to 24.40 (Lilgi Dam)
- It can categorize based on crop type
- The OPIS values are generally low in the Semi-arid region as compared to the Humid region
- This indicator can be kept high by sowing less water-intensive crops with high market price
- This indicator depends upon the ability of farmers and managers to use rainfall effectively

Relative Water Supply (RWS)

Output Relative Water supply of all dams has been shown in Figure 4.89 and the results are summarized below.

- RWS Indicates the Supply-demand situation and how tightly water is supplied in the command. It indicates water scarcity or abundance
- In the study, values of RWS varied from 1.28 to 7.9.
- The best RWS value is 1.5 to 2 considering 30 to 40% water loss in the lined and unlined canal.

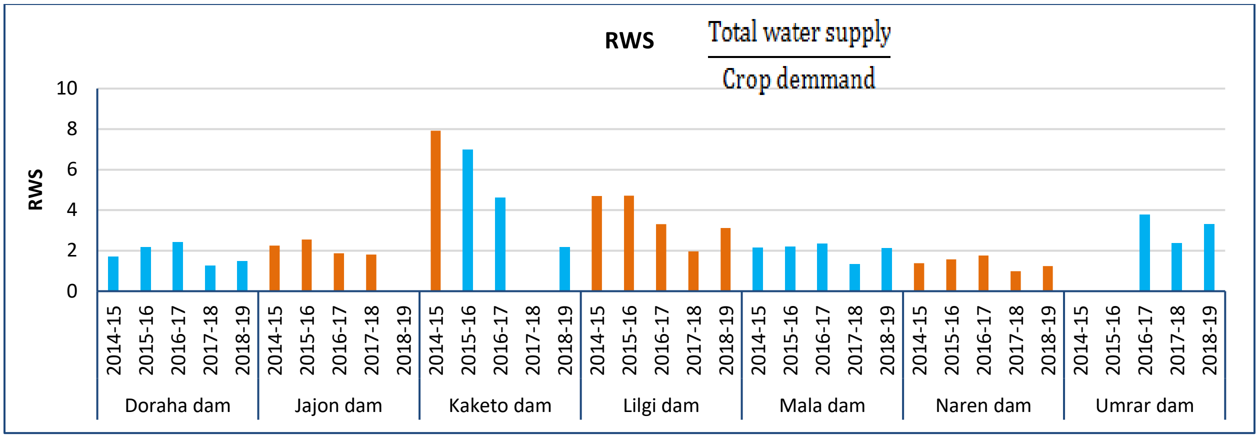


Figure 4.89: Relative Water Supply (RWS)

- RWS value of more than 4 indicates excess supply compared to demand as seen in the case of Kaketo and Lilgi.
- The other four dams are found to have optimum water to meet demand.
- RWS value 2 to 6 indicates that the supply is more than the requirement to meet the demand. So increase cropped area or high water requirement crops in command areas such as Sugarcane, vegetables, cash crops, horticulture, etc.
- RWS value below 1.5 indicates that the supply is not enough to meet the demand for the chosen cropping pattern in different years. Therefore select crops having low water requirements.
- Higher RWS values indicate poor irrigation efficiency and show the water is lost due to poor conveyance and applications. If so Improve irrigation efficiency by canal lining and appropriate methods of irrigation such as border or check basin irrigation method instead of flood irrigation. Use of pressurized irrigation such as drip and sprinkler. Selection of appropriate crop

Relative Irrigation Supply (RIS)

The relative Irrigation Supply of all dams has been shown in Figure 4.90 and the results are summarized below.

- Indicates the Supply-demand situation and how tightly water is supplied and demands are matched.
- This value should be 1.5 or a little higher as the water gets 30 to 40% water loss in the lined and unlined canal.

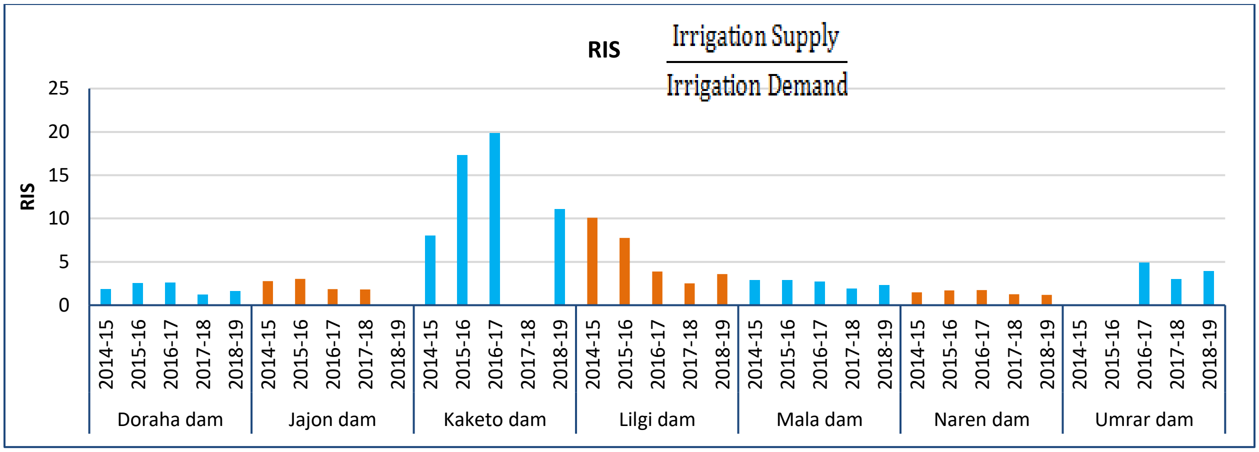


Figure 4.90: Relative Irrigation Supply (RIS)

- These values of the irrigation system studied are ranging from 1.20 to 19.84 (Kaketo).
- RIS value below 1.5 indicates that the supply is not enough to meet the demand for the chosen cropping pattern in different years. Therefore select crops having low water requirements.
- If there is no rain occurring in the Rabi season in a particular year in that area, this index will be the same as the RWS
- RIS value 2 to 6 indicates that the water supply is enough and more than the requirement to meet the demand.
- If the RIS value is higher than the RWS, it means that the rainfall occurred in the command area during the rabi season.
- RIS value 2 to 6 indicates poor efficiency and shows that much of the water is lost through conveyance and applications.
- Help to manage the delta and duty of the area.
- Improve irrigation efficiency by canal lining, appropriate method of irrigation such as a border or check basin irrigation method instead of flood irrigation which is very common in MP. Use of pressurized irrigation such as drip and sprinkler. Selection of appropriate crop.

Water Delivery capacity (WDC)

The Water Delivery capacity of all dams has been shown in Figure 4.91 and the results are summarized below.

- WDC indicates whether the dam infrastructure is capable of meeting the required water demand or not.
- Helps to plan appropriate cropping intensity (Zaid crop can be introduced if capacity is more)

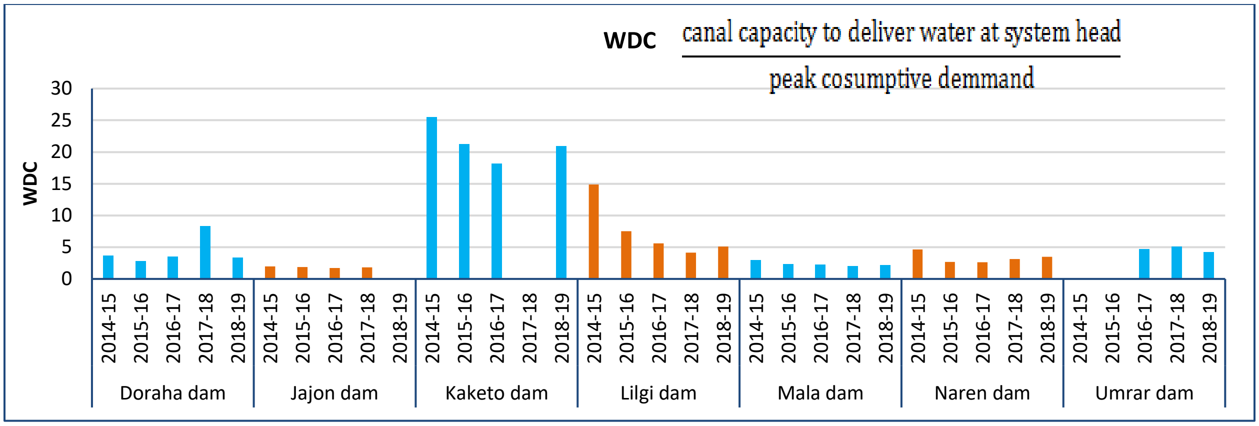


Figure 4.91: Water Delivery capacity (WDC)

- In the study, WDC ranged from 1.70 to 25.48 (Kaketo). (In kaketo head canal is designed to supply to other dams)
- WDC ratio above 1 or 1 to 2 can be considered as good infrastructure and proper Duty has been managed
- WDC ratio above 2 indicates the excess capacity of the system head and Duty is lower than the flow for which it is designed.
- If WDC is above 2: Suggest increasing the command area or changing the cropping pattern, growing high water requirement crop in command
- WDC ratio below 1 indicates insufficient canal capacity to carry flow during the peak water demands. Suggest to change cropping patterns, low water requirement crop, decreasing command area, etc.

Gross Return on Investment (GRI)

The Gross Return on Investment of all dams is shown in Figure 4.92 and the results are summarized below.

- GRI indicates project viability in terms of the cost involved.
- Problems are being faced to estimate the current cost of infrastructure
- Cost at the time of construction can be available in DPR
- The average value of the systems can be estimated within the selected categories for cross-comparison.
- In the study, the GRI value ranged from 3.71 % to 31.39% (in the case of Jajon and Lilgi as these dams are too old and the cost of construction was very low at that time)

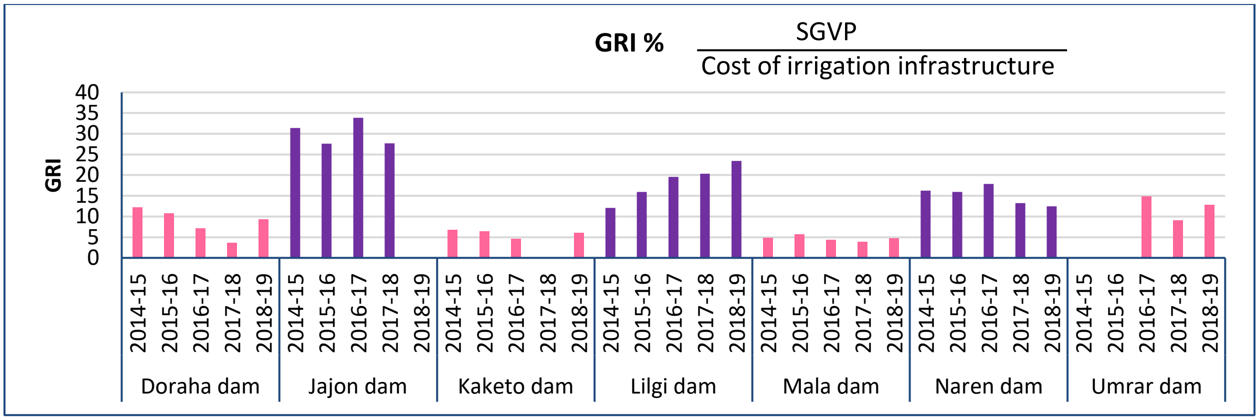


Figure 4.92: Gross Return on Investment (GRI)

Financial self Sufficiency (FSS)

The financial self Sufficiency of all dams is shown in Figure 4.93 and the results are summarized below.

