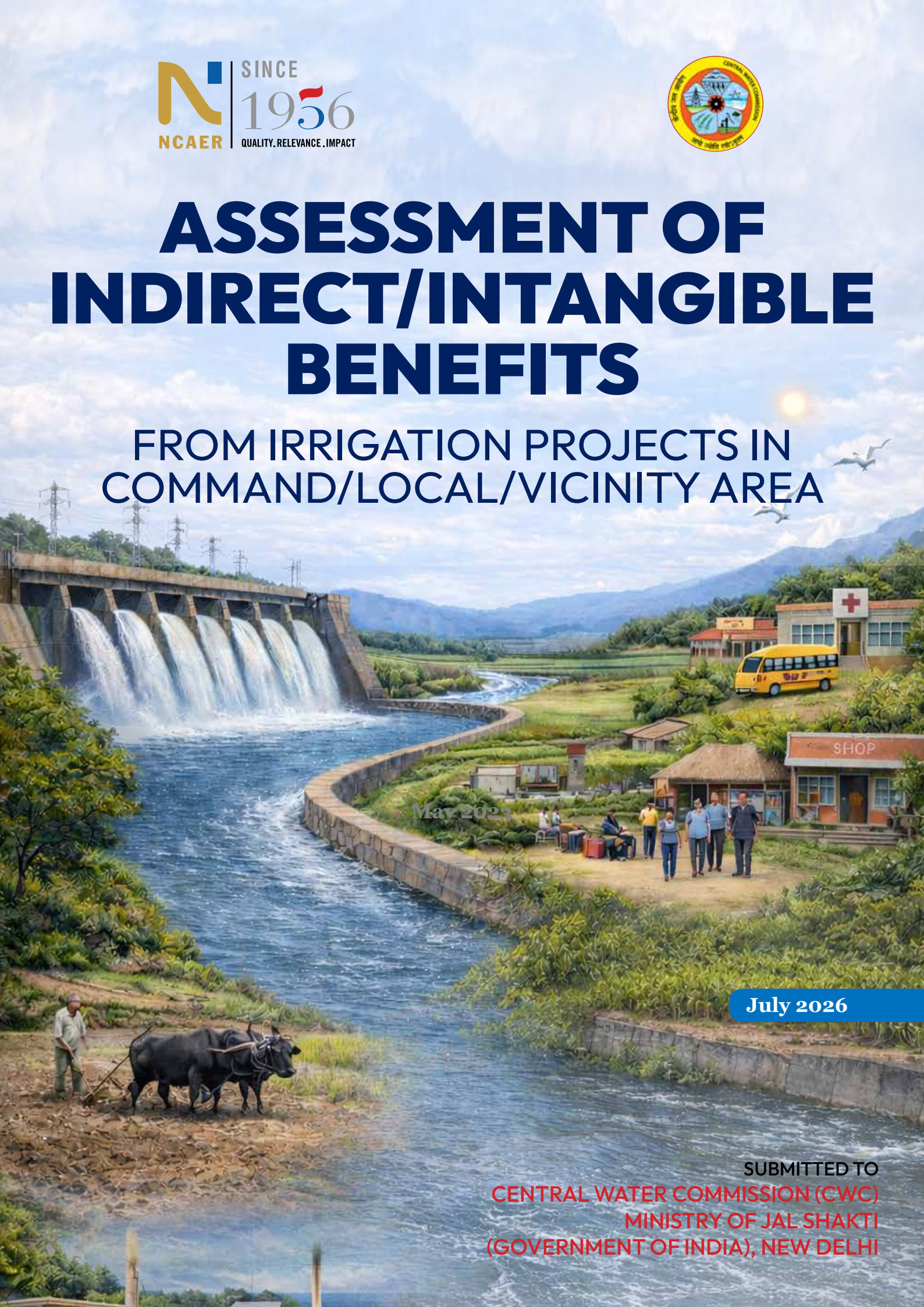
NCAER | SINCE 1956 | QUALITY. RELEVANCE. IMPACT

ASSESSMENT OF INDIRECT/INTANGIBLE BENEFITS

FROM IRRIGATION PROJECTS IN COMMAND/LOCAL/VICINITY AREA



May 2023

July 2026

SUBMITTED TO
CENTRAL WATER COMMISSION (CWC)
MINISTRY OF JAL SHAKTI
(GOVERNMENT OF INDIA), NEW DELHI

ASSESSMENT OF INDIRECT/INTANGIBLE BENEFITS

FROM IRRIGATION PROJECTS IN COMMAND/LOCAL/VICINITY AREA

July 2026

SUBMITTED TO
CENTRAL WATER COMMISSION (CWC)
MINISTRY OF JAL SHAKTI
(GOVERNMENT OF INDIA), NEW DELHI

NCAER | SINCE 1956
QUALITY. RELEVANCE. IMPACT

National Council of Applied Economic Research
NCAER India Centre, 11 Indraprastha Estate, New Delhi 110002, INDIA.

NCAER Study Team

Project Leader
Dr Saurabh Bandyopadhyay

Co-Project Leader
Dr Laxmi Joshi

Research Team
Dr Charu Jain
Mr Kushagra Thakral
Mr CH. S. S. Bharadwaja

Domain Experts
Dr G.C. Manna
Dr Pradip Kumar Biswas
Er S.P. Bansal

Research Intern
Ms Sakshi Chandresh

Executive Project
Ms Shalini Aggarwal

IT Support
Mr Praveen Sachdeva

Field Supervisors
Mr. L Srikanth
Ms Swapna Rani Harpal
Mr Yogesh Chauhan

©National Council of Applied Economic Research, 2026

All rights are reserved. The material in this publication is copyrighted. NCAER encourages the dissemination of its work and will normally grant permission to reproduce portions of the work promptly. For permission to reprint any part of this work, please send a request with complete information to the publisher below.

Published by
Dr Anil K. Sharma
Secretary and Operations Director
National Council of Applied Economic Research (NCAER)
NCAER India Centre
11, Indraprastha Estate, New Delhi–110 002
Tel: +91-11-2345 2657, 6120 2698
Email: aksharma@ncaer.org
www.ncaer.org

The findings, interpretations, and conclusions expressed are those of the authors and do not necessarily reflect the views of the Governing Body of NCAER.

अनुपम प्रसाद
अध्यक्ष
तथा पदेन सचिव, भारत सरकार
ANUPAM PRASAD
CHAIRMAN
& ex-officio Secretary
to the Government of India

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा संरक्षण विभाग
केन्द्रीय जल आयोग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPTT. OF WATER RESOURCES, RD & GR
CENTRAL WATER COMMISSION

Message

Central Water Commission (CWC), a premier technical organization in the field of Water Resources in India for the past 81 years, has been involved in appraising the major & medium irrigation and multipurpose projects. being constructed by various State Governments.

At present, the appraisal process of water resources projects primarily focuses on direct benefits in the calculation of benefit-cost ratio of projects for establishing techno-economic viability of projects. However, the present study undertaken by NCAER under the aegis of CWC has identified various intangible and indirect benefits in the vicinity of projects which have not been assessed so far.

Based on the study, a methodology has been developed by NCAER for estimation of indirect benefits in in this report. The methodology has been circulated to all the stakeholders and widely discussed/deliberated through four regional & one National workshops with participation from the central organizations and state governments.

CWC acknowledges the valuable contribution of NCAER in undertaking this comprehensive study and developing a robust methodology for assessment of indirect and intangible benefits of irrigation projects. The vast domain expertise of officers of CWC, DoWR, RD&GR and NITI Ayog have also played instrumental role in guiding this study. Further, the Commission also appreciates the active participation and insightful inputs received from various Central Ministries, State Governments and other stakeholders during the national and regional workshops.

It is hoped that this instant report will provide a more comprehensive understanding of the overall impacts of irrigation projects on society. Subsequently, the methodology of estimation of intangible benefits will be duly incorporated in the appraisal framework of the future water resources projects which will help in establishing a more realistic and fair economic viability in the Benefit cost analysis of projects.

Yours sincerely,

(Anupam Prasad)

Chairman, CWC

योगेश पैठणकर
YOGESH PAITHANKAR
सदस्य (जल आयोजन एवं परियोजना)
तथा पदेन अपर सचिव, भारत सरकार
Member (WP&P)
& *ex-officio* Additional Secretary
to the Government of India

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
केन्द्रीय जल आयोग
जल संसाधन, नदी विकास
एवं गंगा संरक्षण विभाग
सेवा भवन, रामा कृष्णा पुरम, नई दिल्ली–110066
Govenment of India
Ministry of Jal Shakti
Central Water Commission
Department of Water Resources
River Development and Ganga Rejuvenation
Sewa Bhawan, R.K. Puram, New Delhi-110066

Foreword by CWC

India, primarily an agrarian economy, depends significantly on agriculture, directly and indirectly for about 60% of its population. Agriculture, in turn, heavily depends on assured water availability. Considering the skewed distribution of rainfall pattern in India, it becomes imperative to have assured irrigation facilities in order to feed the large mass and economy which depends on the primary sector, i.e. Agriculture Sector. As a result, large number of Major, Medium & Minor irrigation schemes have been taken up since independence. Irrigation water has been provided through Major, Medium and Minor Irrigation Projects and command area development. Out of Ultimate Irrigation Potential (UIP) of 139.89 Mha, the cumulative Irrigation Potential is created 136.46 Mha up to the year 2023.