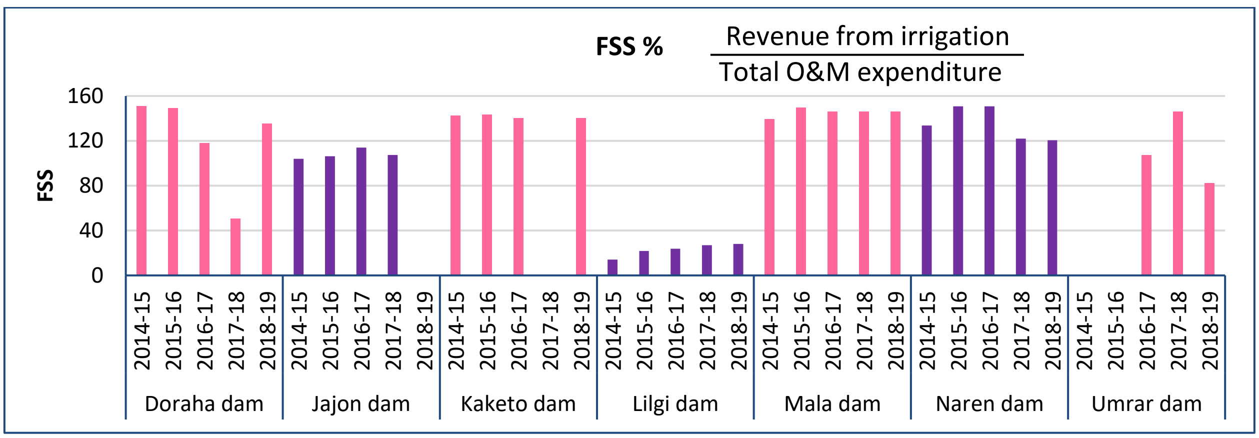


Figure 4.93: Financial Self Sufficiency (FSS)

- Many times it depends upon who is managing the irrigation system, the government, or a local agency like WUA.
- It should be more than 100%
- In most of the cases, FSS was found more than 100% (data used considering per ha irrigation cost for Palewa and subsequent irrigations and O&M cost considered as fund prescribed).

From the analysis of Table 4.18 showing a Cross-System Comparison of the performance of irrigation projects, based on the comparative indicators evaluated for all selected irrigation projects in Madhya Pradesh, the dams performing better are identified. In the year 2014-15, the Lilgi, Doraha, Jajon, and Naren irrigation projects are found to perform better than others in terms of

OPICA indicating better crop productivity. The OPCA indicated land productivity was found better in Doraha in Naren dam this year and the dam was seen to have sufficient water to meet demand as indicated by RIS and RWS. In the year 2015-16 the Lilgi, Naren and Doraha irrigation projects had a better OPICA and OPCA are found to perform better than other dams. These dams had sufficient water to meet demand as indicated by RIS and RWS. In the year 2016-17 Umrar, Naren, and Jajon had a better OPICA, and OPCA was found to perform better than other dams. RIS and RWS were also seen as better and which shown sufficient water availability to meet irrigation demand. From the year 2017-18 and 2018-19, all dams started performing better however the Doraha, Jajon, Lilgi, and Naren were seen performing better. However the Mala and Kaketo dams have not performed up to the mark, hence necessary introspection is needed for strategies for its improvement.

Limitations of Comparative Indicators

- The uncertainty involved in many of the estimates.
- The source of data may affect the outcome as secondary sources are not measured by concerned
- Selection of method of estimation of ET and Effective rainfall.
- Non-availability of data such as reservoir levels, number of borewells in the command, revenue collection information, etc.

4.6.10 Guideline for cross comparison and measures to be adopted to improve performance

Guidelines for cross-comparison and measures to be adopted for further improvement are discussed in Table 4.19 which gives an idea about Comparative indicators and their significance in performance evaluation.

Table 4.19: Comparative indicators and their significance in performance evaluation

Indicator	***Equation***		***Significance/Implication/Importance***
Standardized Gross Value of Production	SGVP	SGVP=$\left[\sum AiYi\frac{P_i}{P_b}\right]P_{word}$	• It should always be high • In general, SGVP is increasing every year due to an increase in crop price and yield. • Increased yield may be due to adaptation strategies such as appropriate and timely irrigation, appropriate farm practices, improved varieties, use of fertilizers, pesticides and insecticides, conservation tillage practices, etc.
Output per unit cropped area (Rs/ha)	OPICA	$\frac{\text{SGVP}}{\text{Irrigated cropped area}}$	• Indicates the crop productivity • If high value – good • If low, then need to improve by adopting appropriate measures such as timely and adequate irrigation water supply, timely field operation and agricultural practices, such as sowing, intercultural and harvesting, pesticide, fertilizers, manure and good seed quality.
Output per unit command area (Rs/ha)	OPCA	$\frac{\text{SGVP}}{\text{Command area}}$	• Indicates land productivity • In addition to the above measures, bring complete command under cropped area, selection of crop and variety
Output per unit water consumed (Rs/m^3)	OPWC	$\frac{\text{SGVP}}{\text{The volume of water consumed by ET}}$	• Indicates water productivity • If the value is high- good depends mainly on the selection of an appropriate crop. • This indicator represents the output per unit water consumed and the concept of more crops per drop
Output per unit irrigation supply (Rs/m^3)	OPIS	$\frac{\text{SGVP}}{\text{Diverted irrigation supply}}$	• Indicates water productivity • If a value is high- good • The output per unit irrigation supply increases year to year as SGVP value is increasing every year due to many reasons • To improve this indicator, improve irrigation efficiency and use agriculture management practices • To improve this indicator use agriculture management and irrigation scheduling. • Conjunctive use practices
Relative Water Supply	RWS	$\frac{\text{Total water supply}}{\text{Crop demand}}$	• Indicates supply-demand scenario and the condition of water abundance or scarcity, and how tightly supply and demand are matched • If the RWS value is 1.5 to 2 – good because the water gets 30 to 40% water loss in the lined and unlined canal. • If RWS is a value below 1.5, it indicates that the supply is not enough to meet the demand for the chosen cropping pattern in different years. Therefore select crops have low water requirements. • If the value of RWS is 2 to 6, it indicates that the supply is enough and more than the requirement to meet the demand for the chosen crop in different years. So increase cropped areas or high water requirement crops in command areas such as Sugarcane, vegetables, cash crops, horticulture, etc. • If the value of RWS is 2 to 6, it also indicates poor irrigation efficiency and shows water is lost due to poor conveyance and application efficiency. • Improve irrigation efficiency by canal lining, appropriate method of irrigation such as a border or check basin irrigation method instead of flood irrigation which is very

			common in MP. Use of pressurized irrigation such as drip and sprinkler. Selection of appropriate crop.
Relative Irrigation Supply	RIS	$\frac{\text{Irrigation Supply}}{\text{Irrigation Demand}}$	• Indicates supply-demand scenario and the condition of water abundance or scarcity, and how tightly supply and demand are matched • If the RIS value is 1.5 to 2 it is good because the water gets 30 to 40% water loss in the lined and unlined canal. • If RIS is a value below 1.5, it indicates that the supply is not enough to meet the demand for the chosen cropping pattern in different years. • Therefore select crops have low water requirements. • If there is no rain occurring in the Rabi season in a particular year in that area, this index will be the same as the Relative Water supply index • If the value of RIS is 2 to 6, it indicates that the water supply is enough and more than the requirement to meet the demand. • If the RIS value is higher than the RWS, it means that the rainfall occurred in the command area during the rabi season. • If the value of RIS is 2 to 6, it indicates poor efficiency and shows that much of the water is lost through conveyance and applications. • Managing delta and duty of the area. • Improve irrigation efficiency by canal lining, appropriate method of irrigation such as a border or check basin irrigation method instead of flood irrigation which is very common in MP. Use of pressurized irrigation such as drip and sprinkler. Selection of appropriate crop.
Water Delivery Capacity	WDC	$\frac{\text{canal capacity to deliver water at the system head}}{\text{peak consumptive demand}}$	• This indicator indicates whether the dam infrastructure is capable of meeting the required water demand or not. To plan appropriate cropping intensity (Zaid crop can be introduced if capacity is more) • If the WDC ratio is above 1 or 1 to 2 then it can be considered a good infrastructure and proper irrigation Duty has been managed in the command area. • If the WDC ratio is above 2, it indicates the excess capacity of the system head and Duty is lower than the flow for which it is designed. • Suggest increasing the command area or changing the cropping pattern, growing high water requirement crops in the command area • If the WDC ratio is below 1, it indicates that the canal capacity is not sufficient to carry flow during the peak water demands. • Suggest to change cropping patterns, low water requirement crop, decreasing command area, etc.
Gross Return on Investment (%)	GRI	$\frac{\text{SGVP}}{\text{Cost of Irrigation Infrastructure}}$	• This indicator considers the SGVP value and the total cost of infrastructure. • The present cost can be estimated by considering a 10% rise in cost every year

Financial Self-Sufficiency	FSS	$\frac{\text{Revenue from Irrigation}}{\text{Total O\&M Expenditure}}$	• This indicator shows the ability of the users to manage the scheme without the help of the government • The financial self-sufficiency result indicates how much of the revenue generated was used for operation and maintenance • This indicator will be weak when most people do not pay water fees

4.6.11 Development of web-based dynamic IT desktop and android-based mobile application for performance evaluation of irrigation project

Background

The performance evaluation of the irrigation project is a part of the benchmarking process, an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. It helps to identify bottlenecks, constraints, managerial laps, and other grey areas in the system and provides direction for improvement therein.

The present work on the development of a Web application and Mobile App for performance evaluation of irrigation projects are being carried out for Madhya Pradesh state Water Resources Department under the National Hydrology Project PDS. In recent times, the Madhya Pradesh state has achieved remarkable growth in the irrigation sector. The Madhya Pradesh state has a setup of a total of 4916 irrigation schemes which includes 22 major irrigation schemes with 13.91 lakh ha irrigated area, 90 medium irrigation schemes with 2.42 lakh ha irrigated area, and 4804 minor irrigation schemes with 7.59 lakh ha irrigated area. The efforts made by the state for the repair, renovation, rehabilitation, and management of existing irrigation schemes and newly developed projects have helped the state to achieve a significant rise in irrigation and agricultural production. The same pace of sustainable development in the waters sector will be a key factor to meet the increasing future water demands in the state. This can be achieved through operating existing irrigation projects at optimum efficiency and their full potential. Formulation of management strategies based on continuous evaluation of the performance of the irrigation project using appropriate indicators is important for the successful operation of a project to reap full benefits. Though the web-based dynamic application and mobile app for performance evaluation of an irrigation project in Madhya Pradesh could not be developed, the website development framework has been elaborated in detail in this section.

Development of a web-based dynamic application and mobile App

One of the important components of the PDS is the development of a web-based dynamic application for performance evaluation of an irrigation project, which can be integrated with India-WRIS, NHP Web portal, or MPWRD portal. At present this work is under progress at NIH Regional Centre, Bhopal.

Objectives of development of this Web and Mobile application

- Development of a web-based dynamic IT desktop and Android-based mobile application for performance evaluation of irrigation projects.
- Online Computation of Standardized Gross Value of Production (SGVP) and nine indicators, Output per unit cropped area (Rs/ha), Output per unit command area (Rs/ha), Output per unit water consumed (Rs/m3), Output per unit irrigation supply (Rs/m3), Relative water supply, Relative irrigation supply, Water delivery capacity, Gross return on investment (%), Financial self-sufficiency using back-end data and data submitted by the user.
- Providing demonstration, training, presentation, user manual and video tutorials

Website and Mobile App Framework

A Web-based dynamic IT desktop and Android-based mobile application for performance evaluation of irrigation project will involve mathematical calculations at the front and back end. The website will be user-friendly and perform computations for multiple comparative indicators, classified into four groups, namely, agricultural, economic, water-use, and physical performance. The input information related to the irrigation project and command areas required to be filled online by the irrigation project in-charge will be, salient features, reservoir capacity table, water released at canal head, water levels of the reservoir, crop area of each crop in command, the yield of each crop, the local price of each crop (present), the local price of the base crop (present), the value of base crop traded at world price (present), command area details, irrigated cropped area, total water supply (surface diversions + net groundwater draft + rainfall), irrigation supply (Surface diversions + net groundwater draft), diverted irrigation supply (Surface diversions + net groundwater draft), canal capacity to deliver water at system head, revenue from irrigation, cost of infrastructure (at the time of construction) and total O&M expenditure. (Figures 4.94 and 4.95)

For carrying out an online computation, the data and information will also be made available at the back end which will be applied for the computation of comparative indicators. This information includes long-term rainfall data of all districts of MP, effective rainfall, evapotranspiration (ETo) for estimation of water demand, crop types, crop coefficients (Kc) values, Prices of the crop, base crop and crop traded at world prices (present and historical values).

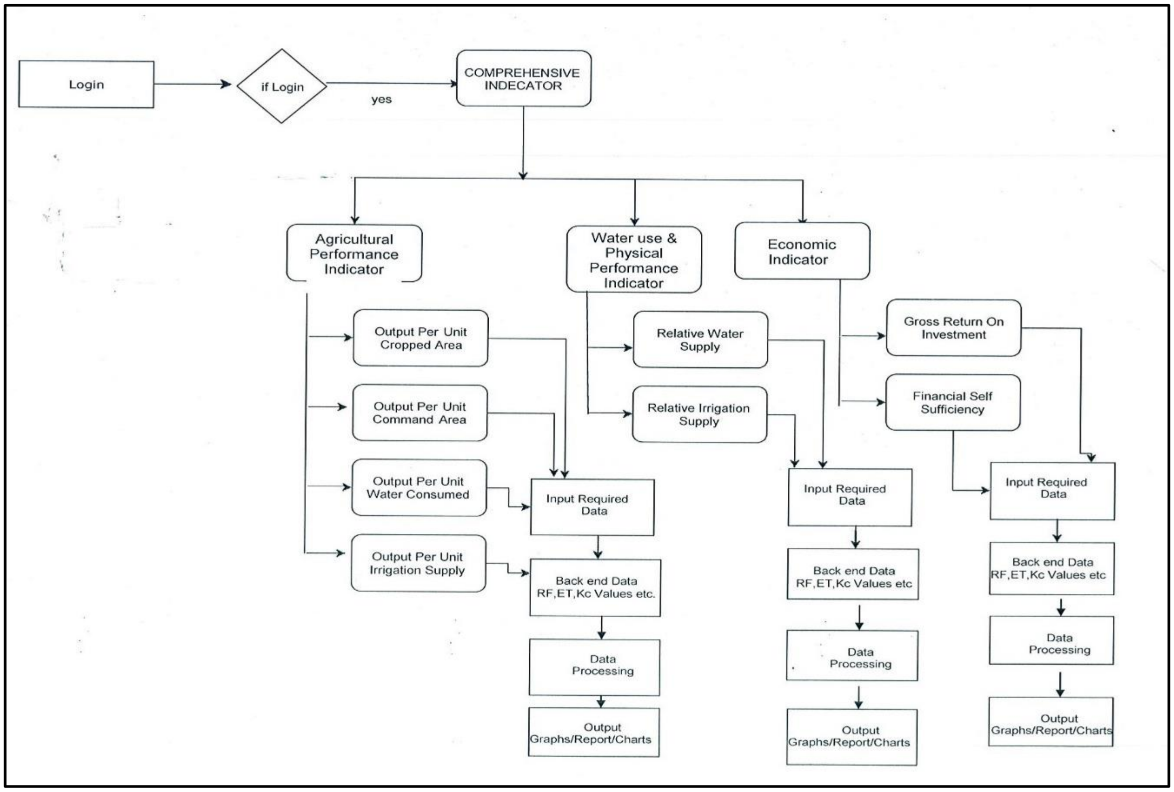


Figure 4.94: Web Programming Flow chart for Irrigation Project Officers for evaluation of Comparative Indicators

Deliverables and output

The web-based dynamic application will enable irrigation project managers of the region to evaluate the performance of projects under their control with the use of project related data and information as input. It will help the project authority to compare the performance of the project with the previous years or with other projects in the region and formulate strategies for further improvement in the system. It will also help to assess the impact and evaluate the benefits of rehabilitation, restructuring, and renovation work undertaken for the irrigation project. It will also help to assess the impacts of operation and management policy on the performance of the irrigation project.

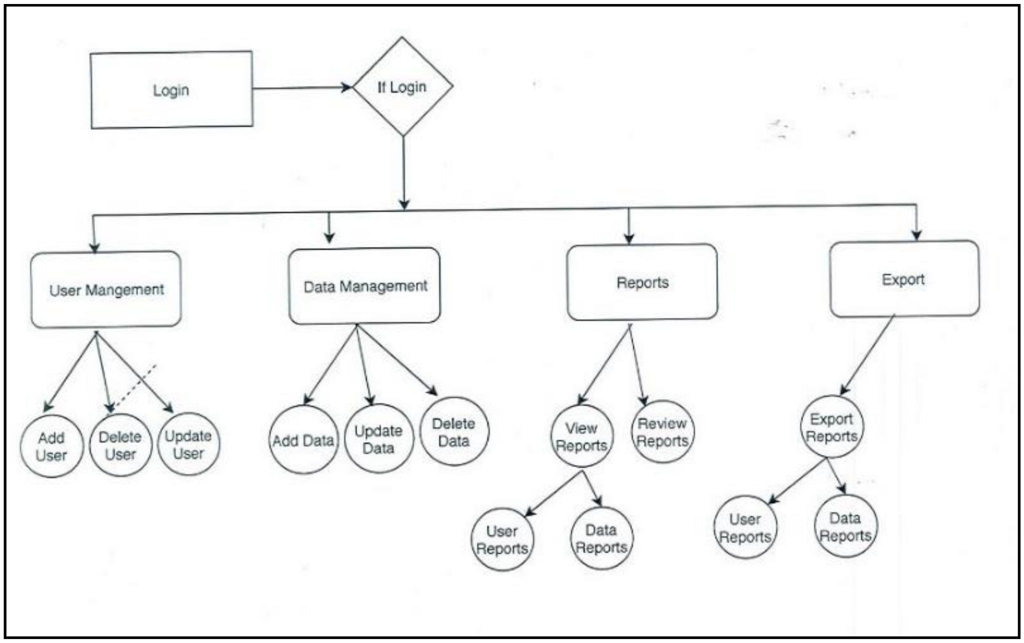


Figure 4.95: Web Programming Flow chart for Admin for analysis and decision making

Calibration of Web application and Mobile App with Field Data

For calibration of the website and mobile app, a similar analysis was carried out manually for eight medium irrigation projects located in the major tributaries of the Ganga and Yamuna basins such as Betwa, Chambal, Dhasan, Ken, Son, tone, and Sindh are identified and selected for the study as given in Table 3.3. The locations of all selected irrigation schemes in Madhya Pradesh are shown in Figure 4.96. All selected irrigation schemes have been analyzed based on the comparative indicator to assess progress against strategic goals, assess the general health of a system, diagnose constraints, compare the performance of a system with others or with the same system over time, and improve system operations.

In the present study, the performance of the eight irrigation schemes of Madhya Pradesh given in Table 3.3 has been evaluated using nine comparative indicators, classified into four groups, namely, agricultural, economic, water-use, and physical performance suggested by International Water Management Institute (IWMI) (Moldenet al., 1998). The agricultural performance has been carried out using four indicators related to the output of different which are Output per cropped area (Rs/ha), Output per unit command (Rs/ha), Output per unit irrigation supply (Rs/mm), and Output per unit water consumed (Rs/mm).

Standardized Gross Value of Production (SGVP) has been developed for cross-system comparisons regardless of where they are or what kinds of crops are grown. SGVP is the output of the irrigated area in terms of the gross or net value of production measured at local or world prices. The crop water demand will be estimated with the help of Reference Evapotranspiration which will be calculated using the Cropwat program (FAO, 1992) and crop coefficient value Kcfor the main crops using FAO guidelines (Doorenbos and Kassam, 1986 and Doorenbos and Pruitt, 1977). The other five indicators that were used for further investigation and performance evaluation of the irrigation project are the Relative water supply indicator, Relative irrigation supply indicator, Water delivery capacity indicator (%), Financial self-sufficiency indicator (%), and Gross return on investment indicator (%).

Elements of Dynamic Web-Based Application

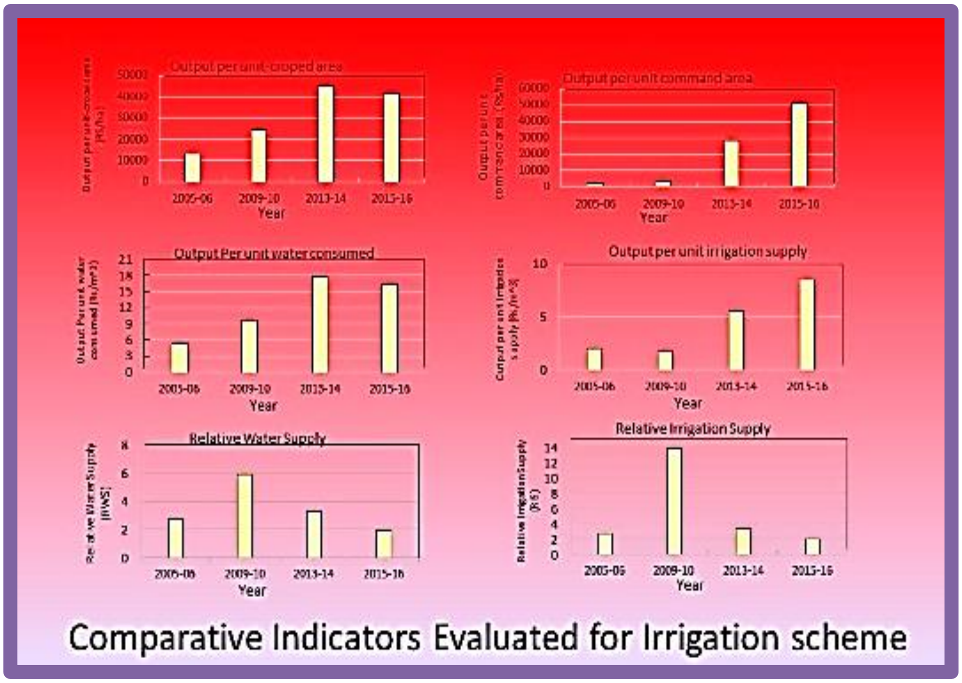
- Development of website using: ASP MVC: ASP.NET MVC, SQL Server, C#(C Sharp), Angular JS, Bootstrap
- Web site interface-user friendly
- Evaluate comparative indicators
- Link to other important sites of MPWRD, MoWR, MoAgril, etc.
- User (Executive Engineer/SDO/Asst Engg/----)
- login to the website
- Available information on the website's back-end
    - Rainfall of each district, Effective rainfall
    - ET (for estimation of water demand)
    - Crop type, Kc values
    - Value of the crop, base crop, and value of crop traded at world prices (Historical)