Central Water Commission (CWC), under Ministry of Jal Shakti is a premier technical organization in the field of Water Resources. One of the major activities of this organization is to appraise Major, Medium irrigation and Multipurpose projects being constructed by various State Governments. Due care is taken to ascertain the economic viability of water resources projects, since Independence. The idea of computing the Benefit Cost Ratio (B.C. Ratio) has been adopted on the recommendations of Gadgil Committee in 1964. Ever since, these norms have been in practice for ascertaining the economic viability of water resources projects.

At present, the appraisal process of water resources projects primarily focuses on direct benefits in the calculation of benefit-cost ratio of projects for establishing techno-economic viability of projects. However, there is an increasing recognition of the importance of various intangible and indirect benefits in the vicinity of projects, which have not been assessed so far.

With a view to conduct a study to assess indirect impacts and benefits of major irrigation projects, the CWC has commissioned the National Council for Applied Economic Research (NCAER), New Delhi. To facilitate specific quantification of intangible benefits, the NCAER study team has conducted extensive field surveys in a total of 130 districts in the command of 57 major irrigation projects covering different parts of the country, focusing on the indirect and intangible benefits perceived by various stakeholders, including farmers and other rural community members. The overall data collection process involved interviews, Focus Group Discussions (FGDs), Key Informant Interviews (KIIs) and primary surveys. Additionally, secondary data related to the project has also been used by NCAER, such as the Advisory Committee Notes, National Register of Major and Medium Irrigation projects in India etc. to understand macro-level impacts and trends.

The commendable efforts and hard work put in by NCAER team and all committee members specifically officers of Project Appraisal Organization (PAO) and Irrigation Management Organization (IMO) of Central Water Commission, DoWR, RD & GR, NITI Aayog, in guiding the study to its conclusion and firming up of the draft report by NCAER, are deeply acknowledged. The support extended by Nodal officers appointed by the water resources departments of respective State governments during field survey is highly appreciated and needs special mention.

It is hoped that the Report shall serve the intended purpose of incorporating intangible and indirect benefits in the B.C. ratio calculations for arriving at just and fair economic viability criteria for the Water Resources projects in current scenario and a more comprehensive understanding of the overall impacts of irrigation projects on society and their contributions to broader socio-economic and environmental goals.

Yours Sincerely,

Ypaithankar

(Yogesh Paithankar)

NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH
NCAER India Centre, 11 Indraprastha Estate, New Delhi 110 002
Tel: +91 11 6120 2686, 2345 2686 Fax: +91 11 2337 0164
aksharma@ncaer.org, www.ncaer.org

Professor Anil K. Sharma
Secretary and Operations
Director

Foreword by NCAER

This report presents the findings of an outcome study conducted by the National Council of Applied Economic Research (NCAER), sponsored by the Central Water Commission (CWC), to assess and quantify the indirect and intangible benefits of irrigation projects across multiple socio-economic, institutional, and environmental dimensions.

The study responds to the growing recognition that irrigation systems must be evaluated not only in terms of engineering efficiency and agricultural output, but also for their broader contributions to rural livelihoods, social development, and environmental sustainability. Traditionally, assessments of irrigation infrastructure in India have focused on indicators such as irrigation potential created, area irrigated, and increases in agricultural productivity. However, irrigation influences rural economies in far more complex and interconnected ways. Beyond farm-level impacts, it generates a wide range of secondary and spillover benefits, including expanded employment opportunities, improved access to education and health services, reduced seasonal migration, groundwater recharge, improved market linkages, and strengthened social cohesion through collective water management.

Accordingly, this study goes beyond conventional project appraisal frameworks and adopts a holistic perspective to examine the economic, social, institutional, and environmental benefits of irrigation infrastructure across diverse agro-climatic and socio-economic contexts. It seeks to capture the multiple pathways through which irrigation contributes to rural transformation, by shaping cropping patterns and productivity, stabilising incomes, improving access to basic services, strengthening local institutions, and enhancing resilience to climatic and economic shocks.

The analysis is grounded in extensive primary fieldwork conducted in both command and non-command areas across 20 states, covering 57 major and medium irrigation projects representing a wide range of agro-climatic regions, river basins, and institutional settings. The primary survey covered nearly 600 villages and approximately 10,000 households. The survey design integrates household-level quantitative data with qualitative insights gathered through interactions with farmers, water user groups, Panchayat representatives, project authorities, and field-level officials. This mixed-methods approach enables the study to contextualise quantitative findings within the institutional and ecological environments in which irrigation systems operate.

Fieldwork was undertaken under challenging conditions in several locations. Despite these challenges, the surveys were completed with rigour and commitment

and the diversity of field settings significantly enriched the analysis by revealing the varied realities of irrigation performance across regions.

A key contribution of this study is the development of a robust and operational analytical framework to identify and quantify the indirect and intangible benefits of irrigation—dimensions that are often acknowledged conceptually but rarely measured systematically. By linking social, environmental, and institutional improvements to observed household-level income differentials between command and non-command areas, the report introduces a new dimension to irrigation evaluation. This approach aligns closely with contemporary policy priorities emphasising sustainability, inclusion, and community resilience, and reinforces the view of irrigation not merely as an agricultural input, but as a catalyst for broader and more durable rural development.