Input Data Required to be filled up by User

- Crop area of each crop in command
- The yield of each crop
- The local price of each crop (present)
- The local price of the base crop (present)
- Value of base crop traded at world price (present)
- Command area and Irrigated cropped area
- Total water supply (Surface diversions + net groundwater draft + rainfall)
- Irrigation supply (Surface diversions + net groundwater draft)
- Diverted irrigation supply (Surface diversions + net groundwater draft)
- Canal capacity to deliver water at system head
- Revenue from irrigation
- Cost of infrastructure (at the time of construction)
- Total O&M expenditure

Output

- Online evaluation of all indicators
- Prepare a report (Table and Graphs)
- Compare with others or the same project (past performance)
- Performance Evaluation of the irrigation project
- Higher authorities can log in and see the report.
- Policy decision



Evaluated comparative indicators

Year	SGVP (Lakh Rs)	Irrigated area (Thousand ha)	Command area (Thousand ha)	Effective Rainfall (mm/season)	Total ER (MCM)	Total water supply (cusec)	Diverted Irrigation supply (MCM)	Volume ET (MCM)
2005-06	31.28	23.13	120.5	11.1	0.25	17176	157.54	57.78
2009-10	46.65	18.95	120.5	16.5	3.12	30570	280.40	47.86
2013-14	342.77	75.80	120.5	21.1	15.99	67042	614.93	192.84
2015-16	618.28	147.63	120.5	10.1	14.91	79095	725.49	379.35
Year	Total water supply DIS+TER (MCM)	CWR (mm/season)	Total CWR (MCM)	Irrigation supply (MCM)	IR (mm/season)	Total IR (MCM)	CCDWSH (cusec)	PCD (l/s/ha)
2005-06	157.80	249.81	57.78	157.54	244.92	56.65	44.15	0.35
2009-10	283.52	252.48	47.86	280.40	106.34	20.16	44.15	0.36
2013-14	630.93	254.41	192.84	614.93	233.96	177.34	44.15	0.35
2015-16	740.40	256.95	379.35	725.49	243.46	359.44	44.15	0.33
Year	PCD (cusec)	RWS	RIS	OPICA (Thou Rs/ha)	OPCA (Thou Rs/ha)	OPIS (Rs/m^3)	OPWC (Rs/m^3)	WDC
2005-06	8.10	2.73	2.78	13.52	2.59	1.99	5.41	5.45
2009-10	6.83	5.92	3.20	24.60	3.86	1.66	9.75	6.47
2013-14	26.53	3.27	3.47	45.22	28.42	5.57	17.77	1.66
2015-16	48.72	1.95	2.02	41.87	51.27	8.52	16.30	0.90

Figure 4.96: Sample output results figures and Tables

CHAPTER - V

CONCLUSIONS, RECOMMENDATIONS, FUTURE SCOPE OF THE WORK AND KNOWLEDGE DISSEMINATION

5.1 Conclusions

The sustainability of the irrigation project can be achieved through the formulation of strategies based on continuous evaluation of the impacts of irrigation schemes in terms of their environmental and economic aspects. The performance evaluation of the projects is equally important to reap its benefit on a long-term basis. The performance evaluation of the irrigation project is a part of benchmarking process, an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. In the recent decade, the Madhya Pradesh state has achieved remarkable growth in the irrigation sector. MP State has been bestowed with the prestigious Krishi Karman award by the Government of India for the last five years in a row. This has been made possible through the water sector restructuring program and sustainable water resources development strategies adopted by the state. States need to keep the same pace of development more consistent and sustainable. Thus it is imperative to evaluate the irrigation schemes in terms of their impacts on hydrology, agricultural production, economy, and society. This can be achieved through the formulation of strategies based on continuous performance evaluation of irrigation schemes. It involves the use of suitable comparative indicators, measuring its performance and comparing with the best practices, identifying bottlenecks, constraints, managerial laps, and other grey areas in the system to formulate a direction for improvement strategies. The present PDS study envisaged the evaluation of the impacts of rabi irrigation on hydrology, agricultural growth, economy, and public health for three selected irrigation projects in the Ganga basin. Another objective was the performance evaluation of medium and minor irrigation projects and the development of a web-based dynamic application for performance evaluation of irrigation projects.

The impact evaluation analysis was carried out for Jajon (minor), Kotwal-Pilowa (major), and Samrat Ashok Sagar (Major) irrigation projects in Madhya Pradesh. A baseline survey was conducted in command areas to collect the primary data. The survey was based on a stratified selection of villages falling in the head, middle, or tail reach, selection of marginal and big farmers according to their landholding size, and selection of farmers households in the village through a random sampling method. The sample Survey size for the household survey was worked out at a 99% confidence level and 10% confidence Interval. Out of around 68700 households in 505 villages falling into three projects, around 1500 households in 302 villages were surveyed to achieve accuracy in the outcome. The secondary data collected from line departments were also used in the study. According to the information derived from the primary data on the landholding size of farmers, around 50 to 55% are distinguished as small farmers (land < 2 ha), 41- 45% of farmers are distinguished as medium farmers (land between 2-10 ha) and 3.5 to 4.6%. are distinguished as large farmers (land > 10 ha). The major crops grown in the rabi season in all three selected irrigation projects are wheat, gram, masoor, mustered, lentil, etc. The groundwater situation has been found better in the head and middle reach of the command area whereas the groundwater level was observed at a very deep level in the tail reach area and has seen high depletion from post to pre-monsoon season. The reason behind this is the insufficient irrigation supply from the canals and the high use of groundwater for irrigation in the tail reach area.

Irrigation interval was reported as 26 to 30 days in the case of all three projects and it was reported longer in the tail-end area causing its impact on wheat production. Crop production was reported as good in the head and middle as compared to tail reach whereas the crop production in the non-command area was seen as less than even the tail reach area of the command. Waterlogging problem was reported in a few places in the head reach area of the Kotwal-Pillowa project.

Most of the farmers have modern farm equipment like tractors, threshers pump sets to perform farm operations, the farmers in a tail reach area make use of hired equipment whereas farmers in the head and middle reach area owns this modern equipment which indicates the difference in social-economic status in different reaches of the command. Nowadays almost all the farmers of command and non-command areas have advanced home appliances like LPG connections, two-wheelers, television sets, etc. at their houses.

From the analysis of primary data obtained from the baseline survey, it was noticed that the farmers in the head reach area receive sufficient irrigation supply whereas the farmers in the middle and tail reach areas are not seen as satisfied with the canal water supply as they are not getting sufficient water supply when required. The farmers in tail-reach areas are making use of groundwater in conjunction with canal water for irrigation. Canal condition was not reported well in all three commands. Canals are reported mostly in non-lining and breached conditions causing water loss. Farmers are hardly seen adopting scientific and specific irrigation methods to save water and most of the farmers have adopted only flood irrigation methods. Progressive and large farmers are seen using advanced techniques and methods to save, conserve and make optimal use of water.

Many farmers in the middle and tail reach region of the command have reported the occurrence of regenerated flow in nalas and other water bodies during the irrigation time. Due to a lack of awareness, the majority of farmers are reluctant to adopt soil and water conservation measures for moisture conservation in their fields. It was observed that the location of the village in its command does not matter the education status. In Jajon command majority of farmers have not obtained formal schooling while the maximum percentage of graduates are found in the middle and tail reach of Jajon command. However, the trend of sending children for higher education to nearby cities and towns was seen as evidence. Only 10 to 15% of farmers of Samrat Ashok Sagar and Kotwal command have availed bank loan facilities for the purchase of goods or vehicles. The majority of farmers have Kisan credit cards and they make use of it when needed. Around 50% of farmers were seen as reluctant to avail crop insurance facilities. Thus the survey indicated reasonable improvement in social status following the economic status in command areas of Jajon, Kotwal-Pilowa, and Samrat Ashok Sagar irrigation projects as compared to the non-command areas. Besides advantages, there are a few disadvantages like the spread of water-borne and vector-borne diseases in the command area which was reported high in the head and middle reach of the irrigation project. Around 60% of farmers reported malaria and 40% of farmers reported other diseases like dengue, diarrhea, chikungunya, etc.

In the present PDS, the performance evaluation analysis has been carried out for eight medium and minor irrigation projects namely Kotwal-Pilowa dam, Doraha dam, Naren Dam, Mala dam, Kaketo, and Lilgi dam, Umrar, and Jajon dam. These dams are located in the major tributaries of the Ganga and Yamuna basins such as Betwa, Chambal, Dhasan, Ken, Son, tone, and Sindh. Nine comparative indicators classified into four groups, Agricultural, Economic, Water-use, and Physical performance as suggested by IWMI (Molden *et al*., 1998) were used for the analysis.

The Kotwal-Pillowa project is a complex project having two separate dams Kotwal and Pillowa on two rivers on Asan and Sankh respectively falling in the Sindh sub-basin of the Chambal river in the Morena district of Madhya Pradesh. The performance of the Kotwal-Pillowa irrigation project has been improved significantly in terms of its agricultural, water use based performance in the recent period, especially after 2013-14, which was due to additional water supply from Gandhi Sagar dam on the Chambal river, increased cropped area, and adoption of appropriate managerial practices. The output per unit cropped area was 13523 Rs/ha in the year 2005-06 and it increased to 45220 Rs/ha in the year 2013-14. The output per unit command area was seen to increase from 28425 Rs/ha in the year 2013-14 to 51272 Rs/ha in the year 2015-16. The analysis indicated improvement in crop productivity and land productivity in the command. The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) index were found better as compared to other irrigation projects in India and worldwide indicating sufficient availability of water in the dam. The Water Delivery Capacity index analysis indicated that the dam's infrastructure is capable of delivering water to meet peak water demand.

In the case of the Kaketo dam constructed on the Parvati river in the Sindh basin located in Shivpuri district, the output per unit cropped area and output per unit command area were seen to increase. The output per unit of irrigation supplies was seen to improve due to the adaptation of proper water management practices and more area cultivation with orchards, industrial crops, vegetables, and more horticulture in the Kaketo command. The Relative Water Supply (RWS) and Relative

Irrigation Supply (RIS) indicators were found reasonable during all selected assessment years indicating sufficient water availability to meet the irrigation demand.

A similar analysis was carried out for all the irrigation projects. From the cross-system comparison of comparative indicators, it was observed that in the year 2014-15, the Lilgi, Doraha, Jajon, and Naren irrigation projects were found to perform better than other projects in terms of crop and land productivity, Relative water supply (RIS) and Relative irrigation supply (RWS). In the year 2015-16, the performance of the Lilgi, Naren, and Doraha irrigation projects was seen better. In the year 2016-17, the performance of the Umrar, Naren, and Jajon irrigation projects was seen better. After 2017-18 and 2018-19, the performances of all irrigation projects were found to improve in terms of output per unit irrigated cropped area, output per unit command area, output per unit water consumed, and output per unit irrigation supply, especially Doraha, Jajon, Lilgi and Naren projects. This indicated the improvement of crop productivity, land productivity and water productivity, and overall performance during recent years. Relative water supply and Relative irrigation supply analysis indicated excess supply as compared to demand, which needs immediate attention. Water delivery capacity was observed between 1 and 2 can be considered as good infrastructure and proper Duty has been managed. Gross return on investment values was found better in the case of all projects. All irrigation projects are seen as financially viable and self-sufficient for revenue collection against the O&M cost. The Mala and Kaketo dams have not performed up to the mark in comparison to other selected dams, which urges the need for necessary introspection of these underperforming irrigation systems to formulate strategies for their improvement.

The performance evaluation has been seen to be a very simple method as comparative indicators are very easy to calculate by using field data and are useful to assess the progress of irrigation projects against strategic goals and formulate strategies to improve system operations. The limitations of the performance evaluation analysis are uncertainty involved in many of the estimates, source of data, selection of method in estimation of evapotranspiration, and effective rainfall. The other concern is the non-availability of data such as reservoir levels, number of borewells in the command, revenue collection information, etc.

The main utility and outcome of this PDS is the development of a knowledge product that involves the development of a Web-based dynamic application and an android-based mobile application for the performance evaluation of an irrigation project. It will enable the project officers to evaluate the performance of the project under their control, compare, identify the problem and formulate strategies for improvement. It will help decision-makers and administrators to monitor the performance of all irrigation projects of the state at a single platform, compare, and identify best practices, gray areas, and bottlenecks in the systems, formulate strategies and make decisions.

5.2 Recommendations

Based on the results of the study, specific recommendations suggested for improving the performance of irrigation projects are given below.

- The Madhya Pradesh Water Resources Department has to adopt and promote presurrize irrigation methos like drip and sprinkler irrigation in command and non-command areas to improve water use efficiency.
- State WRD must take necessary measures to improve canal conditions, including lining of the canals and protecting them from breaching to improve the efficiency of the projects.
- Farmers are to be promoted to adopt advanced methods of irrigation such as a border or check basin irrigation methods instead of flooding to make optimal use of water.
- Conjunctive use of surface and groundwater for equitable distribution in the command area.
- The Relative water supply and Relative irrigation supply were seen very high in all selected irrigation projects indicating excess supply as compared to the demand which may be due to the overestimation of ETo and ETc, which need immediate attention. Need to revise and manage delta and duty. This can also be addressed by appropriate cropping intensity if more water is available or increasing the command area or changing the cropping pattern, growing high water requirement crops in the command area
- Set up suitable reservoir operating guidelines for drought years and crop selections with low water requirements.
- If exces water is available in the irrigation project it can be used for the farmers in the catchment area of the same project as well as in the nearby non-command area.
- Plan to make use of regenerated flow for its beneficial use and bringing additional area under irrigation.
- Irrigation systems should be made self-sufficient by improving the ability of the users to manage the scheme without the help of the government.
- Strengthen Water User Associations and their involvement in Warabandhi or irrigation scheduling for optimal utilization of irrigation water.
- Convergence of government programs to develop agriculture-based businesses, bank facilities, and rural livelihood to improve the social and economic status of farmers.
- Create awareness of the benefits of using proper conservation tillage techniques, water and soil conservation measures, field canal maintenance, soil testing, crop selection and variety, application of fertilisers and pesticides, etc.

5.3 Future Scope of the Work

In the present study, the performance of irrigated agriculture systems has been evaluated using comparative indicators to identify problems associated with the project and formulate strategies to improve water use efficiency. The study can be expanded to include irrigation water dynamics and irrigation infrastructure for irrigation system evaluation. Furthermore, a geospatial approach can be used to evaluate the performance of irrigation command, which will aid in identifying problem pockets and provide opportunities to investigate alternatives for corrective management. The irrigation project's performance can be linked to the agricultural practices used in the command, such as crop selection, crop rotation, cropping intensity, and so on. Remote sensing techniques can be used to appraise the irrigation system quickly. The most appropriate method of ET estimation for the region under study can be chosen carefully.

5.4 Dissemination of Knowledge

5.4.1 First stakeholders workshop (24th April 2019) at Bhopal

The First Stakeholders Workshop on PDS under NHP was organized on 24th April 2019 at Data Centre, MPWRD, Bhopal. The photograph of the workshop is shown in Figure 5.1.

Figure 5.1: Photograph of First Stakeholders Workshop

5.4.2 Second stakeholders workshop (19th March 2021) at Bhopal

One day Stakeholders workshop on a PDS "Evaluation of Impact of Rabi Irrigation in Ganga sub-basin of Madhya Pradesh" was jointly organized by Madhya Pradesh WRD and NIH RC Bhopal on 19-03-2021 at Hotel Palash, Bhopal. The main purpose of this workshop was the knowledge dissemination and to present PDS outcomes and other related issues to stakeholders so that it will be helpful to state MPWRD for formulating strategies for planning and management of irrigation projects to achieve optimal utilization of water resources for irrigation and agricultural production. The photographs of the workshop are shown in Figure 5.2.

Figure 5.2: Photographs of Second Stakeholders Workshop

Dr. J.V. Tyagi, Director, NIH, Dr. A K Lohani, Coordinator NIH Bhopal, Er. G.P Soni, Chief Engineer, Bodhi, Er. Aditya Sharma, Chief Engineer, CWC, Bhopal was the Chief Guest of the workshop. Around 100 officials from different agencies like MPWRD, Central Water Commission, CGWB, BODHI, NIH, WALMI, etc. participated in the workshop. The program began with the welcome of delegates by Er. Gupta, Dy Director, BODHI, welcomed all the delegates on the dais followed by Lamp Lightening. During the inaugural address, Er. G.P Soni, CE, BODHI discusses the NHP activities being carried out in the Madhya Pradesh state. He briefed about RTDAS installation in MP and PDS activities of the state in collaboration with NIH. He explained how the present PDS will be helpful to MPWRD in decision-making for irrigation projects in MP Chairman of the program Dr. J.V. Tyagi, Director NIH gave a brief introduction of NIH and NHP activities in NIH appreciated the support of MPWRD in scientific activities of NIH Bhopal, especially PDS studies. Er. Aditya Sharma, Chief Engineer, CWC, Bhopal informed about the role of CWC in NHP activities.

The workshop presentations began with the presentation of Er. Paliwal, Dy Director, MPWRD gave a detailed presentation on NHP activities in Madhya Pradesh. Dr. A.K. Lohani, Scientist-G, Coordinator Training (NHP) & RC Bhopal gave a presentation on the NHP activities of NIH. He explained the role of NIH in HP-1, HP-2, and NHP. The role of NIH in NHP is to provide training and monitor PDS studies for all the implementing agencies in the country.

Er. Ravi Galkate, Scientist E & Head NIH Bhopal presented the progress of a PDS Evaluation of the Impact of Rabi Irrigation in the Ganga sub-basin of Madhya Pradesh. He discussed the outcome of PDS work and explained how impact evaluation and performance evaluation of irrigation projects in important for better management of irrigation projects in the state. He showcased case studies of eight selected irrigation projects of Madhya Pradesh and explained how problem areas, managerial gaps, and grey areas in the irrigation system can be identified using comparative indicators. He also gave details of the development of a Dynamic website and mobile app for performance evaluation of irrigation projects as a Knowledge Product under NHP. During the discussion number of suggestions were given by the experts and participants which will help to improve the outcome of the PDS work. Sh. Ajil Joseph, a software engineer from Tattva Foundation, Lucknow presented a demonstration of the proposed dynamic website to be developed under the PDS. The PDS highlights were circulated in the form of Fliers for knowledge dissemination. The workshop came to an end with a vote of thanks from Dr. R.K. Jaiswal, Scientist D, NIH, RC, Bhopal.

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APPENDIX-A

Project summary

Table A.1: Summary

Project objectives		
Objectives as per project document	Revised objective	Reasons for revision
- *Evaluation of impacts of Rabi irrigation on hydrology, agricultural growth, economy, and public health for selected irrigation projects in the Ganga basin.* - *Performance evaluation of medium/minor irrigation projects.* - *Development of a web-based dynamic application for performance evaluation of irrigation project.* - *Recommendations and dissemination of knowledge, and findings through training and workshops.*	*Objective added*	*On the suggestion of Review committee*

***Manpower* deployed (against sanctioned manpower)**			
Sanctioned		Deployed	
Designation	Person months	Designation	Person months
Junior Research fellow/ Project Associate-I	*1 person Till end of PDS*	*Junior Research fellow/ Project Associate-I*	*1 one Person 45 month*

Infrastructure/ equipment		
Planned (as per project proposal)	Developed/ procured	Reasons for deviation
Laptop, Desktop (workstation) and Printer	*Procured*	---

Field work		
Planned (as per project proposal)	Completed	Reasons for deviation
Field visits to Dam sites and command area for data collection and survey	*Completed*	

Workshop/ Capacity building/ technology transfer		
Planned (as per project proposal)	Organized	Reasons for deviation
Two workshops	*Organized*	

Study area	
Planned	Extended
Command of 10 dams	*No*

New data generated in the project		
Planned (as per project proposal)	Achieveme nt	Reasons for deviation
Primary data through base line survey	*Achieved*	

Envisaged contribution of the project		
Planned (as per project proposal)	Contribution made	Reasons for deviation
Study will help to understand impacts evaluation of rabi irrigation on hydrology, agricultural production, economy and society. The performance evaluation will help to formulate strategies by measuring its own performance and comparing with the best practices. Identify bottlenecks, constraints, managerial laps and other grey areas in the system to formulate direction for improvement strategies to reap its full benefits on a long term basis in MP.	*Done*	
How research outcome benefited the end user department and society		
Planned (as per project proposal)	Benefit derived	Reasons for deviation
State will apply the outcome of PDS to the field for further investigation and implementation.	*Measures to be initiated soon*	
End-of-project deliverables		
Planned (as per project proposal)	Achieved	Reasons for deviation
The Web-based dynamic application and android based mobile application will enable the MPWRD to evaluate performance all irrigation project.	*No*	*This task could not be completed due to unavailability of sufficient fund for consultancy payment*

Outsourcing (>1 lakh)/ consultancy (All)			
Consultant (name and qualifications), organization / outsource agency	Work assigned	Estimated cost Rs	Actual cost Rs

Financial achievement (NIH, CIHRC, Bhopal out of total budget 36.99)					
S No	Head	Approved budget	Approved revised budget	Final expenditure	Reasons for deviation
1	Remuneration/Emoluments for Manpower etc.			*16.94*	
2	Travelling Expenditure			*8.24*	
3	Infrastructure/Equipment			*1.80*	
4	Experimental Charges/Field work/Consumables			*0.50*	
5	Capacity building/Technology transfer			*2.40*	

6	Contingency			*0.30*	
7	Outsourcing/ consultancy			*0.56*	
	Total			*30.18*	

Table A.2: Quantitative outcome

i. Research papers published/ submitted		
S No	Research paper (National/ International Journal/ conferences/ symposium/ workshop/ seminar)	Impact factor for Journal
1	*Paper published in International conference* *R.V. Galkate, V. Morya, R.K. Jaiwal, T.R. Nayak (2020) Comparison of performance indication for the evaluation of irrigation scheme in Madhya Pradesh. Water Conclave 26-28, Feb 2020 at Roorkee.*	
Reports/Monographs/Internal publications brought out		
S. No.	Reports/Monographs/Internal publications	
ii. New techniques/models/ software/ knowledge developed, if any		

iii. Web site/ application developed				
Name	Web address	Server location	Launch date	Details of information available
iv. Patents filed/awarded, if any				

Workshop/ conferences/ seminars/capacity building programmes organised			
S. No.	Topic	Dates, duration, No. of participants	Report published (Y/N)
1 2	*Need assessment to formulate strategies to achieve objectives of the study*	*First one day workshop organized on 17th April 2019*	*Report sent to NIH, NHP cell*

	Dissemination of findings and application of the developed techniques with field engineers and officers of MPWRD and Line departments of State and Central Government in MP	*Second one day workshop organized on 19th March 2021 to*	*Report sent to NIH, NHP cell*

v. Stake holders feedback and action taken on constructive feed back

S No.	Feedback received	Action taken
Stake holder meet (Topic and date)		

vi. Field observations obtained, thematic maps generated (water quality and salinity, isotope, soil moisture, stage and discharge, sediment, water level, river cross sections, geophysical/ resistivity survey, hydrogeological investigations etc.)