The study was led by Dr. Saurabh Bandyopadhyay and co-led by Dr. Laxmi Joshi. The core research team included Dr. Charu Jain; Mr. CH. S. S. Bharadwaja; Mr. Kushagra Thakral; Ms. Shalini Aggarwal; Er. Shish Pal Bansal; and, Ms. Sakshi Chandresh. The study benefited from the technical guidance of Dr. G. C. Manna, Senior Advisor, NCAER, and former Director General of the National Sample Survey Office (NSSO), and Professor Pradip Biswas, Senior Consultant, NCAER. Coordination support provided by Mr. Praveen Sachdeva, ensured the smooth execution of the multiple and interlinked components of this complex, multi-state exercise.

The research also benefited from the cooperation and support of officials from state and project-level irrigation departments, whose facilitation and contextual insights during field visits enhanced both the quality and relevance of the findings. The authors gratefully acknowledge their time, openness, and willingness to engage with the study team.

The findings presented in this report are intended to assist policymakers, planners, and water sector practitioners in designing, prioritising, and modernising irrigation investments to maximise long-term developmental returns. The analytical tools, composite indices, and comparative frameworks developed through the study provide a replicable and scalable template that can be integrated into project appraisal, monitoring, and evaluation processes under the CWC and the Ministry of Jal Shakti.

It is hoped that this report will serve as a valuable resource for advancing evidence-based approaches to irrigation and water resource planning in the country, and will contribute meaningfully to ongoing efforts to ensure the equitable, efficient, and sustainable utilisation of the country's irrigation potential.



Anil K. Sharma
Secretary and Operations Director
National Council of Applied Economic Research

Acknowledgement

The study on estimating the indirect and intangible benefits of major irrigation projects in India was commissioned by the Central Water Commission (CWC) under the aegis of the Ministry of Jal Shakti (MoJS). We gratefully acknowledge the invaluable cooperation and support extended by officials of the Ministry and the CWC throughout the course of this study.

We are particularly thankful to Shri Yogesh Paithankar, Member, CWC, for his initiative and sustained efforts in conceptualising and facilitating this study. Our sincere appreciation is also due to the Members of the Consultancy Management Committee (CMC) for their guidance and oversight, especially Shri Rakesh Kumar, Chief Engineer (PAO), CWC, who served as the Chairman of the CMC. We also place on record our sincere thanks to Shri Amit Jha, Senior Joint Commissioner, DoWR, RD & GR; Shri A. Murlidharan, Deputy Adviser, NITI Aayog, for their valuable guidance, and prompt insights at various stages of the study.

Furthermore, we acknowledge the collaboration and data support provided by Shri Manish Kumar and Shri Utkarsh Shukla, Deputy Directors of CWC, which were immensely helpful in strengthening the analysis. Their attention and support were very appreciated. The study covered 20 states, nearly 600 villages, and approximately 10,000 households, including many located in remote and interior regions. Such extensive field coverage would not have been possible without the dedicated support of state nodal officers and irrigation department officials. We extend our sincere thanks to all officers and respondents who, despite demanding professional commitments, generously contributed their time and assistance during the fieldwork. While it is not feasible to acknowledge each individual by name, we gratefully recognise the contributions of key officials, whose names are listed alphabetically by state in the table appended below.

We also express our gratitude to officials of the networking institutions for their crucial role in facilitating coordination and logistical support during the field survey. The NCAER study team is especially indebted to Dr Anil Kumar Sharma, Secretary and Operations Director, NCAER, and Dr Bornali Bhandari, Professor, Agriculture, Industry, Trade, Technology and Skills Vertical, for their constant encouragement, guidance, and institutional support. Their unwavering backing was instrumental in the successful completion of this study.

Table Annex: Name of the Officials who Cooperated/Contributed in the NCAER Study during Primary Survey*

S. No.	Nodal/Irrigation Officer	Designation	State
1	Er Sri Ch. Srinivasulu	Executive Engineer, Drainage Division	Andhra Pradesh
2	Sh. S K Chandbasha	Assistant Director Fishery	Andhra Pradesh
3	Smt Kavitha Nayyar,	Assistant Agriculture Director	Kerala
4	Er Supraba N	Superintending Engineer	Kerala

5	Er Saritha	Executive Engineer	Kerala
6	Er Asathy	Assistant Executive Engineer	Kerala
7	Er Satis Kumar Janaaa	Superintending Engineer	Haryana
8	Dr Jitender Kumar	Deputy Director Agriculture	Haryana
9	Sh. Naveen Kumar	Junior Engineer	Haryana
10	Er R K Phulia	Executive Engineer	Haryana
11	Sh. B. Govind Sharma	Superintending Engineer, Thoubal Circle No. II	Manipur
12	Sh. B.K. Kumpavat (i/c)	Executive Engineer (WALMI, Gandhinagar)	Gujarat
13	Sh. Kankan Goswani,	Director O/o the A.C.E. (Central Nodal Officer) (implementation) Major/Medium, Irrigation	Assam
14	Sh. Deba Saikia,	Executive Engineer, Jamunamukh-Hojai-Lümding Division, Irrigation, Dept.	Assam
15	Sh. Nilam Prasad Bora,	Executive Engineer, Kaljabor- Samaguri Division, Irrigation Dept, Jakhalabanda	Assam
16	Sh. Pranav Prasad	Executive Engineer, Dam Division, Gorur, Hassan	Karnataka
17	Sh. Girish C. Mati	Executive Engineer, Tungabhadra Reservoir Division, Munirabad	Karnataka
18	Sh. Rajan S Kamble	Superintending Engineer, Circle IV, Water Resources Department, Gogal- Margao,	Goa
19	Sh. Aniket Sawant	Executive Engineer, Uppar Wardha	Maharashtra
20	Sh. Rajeev Kurekar	Executive Engineer, Bagh Itiadoh lrrigation Division, Gondiya	Maharashtra
21	Shri Samadhan Sabbinvar	Superintending Engineer, Chatrpati Sambhajinagar	Maharashtra
22	Sh. Arun Naik	Superintending Engineer, Satara Irrigation circle	Maharashtra
23	Sh. Madan Mohan Sethi	Superintending Engineer	Odisha
24	Sh. Abhimanyu Pradhan	Executive Engineer	Odisha
25	Sh. Gobardhan Nayak	Superintending Engineer	Odisha
26	Sh. Ashok Kumar	Executive Engineer	Jharkhand
27	Sh. Balvir Singh	Executive Engineer	Punjab
28	Sh. Mahesh Kujur	Executive Engineer	Jharkhand
29	Sh. Rajendra Singh	Executive Engineer & TA to Superintending Engineer, WR Circle Nohar	Rajasthan
30	Sh. Shashi Ranjan Kumar	Executive Engineer	Bihar

31	Sh. Rohitashva Kr. Jaiminy	Superintending Engineer WR Circle Kota	Rajasthan
32	Sh. K. Kishore	Executive Engineer	Andhra Pradesh
33	Sh. Rakesh Kumar	Additional Chief Engineer IGNP, Bikaner	Rajasthan
34	Sh. M Muralidhara	Executive Engineer	Andhra Pradesh
35	Er. P. Thirumoorthy, BE,	Executive Engineer	Tamil Nadu
36	Smt S Gayatri	Dy Chief Engineer	Tamil Nadu
37	Sh. M Jagadeesh	Assistant Executive Engineer	Tamil Nadu,
38	Sh. V. Ajay Kumar	Chief Engineer (I), Nalgonda	Telangana
39	Sh. T Srinivas Rao Gupta	Superintending Engineer	Telangana
40	Sh. Rajendra Prasad	Executive Engineer	Uttar Pradesh
41	Sh. Manoj Gupta	Chief Engineer	Jammu & Kashmir
42	Sh. Kausal Kishore Diwakar	Executive Engineer	Uttar Pradesh
43	Sh. PK Dikshit	Superintending Engineer	Uttar Pradesh
44	Sh. Subhrangshu Biswas	Chief Engineer (TBO)	West Bengal
45	Sh. Sunil Kumar Tudu	Executive Engineer	Jharkhand

** Please note that the list of names provided in the Table above is not exhaustive*

Saurabh Bandyopadhyay
Senior Fellow
NCAER

Table of Contents

NCAER Study Team ..... *ii*
Foreword by CWC ..... *v*
Foreword by NCAER ..... *v*
Acknowledgement ..... *ix*
Table of Contents ..... *xiii*
List of Tables and Boxes ..... *xvii*
List of Figures ..... *xix*
List of Annexures ..... *xx*
Executive Summary ..... *xxi*

Chapter 1: Background **1**
1.1 Introduction and Context 1
1.2 Irrigation and Economic Development 1
1.3 Recognising the Indirect Benefits of Irrigation Projects 1
1.4 Classification of Indirect Benefits 2
1.5 Challenges in Valuing Intangible Benefits 2
1.6 Objective of the Study 2
1.7 Study Rationale and Policy Relevance 2

Chapter 2: Review of Literature **3**
2.1 Background 3
2.2 Expanding the Scope of Irrigation Benefits 3
2.3 Economic Spillovers and Rural Multiplier Effects 4
2.4 Social and Welfare Outcomes 4
2.5 Environmental and Ecological Dimensions 5
2.6 Tourism-related Aspects of Rural Diversification 5
2.7 Institutional and Governance Impacts 5
2.8 Synthesis and Emerging Research Directions 6
2.9 Concluding Reflections and Linkages to the Present Study 6