S No	Parameter, frequency, period, groundwater/ river/ tank/ hand pump/ spring/ sea-water	Number (planned)	Numbers (measured)

vii. Field installations (piezometers, river stage/ discharge, soil moisture etc.)

S. No	Name, make/ model	Unit price, total price, quantity	Date of installation	% utilization	Remarks regarding maintenance/ breakdown

viii. Equipment/ software purchased

a. Equipment purchased

S. No	Name, make/ model	Unit price, total price, quantity	Date of installation	% utilization	Remarks regarding maintenance/ breakdown

b. Software purchased

S. No	Name, version, license	Unit price, total price, quantity	Date of installation	% utilization	Remarks regarding maintenance/ breakdown

ix. Plans for utilizing the equipment facilities in future

S. No.	Installation/ equipment	Planned future use

x. Data dissemination policy for data generated in the project

Data can be provided to any user for further investigation

xi. Number of post-graduate/doctoral candidates completed their courses (Please give a list of such candidates) - *NIL*
xii. Foreign deputation/visit of PI/Co-PIs/students, if any - *NIL*

A.3 Activity chart
Include activity chart/ modified activity chart, reasons for modification of activity chart.

Appendix B Supplementary results

Provide supplementary results here, if any - **NIL**

Annexure-I

Survey Forms

राष्ट्रीय जलविज्ञान संस्थान

मध्य भारत जलविज्ञान क्षेत्रीय केन्द्र

वाल्मी केम्पस, भोपाल (म.प्र.)

राष्ट्रीय जलविज्ञानोय परियोजना अंर्तगत पी. डी. एस. के तहत सर्वेक्षण

परियोजना का शीर्षक : मध्यप्रदेश के गंगा नदी के उपबेसिन में रबी सिंचाई के प्रभावो का मूल्यांकन

सर्वेक्षण कं: ....

दिनांक:..........................

सिंचाई परियोजना का नामः ....डिवीजन.:...............................

किसान का परिचय

नामः.. आयु:........... पिता का नामः ....

गॉवः .... तहसीलः .... जिलाः ....

संपर्क नंबरः .... ई–मेल आई डीः ....

कृषि का क्षेत्रफलः .... भूमि का स्थानः हेड रीच / मीडिल रीच / टेल रीच

(स्वयं की जमीन /किराए पर)ः .... सिंचित क्षेत्रः ....

1. कृषि फसल सूचना (पिछले 4–5 साल में)

मैासम	फसल का प्रकार	फसल का क्षेत्रफल	बीज की गुणवत्ता	सिंचाई की अवधि	सिंचाई की संख्या	उत्पादन (क्विंटल) / हेक्टेयर	खरीदा गया सरकारी /प्राइवेट
रबी							
खरीफ							
जायद							
बागवानी							
कोई अन्य फसल (वार्षिक फसल)							

- **शंकर बीज, उर्वरक और अन्य बेहतर प्रौद्योगिकी का कृषि उपयोग**
  - शंकर बीज ....किग्रा/हेक्टेयर.................. मूल्य............... रुपये/किग्रा............
    - ....किग्रा/हेक्टेयर..................... मूल्य............. रुपये/किग्रा............
    - ....किग्रा/हेक्टेयर..................... मूल्य............... रुपये/किग्रा............
  - उर्वरक.........................किग्रा/हेक्टेयर...................... मूल्य.............. प्रतिबैग ....
    - ....किग्रा/हेक्टेयर...................... मूल्य.............. प्रतिबैग ....
    - ....किग्रा/हेक्टेयर.................... मूल्य.............. प्रतिबैग ....
- **कृषि उपकरण स्वयं का या किराये पर**

	बैल/बैलगाड़ी	ट्रैक्टर	ट्रैक्टर–ट्रॉली	थेसर	पंपलेट
स्वय	....	....	....	....	....
किराये पर	....	....	....	....	....

- क्या आप उच्च "िाक्षा के लिए बच्चो को (शहर) भेजते हो: हॉ /नही
- बच्चो की विवाह आयु: लड़की ....लड़का ....
- उत्सव मनाने की शैलीः

बडे स्तर पर	मध्यम स्तर पर	निम्न स्तर पर	उत्सव नही मनाते

- शादी समारोह की शैलीः

बडे स्तर पर	मध्यम स्तर पर	साधारण स्तर पर	सामूहिक विवाह

- क्या आपके पास बैंक खाता हैः हॉ/ नही
- क्या आपने उपभोग्य सामग्रियो/वाहनो के लिए बैंक ऋण लिया हैः हॉ/ नही
- क्या आप फसल बीमा योजना का लाभ लेते हैः हॉ/ नही
- क्या आपके पास किसान केडिट कार्ड हैः हॉ/ नही
- क्या आप मिट्टी परिक्षण कराते हैः हॉ/ नही
- क्या आपने कभी किसान प्रशिक्षण लिया है हॉ/नही यदि हॉ तो नामः.............................
- कृषि के अलावा आजीविकाः हॉ/नही यदि हॉ तो नामः.............................

डेयरी	वन आधारित	मुर्गी पालन	हस्त"िाल्प	अन्य

- मनोरंजन सुविधाः

टीवी/रेडियो	टेप रिकॉर्डर	अन्य

- पीने के पानी के लिए व्यवस्थाः

हेंड पंप	तलाब	नदी	कुंआ	बेरबेल	अन्य

- घर का प्रकारः

कच्चा घर	पक्का घर	दोनो	झोपडी

2. घर में उपलब्ध प्रौघोगिकी सामग्री

मद	उपलब्धता	मद	उपलब्धता
गैस (एलपीजी)		रेडियो	
बायो गैस संयंत्र		टीवी / LCD/ LED	
उन्नत चूल्हा		दो पहिया वाहन /चार पहिया वाहन	साईकिल/मोटरसाईकिल/ स्कूटर/कार/जीप
सादा चूल्हा		मोबाइल	

3. सिंचाई जल आपूर्ति

- सिंचाई का स्रोत

नहर	बोरवेल	कुआ	तालाब	नदी	नाला	स्टॉपडेम

- नहर से पानी कैसे लिया जाता है।

नहर को तोडकर	सिफोनिंग	पंप	फील्ड चैनल	अन्य

- नहर में कब तक पानी रहता हैः

हमे"ाा	सिंचाई के बाद	सिंचाई के समय	कुछ समय	कभी नही

- नहर की स्थिति

लाईनिंग	गैरलाईनिंग	नहर टूटी हुई है	अन्य

- सिंचाई जल पूर्ति की जरूरत कब होती है।

रबी	खरीफ	जायद

- सिचांई की जल पूर्ति कोन से सीजन में होती है।

रबी	खरीफ	जायद

- क्या पानी की आपूर्ति पर्याप्त है.

पर्याप्त है	कम	बहुत कम है	नही है

- क्या आपको आवश्यकता होने पर पानी मिलता है.

हमे"ाा	कभी कभी	कभी नही

- सिंचाई का तरीका

फ्लाडिंग	बोर्डर	स्प्रिंकलर	ड्रिप	अन्य

- नहर के पानी के लिए क्या भुगतान किया जाता है। :– हॉ/नही
- सिंचाई विभाग द्वारा रसीद दी जाती हैः– हॉ/नही

अन्य कोई जानकारीः...

....

4. सामाजिक पहलूः

- परिवार मे सदस्यों का विवरण

कुल सदस्य	पुरूष	महिला

- परिवार की शैक्षणिक स्थितिः

नाम	10वी	12वी	स्नातक	अन्य	सम्बंध

- घर पर सुविधाए उपलब्ध हैः

शौचालय	अपशिष्ट डिस्पोजेबल चैनल	कृषि अपशिष्ट पिट	डेयरी शेड	वार्मी कंपोस्ट यूनिट	अन्य

अन्य कोई जानकारीः...

....

5. जल विज्ञानीय पहल;

- मृदा के प्रकारः

काली	लाल	दोमट	रेतीली	अन्य

- आसपास के कुओ/बोरो में भूजल स्तरः ....फीट।

बहुत उच्च	उच्च	मध्यम	कम

- आसपास के नाले में पानी कब उपलब्ध रहता हैः

सिंचाई के दौरान	मॉनसून के दौरान	कभी नही	अन्य

- परियोजना के लाभ क्षेत्र/खेत से जल निकास की व्यवस्था :

नदी	स्थानीय नाला	झील/ तालाब	अन्य

- मृदा एवं जल संरक्षण उपायो को अपनाया हैः हॉ/नही,यदि हॉ तो नाम......................

मल्चिंग	फसल रोटे"ान	कन्टूर की खेती	पौधारोपण	नाला नियंत्रण बंड	चेक डेम	खेत की जुताई	अन्य

6. अर्थव्यवस्थाः

- गॉव में उपलब्ध लघु उघोग हॉ/नही यदि हॉ तो नाम......................
- गॉव में बैंक सुविधा है हॉ/नही यदि हॉ तो नाम......................
- उधमियो हेतु योजनाये हॉ/नही यदि हॉ तो नाम......................
- स्वव्यापार की संभावना हॉ/नही यदि हॉ तो नाम......................
- स्कूल सुविधा है हॉ/नही यदि हॉ तो नाम......................
- सड़क हॉ/नही यदि हॉ तो स्थिति ....
- बिजली हॉ/नही यदि हॉ तो स्थिति......................
- अस्पताल सुविधा है हॉ/नही यदि हॉ तो उस का प्रकार ....
- इंटरनेट ब्रॉडबैंड हॉ/नही यदि हॉ तो कंपनी का नाम.................

7. स्वास्थ्य मुद्दे

- आपके क्षेत्र कौन सी आम बीमारी होती है।

मलेरिया	डेंगू	चिकनगुनिया	दस्त	दस्त के साथ उल्टी	अन्य

- **मलेरियाः**

➢ क्या बुखार आने पर ठंड लगती हैः हॉ/नही
➢ आशा कार्यकर्ता गांव में कार्यरत है हॉ/नही
➢ क्या आशाकार्यकर्ता बुखार के बाद रक्त स्लाइड तैयार करती हैः हॉ/नही
➢ क्या आशाकार्यकर्ता बुखार के बाद RDK से रक्त की जॉच कराती हैः हॉ/नही
➢ RDK स्लाइड का परिणाम सकारात्मक ☐ नकारात्मक☐
➢ आशा ने मलेरिया का इलाज कराया 3दिन ☐ 14 दिन ☐
➢ क्या गांव में उपचार के लिए सुविधा उपलब्ध है। हॉ/नही
✓ नही है, तो आप इलाज के लिए कहॉ गये सरकारी ☐ प्राइवेट ☐
➢ क्या परिवार में मच्छरदानी का उपयोग किया जाता है? हॉ/नही

- **डेंगू/चिकनगुनिया**

➢ बुखार के साथ जोडो में दर्द/मांसपे"ायो में दर्द होता है। हॉ/नही
➢ घर में नहाने धोने का पानी कहॉ एकत्रित किया जाता है।

सीमेंट टंकी	बेरल	छत की टंकी	घर के बाहर टंकी	अन्य

➢ क्या कंटेनर में पानी के उपरोक्त कोई कीड़े चलते दिखते हैः हॉ/नही
➢ पानी के कंटेनर से पानी को कितने समय में खाली करते हैः
☐ एक सप्ताह ☐ एक महीने ☐ अन्य
➢ डेंगू /चिकुनगुनिया होने पर किस अस्पताल से उपचार लिया जाता है।
सरकारी ☐ प्राईवेट ☐

- **दस्त लगनाः**

➢ परिवार में दस्त के साथ उल्टी की शिकायत हुई हैः हॉ /नही
➢ पीने का पानी कहॉ से लाते हैः

नल	कुँआ	नहर	हेंड पंप	नदी

➢ क्या पानी में ब्लीचिंग किया जाता है? हॉ /नही
➢ क्या फिल्टर का पानी का उपयोग करते ह?: हॉ /नही
➢ क्या उपचार की व्यवस्था ग्राम में है? हॉ /नही

- **अन्य रोगः**
  - ....
  - ....
  - ....