Chapter 3: Sampling Methodology **7**
3.1 Study Coverage and Scope 7
3.1.1 Selection of Irrigation Projects Across States 7
3.2 Sampling Framework and GIS-Based Village Selection 11
3.2.1 Command and Non-Command Areas 11
3.2.2 Development of a Project-Wise Village Database 11
3.2.3 GIS Methodology for Village Selection 11
3.2.4 Illustration Sample 12
3.2.4.1 Example of the Upper Ganga Irrigation Project 12

3.3 Household Listing and Sampling Strategy 13
3.3.1 Listing Exercise 14
3.3.2 Household Stratification 14
3.3.3 Social Representation 14
3.3.4 Sample Selection 14
3.3.5 Summary of Household Selection and Total Sample Size 15
3.4 Why is the Command-Area Sample Substantially Larger than the Non-Command Sample? 16
3.5 Questionnaire Scope and Design 17
3.6 Concluding Remarks 18

Chapter 4: Impact of Irrigation Projects on Rural Livelihoods: A With–Without Comparative Perspective in a Geo-Physical and Socio-Economic Framework 19
4.1 Background and Context 19
4.2 Comparative Assessment between Command and Non-Command Areas 20
4.2.1 Household Social Profile 20
4.2.2 Land and Irrigation 21
4.2.3 Economic Outcomes 23
4.2.4 Market and Business Linkages 24
4.2.5 Migration and Livelihoods 25
4.2.6 Social Development 26
4.2.7 Environmental Outcomes 28
4.2.8 Infrastructure and Access to Services 29
4.2.9 Tourism-related Activities in the Project Areas 30
4.2.10 Overall Well-being 30
4.3 Comparative Assessment of Irrigation Projects 31
4.4 Concluding Remarks 32

Chapter 5: Analytical Framework for Estimating the Indirect Benefits of Irrigation Projects 33
5.1 Introduction 33
5.1.1 Stages of Model Formulation 33
5.2 Stage 1: Identification of Relevant Parameters 34
5.3 Stage 2: Computation of Composite Score 37
5.3.1 Normalisation Formula 37
5.3.1.1 Improvements Associated with Higher Command Responses 37
5.3.1.2. Improvements Associated with Lower Command Responses 38
5.3.2 Computation of Normalised Scores 38
5.3.2.1 Min-Max Normalisation Approach 38
5.3.2.2 Treatment of Negative Index Values 38
5.3.2.3 Computation of the Composite Index 38
5.4 Stage 3: Calculation of Income Differences 40
5.4.1 Command Households' Annual Average Income 40
5.4.2 Non-Command Households' Annual Average Income 41
5.5 Stage 4: Computation of National-level Beta Coefficients 41
5.5.1 Regression Framework and Interpretation 41
5.5.2 National-level Beta Value 42
5.5.3 Robustness Checks and Validation 42
5.5.3.1 Inclusion Exercise 42
5.5.3.2 Exclusion Exercise – 1 43
5.5.3.3 Exclusion Exercise – 2 43
5.5.3.4 Overall Interpretation 43
5.5.3.5 Validation Check 44

5.6 Treatment of Tourism-related Effects 44
5.7 Stage 5: Quantification of Benefits from a Reduction in the Water-Fetching Burden 44
5.7.1 Regression Framework 45
5.7.2 Review of Various Reports 46
5.8 Limitations of the Model and Possible Workarounds 46
5.9 Conclusion 49

Chapter 6: Operationalisation of the Methodology –Application by the Central Water Commission 51
6.1 Introduction 51
6.2 Conceptual Foundation of the Alpha Coefficient 51
6.2.1 Why and How Alpha Was Developed 51
6.2.2 Derivation of the National Alpha Coefficient 52
6.3 Procedure to be Followed by the Central Water Commission for Using Alpha and Beta Coefficients 52
6.3.1 Required Inputs for the Assessment 52
6.3.2 Stages of Computation 52
6.3.2.1 Stage 1: Derivation of Change in Per Hectare Agricultural Income 52
6.3.2.2 Stage 2: Calculation of Composite index from Aplha 53
6.3.2.3 Stage 3: Computation of Per-Household Indirect Benefits 53
6.3.2.4 Stage 4: Computation of Total Indirect Benefits 53
6.4 Assessment of Extension, Renovation, and Modernisation (ERM) Projects 53
6.4.1 Nature of ERM Projects and Analytical Implications 53
6.4.2 ERM-Specific Projects and their Coefficients 53
6.5 Linking Current and Proposed Benefit-Cost Ratio Computation Methodologies 54
6.5.1 Introduction 54
6.5.2 Estimation of Cost 54
6.5.3 Current Benefit Estimation Methodology 54
6.5.4 Proposed Benefit Estimation Methodology 55
6.5.5 Revised Benefit-Cost Ratio 55
6.6 Conclusion and Closing Remarks 55

Chapter 7: Regional Perspectives on Indirect Benefits: FGD Insights 57
7.1 Introduction and Context 57
7.1.1 Tamil Nadu – Lower Bhavani Irrigation Project: Water Security, Crop Diversification, and Women's Economic Empowerment 58
7.1.2 Kerala – Kallada Irrigation Project: Smallholders, Collective Institutions, and Human Development 59
7.1.3 Telangana – Sri Ram Sagar Project: From Subsistence to Commercial Agriculture 59
7.1.4 Maharashtra – Krishna Irrigation Project: Irrigation-Industry Linkages and Rural Modernisation 60
7.1.5 Gujarat – Hathmati Irrigation Project: Community Ownership and Water Governance 60
7.1.6 Uttar Pradesh – Deokali Irrigation Project: Emerging Gains in the Gangetic Plains 61
7.1.7 Bihar – Western Sone High-Level Canal: Latent Potential, Uneven Realisation, and Infrastructure First Irrigation Limits 62
7.1.8 Manipur - Loktak Lift Irrigation Project: Year-round Vegetable Economy and Women's Time-Use Gains 62
7.2 Cross-Regional Synthesis 63
7.3 Conclusion 64

Chapter 8: Quantifying the Indirect Health Benefits of Irrigation Projects in India: A DALY-Based Analysis 67
8.1 Introduction 67
8.2 Methodological Framework 67
8.3 DALY Saved Computation Steps 69
8.3.1. Step 1: Proportion Difference 69
8.3.2 Step 2: Estimation of Affected Population 70
8.3.3 Step 3: DALY Saved 71
8.4 Limitations and Assumptions 72
8.5 Concluding Reflections 72

Chapter 9: Regional and National Workshops 75
9.1. Introduction 75
9.2. Objectives of the Workshops 75
9.3. Summary of Workshops 75
9.4. Regional Consultations: Key Discussion Points 75
9.5. National Workshop: Key Outcomes 76
9.6 Key Findings and Policy Implications 76
9.7. llustrative Photographs from Regional and National Workshops 76

Chapter 10: Groundwater Sustainability: A Cross-Regional Assessment 81
10.1: Introduction 81
10.2: Regional Analysis 82
10.2.1 Northern Region 82
10.2.1.1 Makhu Canal Irrigation Project – Punjab 82
10.2.1.2 Sirhind Canal Irrigation Project – Punjab 84
10.2.2 Western Region 86
10.2.2.1 Karjan Irrigation Project – Gujarat 86
10.2.2.2 Girna Irrigation Project – Maharashtra 88
10.2.3 Eastern Region 90
10.2.3.1 Sakri Lower Valley Project – Bihar 90
10.2.3.2 Uderusthan Irrigation Project – Bihar 91
10.2.4 Southern Region 93
10.2.4.1 Kallada Irrigation Project – Kerala 93
10.2.4.2 Tungabhadra Irrigation Project – Karnataka and Andhra Pradesh 95
10.3 Comparative Assessment Across Selected Irrigation Projects 97
10.4 Key Findings and Policy Implications 99

Chapter 11: Conclusion and Way Forward 101
11.1 Overview 101
11.2 Key Insights 102
11.3 Implications for Policy and Practice 102
11.4 Key Challenges and Study Limitations 103
11.4.1 Key Challenges 103

References 109

List of Tables and Boxes

Table 3.1: Projects selected for the study 9
Box 3.1: Why un-weighted income estimation 15
Table 3.2.1: Selection criteria of sample households through listing 15
Table 3.2.2: Additional gender representation 15
Table 3.2.3: Final sample per village 16
Table 3.3: Total sample size of the study 16
Table 4.1: Distribution of respondent households (%) by market and business linkages 25
Table 4.2: Distribution of households (%) by opportunities in non-agriculture and agriculture business development 26
Table 4.3: Distribution of households (%) by improvements in social development indicators 27
Table 4.4: Distribution of respondent households (%) by infrastructure development and access to various services 29
Table 5.1: List of selected parameters 35
Table 5.2: Detailed summary of selected parameters along with their questionnaire references 36
Table 5.3: Composite scores of all selected irrigation projects 39
Table 5.4: Landholding category respective area 41
Table 5.5: Example of income calculation in the command area 41
Table 5.6: National estimated beta value 42
Table 5.7: Sensitivity under inclusion 43
Table 5.8: Sensitivity under closest exclusion 43
Table 5.9: Sensitivity under farthest exclusion 43
Table 5.10: List of projects with significant time-saving 44
Table 5.11: Regression output linking income 45
Table 5.12: Inputs required for indexation 47
Box 5.1: Methodological Note for Policymakers 48
Table 6.1: National-level alpha coefficient 52
Table 6.2: National-level alpha and beta coefficients 52
Table 6.3: List of Projects Considered under ERM 54
Table 6.4: Beta and alpha coefficients of ERM projects 54
Table 6.5: Current cost components for direct benefit calculations 54
Table 7.1: Regional variation in outcomes – evidence from FGDs 64
Table 8.1: Severity distribution, disability weights, and duration of diarrhoeal episodes among children under five 68
Table 8.2: Systematic approach to quantify health benefits resulting from improved water management 69
Table 8.3: Comparison of perceived diarrhoeal illness in CMD and NCMD regions 69