- **मच्छर के काटने के संबंध में जानकारीः**

➢ क्षेत्र में नहर आने से पहले मच्छर का काटनाः– कम/अधिक
➢ क्षेत्र में नहर आने के बाद मच्छर का काटनाः– कम/अधिक
➢ मच्छर के काटने का समय
❖ दिन के समय – हॉ/नही
❖ रात के समय – हॉ/नही
❖ दोनो समय– हॉ/नही
❖ शाम के समय – हॉ/नही
➢ ग्राम से सरकारी अस्पताल की दूरी .... कि.मी.
➢ कौनसे सरकारी स्वास्थ्य सुविधॉ कार्यकर्ता ग्राम में भ्रमण करते है।

पुरुष बहुउदेशीय कार्यकर्ता (MPW)	महिला बहुउदेशीय कार्यकर्ता (ANM)	दोनो	कभी नही

➢ सर्प काटने के मामलेः– हॉ/नही
➢ ग्राम मे वर्तमान में या विगत वर्ष में मलेरिया के प्रकरणः हॉ/नही
➢ ग्राम मे वर्तमान में या विगत वर्ष में डेंगू /चिकुनगुनिया के प्रकरणः हॉ/नही

(RDK: Rapid Diagnostic Test, MPW: Multipurpose Health Worker, ANM: Auxiliary Nurse Midwife, PHC: Primary Health Centre)

8. **लाभ क्षेत्र (कमांड एरिया) से जुड़े मुदे एवं प्रंबंधन**

- क्या आपके यहॉं जल उपभोक्ता समिति (WUA)है: हॉं/नही
- क्या आप (WUA) की बैठको मे नहर से संबंधित मुद्दो को उठाते ह? हॉं/ नही
- क्या आपको लगता है कि WUAकी बैठको मे समस्याए हल होती है: हॉं/ नही
- क्या पानी के वितरण को लेकर विवाद की स्थिति होती है: हॉं/ नही
- क्या WUAके अध्यक्ष के द्वारा विवादो को सफलतापूर्वक हल किया जाता है: हॉं/ नही
- क्या बांध प्राधिकरण फसल की आवश्यकता के अनुसार बांध से पानी छोड़ा जाता है: हॉं/ नही
- क्या आप सूखे के दौरान पानी प्रतिरोध/लघु अवधि की किस्मे बोते है: हॉं/ नही
- क्या सूखे के वर्षो में उन्हे कम उत्पादन मिलता है: हॉं/ नही
- क्या आपने जल संरक्षण हेतु खास सिचाई की विधि अपनाई है: हॉं/ नही
  यदि हॉं तो कौन सी ....
- क्या आप परियोजना के लिए अपनापन महसूस करते है।

हॉं	आंशिक	न्ही

- क्या आपकी शिकायतो को समय पर हल किया जाता है।

हॉं	कुछ समय बाद	न्ही

- नहर और पानी वितरण संबंधित अन्य समस्याऐं:....................
  ....
  ....
- आगे के सुधार के लिए किन उपायो की आवश्यकता है:–

समय पर पानी छोडना	नहरो की लाईनिंग	प्रंबंधन	जल संरक्षण उपाय	ड्रिप/स्प्रिंकलर सिंचाई

- किसानो, WUAऔर WRDके बीच संबंध:....................
  ....

अन्य कोई जानकारी –
....
....

सर्वेकर्ता हस्ताक्षर

9- **WUA संबंधित सर्वेक्षण (WUA के कार्यकारी समिति सदस्य द्वारा जानकारी)**

- क्या आप ईरीगेयशनशेड्यूलिंग का पालन करते है: हॉं/ नही
- सूखे के वर्षो के दौरान किये जाने वाले उपाय ....
  ....
- जल प्रभार कर वसूलने की प्रकिया ....
  ....
- क्या जल प्रभार कर वसूलने में कोई समस्या आती है? ....
  ....
  ....
- परियोजना एवं नहरो से जुडी समस्याऐं:

नहरो पर अतिक्रमण	पानी की चोरी	नहर का तोडना	नहर में गाद एवं कचड़ा

- टेल एण्ड पर जल उपलब्धता पर अपनाए गए उपाये
  ....
- बांध प्राधिकरण / डब्लूआरडी की भूमिका ....
  ....
- क्या डब्ल्यूयूए के चुनाव नियमित रुप से किये जाते है
  हॉं / नही/ कितने वर्षो में
- सिंचाई परियोजना का उपयोग और कैसे किया जाए–

मत्स्यपालन	सिघांडा की खेती	अन्य

- क्या WUA में सुधार और प्रबंधन की आवषयकता है? हॉं / नही
- किसानो, WUA और WRD के बीच संबंध :....................
  ....

अन्य कोई जानकारी –
....
....

किसान हस्ताक्षर

Annexure-II

Salient Features of Samrat Ashok Sagar Dam

Sr.No.	Attribute	Details
1	Name of Dam	Samrat Ashok Sagar (Halali) Dam
2	River	Halali
3	Nearest City	Vidisha
4	District	Vidisha
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation, Drinking / Water Supply
9	Year of Commencement (YYYY)	--
10	Year of Completion (YYYY)	1997
11	Operating and Maintenance Agency	--
12	Dam (Interstate/ International)	--
13	Dam as per Parliamentary Constituency	Vidisha
14	Seismic Zone	Seismic Zone-II
15	Type of Dam	Earthen
16	Length of Dam (m)	945
17	Max Height above Foundation (m)	29.57
18	Instrumentation Embedded in Dam	--
19	Total Volume Content of Dam (TCM)	678.27
20	Design Flood (cumec)	3682
21	Type of Spillway	Other (Waste weir)
22	Length of Spillway (m)	41.16
23	Crest Level of Spillway (m)	459.76
24	Spillway Capacity (cumec)	811.92
25	Type of Spillway Gates	--
26	No. of Spillway Gates	2
27	Size of Spillway Gates (m x m)	2.13 x 2.44

Salient Features of Umrar Dam

Sr. No.	Attribute	Value
1	Name of Dam	Umrar Dam
2	River	Umrar
3	Nearest City	Bandhogarh
4	District	Umaria
5	State	Madhya Pradesh

6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation
9	Year of Commencement (YYYY)	--
10	Year of Completion (YYYY)	1978
11	Operating and Maintainance Agency	WRD, Govt. of MP
12	Dam (Interstate/ International)	--
13	Dam's (Interstate/ International) Agreement	--
14	Dam as per Parliamentary Constituency	Shahdol
15	Seismic Zone	Seismic Zone-III
16	Type of Dam	Earthen
17	Length of Dam (m)	995
18	Max Height above Foundation (m)	27.76
19	Instrumentation Embeded in Dam	--
20	Total Volume Content of Dam (TCM)	--
21	Design Flood (cumec)	212.58
22	Type of Spillway	--
23	Length of Spillway (m)	--
24	Crest Level of Spillway (m)	--
25	Spillway Capacity (cumec)	212.58
26	Type of Spillway Gates	--
27	No. of Spillway Gates	--
28	Size of Spillway Gates (m x m)	--
29	Mode of Operation	--
30	Type of Energy Dissipation	--
31	No. of River Sluice	--
32	Sluice Purpose	--
33	Size of Sluice (m x m)	--
34	Remarks	--
35	NRLD No.	MP08MH0710

Salient Features of Mala Dam

Sr. No.	Attribute	Details
1	Name of Dam	Mala Dam
2	River	Sun Nadi
3	Nearest City	Damoh
4	District	Damoh
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation

9	Year of Commencement (YYYY)	
10	Year of Completion (YYYY)	1929
11	Operating and Maintainance Agency	WRD,Govt. of MP
12	Dam (Interstate/ International)	
13	Dam's (Interstate/ International) Agreement	
14	Dam as per Parliamentary Constituency	Damoh
15	Seismic Zone	Seismic Zone-II
16	Type of Dam	Earthen
17	Length of Dam (m)	2518
18	Max Height above Foundation (m)	16.76
19	Instrumentation Embeded in Dam	
20	Total Volume Content of Dam (TCM)	
21	Design Flood (cumec)	886.6
22	Type of Spillway	
23	Length of Spillway (m)	
24	Crest Level of Spillway (m)	
25	Spillway Capacity (cumec)	886.6
26	Type of Spillway Gates	
27	No. of Spillway Gates	
28	Size of Spillway Gates (m x m)	
29	Mode of Operation	
30	Type of Energy Dissipation	
31	No. of River Sluice	
32	Sluice Purpose	
33	Size of Sluice (m x m)	
34	Remarks	
35	NRLD No.	MP08MH0076

Salient Features of Kaketo Dam

Sr. No.	**Attribute**	**Value**
1	Name of Dam	Kaketo Dam
2	River	Parwati
3	Nearest City	Pohri
4	District	Shivpuri
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation
9	Year of Commencement (YYYY)	
10	Year of Completion (YYYY)	1934
11	Operating and Maintainance Agency	WRD, Govt. of MP

12	Dam (Interstate/ International)	
13	Dam's (Interstate/ International) Agreement	
14	Dam as per Parliamentary Constituency	Gwalior
15	Seismic Zone	Seismic Zone-II
16	Type of Dam	Gravity and Masonry
17	Length of Dam (m)	1047
18	Max Height above Foundation (m)	37.64
19	Instrumentation Embeded in Dam	
20	Total Volume Content of Dam (TCM)	
21	Design Flood (cumec)	1811
22	Type of Spillway	other (weir)
23	Length of Spillway (m)	190.5
24	Crest Level of Spillway (m)	64.5
25	Spillway Capacity (cumec)	1811
26	Type of Spillway Gates	
27	No. of Spillway Gates	
28	Size of Spillway Gates (m x m)	2.4384 x 2.4384
29	Mode of Operation	
30	Type of Energy Dissipation	
31	No. of River Sluice	
32	Sluice Purpose	
33	Size of Sluice (m x m)	
34	Remarks	DM_SPIL_TYPE-Sharp Crestal and Broad Crest
35	NRLD No.	MP08HH0082

Salient Features of Jajone Dam

Sr. No.	**Attribute**	**Value**
1	Name of Dam	Jajone Dam
2	River	Local
3	Nearest City	Basoda
4	District	Vidisha
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation
9	Year of Commencement (YYYY)	
10	Year of Completion (YYYY)	1968
11	Operating and Maintainance Agency	WRD, Govt. of MP
12	Dam (Interstate/ International)	
13	Dam's (Interstate/ International) Agreement	
14	Dam as per Parliamentary Constituency	Sagar

15	Seismic Zone	Seismic Zone-II
16	Type of Dam	Earthen
17	Length of Dam (m)	480
18	Max Height above Foundation (m)	18.6
19	Instrumentation Embeded in Dam	
20	Total Volume Content of Dam (TCM)	104
21	Design Flood (cumec)	108.67
22	Type of Spillway	
23	Length of Spillway (m)	
24	Crest Level of Spillway (m)	
25	Spillway Capacity (cumec)	108.67
26	Type of Spillway Gates	
27	No. of Spillway Gates	
28	Size of Spillway Gates (m x m)	
29	Mode of Operation	
30	Type of Energy Dissipation	
31	No. of River Sluice	
32	Sluice Purpose	
33	Size of Sluice (m x m)	
34	Remarks	
35	NRLD No.	MP08MH0181

Salient Features of Lilgi Dam

Sr. No.	Name of Dam	Lilgi Dam
1	River	Lilgi nalla
2	Nearest City	Maihar
3	District	Satna
4	State	Madhya Pradesh
5	Basin	Ganga
6	Status	Completed
7	Purpose of Dam	Irrigation
8	Year of Commencement (YYYY)	
9	Year of Completion (YYYY)	1960
10	Operating and Maintenance Agency	WRD, Govt. of MP
11	Dam (Interstate/ International)	
12	Dam's Agreement	
13	Dam as per Parliamentary Constituency	Satna
14	Seismic Zone	Seismic Zone-II
15	Type of Dam	Earthen
16	Length of Dam (m)	960

17	Max Height above Foundation (m)	13.7
18	Instrumentation Embeded in Dam	
19	Total Volume Content of Dam (TCM)	
20	Design Flood (cumec)	171
21	Type of Spillway	
22	Length of Spillway (m)	
23	Crest Level of Spillway (m)	
24	Spillway Capacity (cumec)	171
25	Type of Spillway Gates	
26	No. of Spillway Gates	
27	Size of Spillway Gates (m x m)	
28	Mode of Operation	
29	Type of Energy Dissipation	
30	No. of River Sluice	
31	Sluice Purpose	
32	Size of Sluice (m x m)	
33	Remarks	
34	NRLD No.	MP08LH0085

Salient Features of Nagda Dam

Sr. No.	Attribute	Value
1	Name of Dam	Nagda Dam
2	River	Nagda Nalla
3	Nearest City	Tikamgarh
4	District	Tikamgarh
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation
9	Year of Commencement (YYYY)	
10	Year of Completion (YYYY)	1964
11	Operating and Maintenance Agency	WRD, Govt. of MP
12	Dam (Interstate/ International)	
13	Dam's (Interstate/ International) Agreement	
14	Dam as per Parliamentary Constituency	Tikamgarh
15	Seismic Zone	Seismic Zone-II
16	Type of Dam	Earthen
17	Length of Dam (m)	2866
18	Max Height above Foundation (m)	27.24
19	Instrumentation Embeded in Dam	

20	Total Volume Content of Dam (TCM)	
21	Design Flood (cumec)	425
22	Type of Spillway	
23	Length of Spillway (m)	
24	Crest Level of Spillway (m)	
25	Spillway Capacity (cumec)	425
26	Type of Spillway Gates	
27	No. of Spillway Gates	
28	Size of Spillway Gates (m x m)	
29	Mode of Operation	
30	Type of Energy Dissipation	
31	No. of River Sluice	
32	Sluice Purpose	
33	Size of Sluice (m x m)	
34	Remarks	
35	NRLD No.	MP08MH0147

Salient Features of Naren Dam

Sr. No.	**Attribute**	**Value**
1	Name of Dam	Naren Dam
2	River	Naren
3	Nearest City	Basoda
4	District	Vidisha
5	State	Madhya Pradesh
6	Basin	Ganga
7	Status	Completed
8	Purpose of Dam	Irrigation
9	Year of Commencement (YYYY)	
10	Year of Completion (YYYY)	1981
11	Operating and Maintenance Agency	WRD, Govt. of MP
12	Dam (Interstate/ International)	
13	Dam's (Interstate/ International) Agreement	
14	Dam as per Parliamentary Constituency	Sagar
15	Seismic Zone	Seismic Zone-II
16	Type of Dam	Earthen
17	Length of Dam (m)	3567
18	Max Height above Foundation (m)	29.85
19	Instrumentation Embedded in Dam	
20	Total Volume Content of Dam (TCM)	479
21	Design Flood (cumec)	430
22	Type of Spillway	

23	Length of Spillway (m)	
24	Crest Level of Spillway (m)	
25	Spillway Capacity (cumec)	430
26	Type of Spillway Gates	
27	No. of Spillway Gates	
28	Size of Spillway Gates (m x m)	
29	Mode of Operation	
30	Type of Energy Dissipation	
31	No. of River Sluice	
32	Sluice Purpose	
33	Size of Sluice (m x m)	
34	Remarks	
35	NRLD No.	MP08MH0445

Annexure-III

Crop factor (Kc) values for Madhya Pradesh

(*Source: Madhya Pradesh Irrigation Department Design Series Technical Circular No 25*)

VALUES OF CROP FACTOR FOR VARIOUS CROPS

Annexure - 3

S.No	Crop	First Planting fort-night	Growing Season No. of fortnights	Crop Factor January		February		March		April		May		June		July		August		September		October		November		December	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	RICE OHYVTP	14	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.08	1.10	1.11	1.15	1.10	0.99	0.00	0.00	0.00	0.00	0.00
2	RICE 1HYVTP	13	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	1.10	1.10	1.15	1.15	1.06	0.99	0.00	0.00	0.00	0.00	0.00
3	RICE 2HYVTP	14	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	1.10	1.10	1.15	1.15	1.06	0.99	0.00	0.00	0.00	0.00
4	RICE 3HYVTP	15	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	1.10	1.10	1.15	1.15	1.06	0.99	0.00	0.00	0.00
5	RICE 1LVTP	13	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	1.10	1.10	1.12	1.15	1.15	1.04	0.98	0.00	0.00	0.00	0.00
6	RICE 2 BI	12	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	1.10	1.10	1.10	1.13	1.15	1.15	1.10	1.03	0.98	0.00	0.00	0.00
7	RICE 4 BI	13	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	1.10	1.10	1.10	1.10	1.15	1.15	1.10	1.03	0.98	0.00	0.00
8	G. NUT 1 KH	12	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.54	0.82	0.97	1.00	1.00	0.93	0.69	0.00	0.00	0.00	0.00	0.00
9	G. NUT 2 KH	13	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.54	0.82	0.97	1.00	1.00	0.93	0.69	0.00	0.00	0.00	0.00
10	MAIZE 1 KH	12	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.59	0.91	1.10	1.10	1.01	0.71	0.00	0.00	0.00	0.00	0.00	0.00
11	MAIZE 2 KH	13	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.59	0.91	1.10	1.10	1.01	0.71	0.00	0.00	0.00	0.00	0.00
12	SOYABEEN 1KH	12	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.63	0.91	1.00	1.00	1.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00
13	SOYABEEN 2KH	13	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.63	0.91	1.00	1.00	1.00	0.66	0.00	0.00	0.00	0.00	0.00
14	JOWAR 0KH	12	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.63	0.91	1.05	1.05	0.96	0.64	0.00	0.00	0.00	0.00	0.00	0.00
15	JOWAR 1KH	12	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.59	0.82	1.02	1.05	1.05	0.92	0.63	0.00	0.00	0.00	0.00	0.00
16	JOWAR 2KH	13	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.59	0.82	1.02	1.05	1.05	0.92	0.63	0.00	0.00	0.00	0.00
17	CHILLI 0KH	12	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.52	0.65	0.85	1.03	1.10	1.10	1.08	0.00	0.00	0.00	0.00	0.00
18	CHILLI 1KH	13	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.52	0.65	0.85	1.03	1.10	1.10	1.08	0.95	0.73	0.00	0.00
19	COTTON 1 KH	11	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.37	0.48	0.77	0.99	1.08	1.10	1.10	1.09	1.01	0.85	0.71	0.00	0.00
20	COTTON 2 KH	12	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.37	0.48	0.77	0.99	1.08	1.10	1.10	1.09	1.01	0.85	0.71	0.00
21	PULSE 1 KH	12	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.75	1.10	1.10	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	PULSE 2 KH	13	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.75	1.10	1.10	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	FODDER 1 KH	12	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.54	0.77	0.99	1.05	1.05	1.04	0.98	0.00	0.00	0.00	0.00	0.00
24	VEGETABLE 1KH	12	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.46	0.69	1.00	1.00	1.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00
25	ARHAR 1 KH	13	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.47	0.65	0.98	1.03	1.05	1.05	1.03	0.83	0.48	0.00	0.00
26	WHEAT OLV	19	9	1.07	0.87	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.42	0.80	1.08	1.10	1.10
27	WHEAT OMV	19	9	1.07	0.87	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.42	0.80	1.08	1.10	1.10
28	WHEAT 1MV	21	9	1.10	1.10	1.07	0.87	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.42	0.80	1.08
29	WHEAT 2MV	22	9	1.08	1.10	1.10	1.07	0.87	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.42	0.80
30	WHEAT 3MV	23	8	0.92	1.10	1.10	1.10	0.92	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.44
31	FODDER 1RA	20	8	1.10	1.02	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.47	0.83	1.07	1.10
32	GRAM N1 RA	20	9	1.04	0.89	0.63	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.28	0.69	1.02	1.05
33	GRAM S1 RA	20	9	1.04	0.89	0.63	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.29	0.83	1.05	1.05
34	GRAM N2 RA	21	8	1.05	0.96	0.68	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.29	0.83	1.05
35	GRAM S2 RA	21	8	1.05	0.96	0.68	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.29	0.83	1.05
36	POTATO RA	22	7	1.15	1.15	1.11	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.72	1.00
37	VEGETABLE RA	22	7	1.00	1.00	1.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.37	0.67
38	OIL SEEDS 2 RA	20	9	1.10	1.09	0.93	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.48	0.50	1.09	1.10
39	BERSEEM/LUC	21	10	1.10	1.10	1.10	1.10	1.08	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.52	0.92	1.10
40	SUGARCANE	20	24	0.61	0.64	0.66	0.70	0.75	0.81	0.87	0.92	0.96	1.00	1.05	1.09	1.10	1.10	1.10	1.10	1.10	1.06	1.02	0.51	0.53	0.55	0.57	0.59
41	BANANA	13	24	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.03	0.94	0.86	0.76	0.65	0.51	0.53	0.56	0.66	0.77	0.83	0.87	0.91	0.95	1.00	1.02	1.04
42	ORCHARD	13	24	0.65	0.65	0.65	0.65	0.65	0.66	0.69	0.70	0.71	0.72	0.75	0.74	0.75	0.74	0.73	0.72	0.70	0.70	0.70	0.69	0.67	0.65	0.65	0.65
43	G NUTS HW	2	8	0.00	0.23	0.29	0.69	1.02	1.05	1.05	0.98	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	MAIZE HW	2	8	0.00	0.23	0.38	0.83	1.07	1.10	1.10	1.02	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	MOONG HW	4	4	0.00	0.00	0.00	0.26	0.84	1.15	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00