Table 8.4: Saved households: Estimated number of households avoiding diarrhoeal illness in command areas compared to non-command areas 70
Table 8.5: Disability-adjusted life years (DALYs) saved due to irrigation 71
Table 8.6: Limitations and assumptions used in DALY calculation 72
Table 10.1: Primary Survey findings - Makhu 82
Table 10. 2: GIS- based list of command and non-command villages - Makhu 82
Table 10.3: Primary Survey findings - Sirhind 84
Table 10.4: GIS- based list of command and non-command villages - Sirhind 84
Table 10.5: GIS- based list of command and non-command villages - Karjan 86
Table 10.6: Primary Survey findings - Karjan 86
Table 10.7: GIS- based list of command and non-command villages - Girna 88
Table 10.8: Primary Survey findings - Girna 88
Table 10.9: GIS- based list of command and non-command villages - Sakri Lower Valley Project 90
Table 10.10: Primary Survey findings - Sakri Lower Valley Project 90
Table 10.11: GIS- based List of command and non-command villages - Uderusthan 92
Table 10. 12: Primary Survey findings - Uderusthan 92
Table 10. 13: GIS- based List of command and non-command villages – Kallada 94
Table 10.14: Primary Survey findings - Kallada 94
Table 10. 15: GIS- based List of command and non-command villages - Tungabhadra 96
Table 10.16: Primary Survey findings - Tungabhadra 96
Table 10.17: Comparative Assessment of Groundwater Conditions Across Selected Irrigation Projects Using Primary Survey and CGWB Data 98
Table A4.1: Comparison between command and non-command 167
Table A4.2: Project-wise market value of land owned and change in land value (%) 168
Table A4.3: Project-wise changes in irrigation system of land in last 5 years (%) 170
Table A4.4: Project-wise changes in agriculture productivity (%) 172
Table A4.5: Project-wise changes in market linkages and agricultural trade (%) 174
Table A4.6: Project-wise changes in household income (%) 176
Table A4.7: Project-wise employment and business opportunities (%) 178
Table A4.8: Project-wise reduction in migration and contribution to local agri-business development (%) 180
Table A4.9: Project-wise improvement in education/ healthcare facilities & women participation (%) 182
Table A4.10: Project-wise benefits in environmental conditions (%) 184
Table A4.11: Project-wise tourism development (%) 186
Table A.5.1: List of irrigation projects with reported tourism-related activities 188
Table A.5.2: Estimates of marginal benefits from tourism at national level 189
Table A.5.3: Comparative Estimates with and without Tourism Effects 189
Table A6.1: Validation steps 190
Table A6.2: Agricultural income difference per hectare (Rs.) 191
Table A6.3: Estimated composite index value 191
Table A6.4: Estimated monetised value of indirect benefits per household 191
Table A6.5: Estimated monetised value indirect benefits per hectatre 192
Table A6.6: Indirect benefits as a percentage of total benefits 192
Table A7.1: Ranking of each parameter for all the Irrigation Projects 193
Table A7.2: Project-level FGD insights 197

List of Figures

Figure 3.1: Project selection process (Flow diagram illustrating the multi-stage procedure used to select irrigation projects from the national database provided by the Central Water Commission) 9

Figure 4.1: Distribution of respondent households (%) by social characteristics 20

Figure 4.2: Distribution of respondent households (%) by highest educational attainment 20

Figure 4.3: Distribution of respondent households (%) by source of earning 21

Figure 4.4: Distribution of respondent households (%) by type of house 21

Figure 4.5: Distribution of respondent households (%) by type of irrigation facilities used 22

Figure 4.6: Distribution of respondent households (%) by dependence on rainfall for agriculture 22

Figure 4.7: Distribution of respondent households (%) by size of land owned and ownership type 22

Figure 4.8: Distribution of respondent households (%) by market value of land and change in land value 23

Figure 4.9: Distribution of respondent households (%) by agricultural productivity and change in household income 24

Figure 4.10: Distribution of respondent households (%) by development of agriculture input markets and agro-processing units in command areas 25

Figure 4.11: Distribution of respondent households (%) by migration trends 26

Figure 4.12: Distribution of households (%) by change in women participation 27

Figure 4.13: Distribution of households (%) by environmental improvements 28

Figure 4.14: Distribution of respondent households (%) by resilient and climate-smart agriculture practices 28

Figure 4.15: Distribution of respondent households (%) reporting tourism-related or recreational activities in the area 30

Figure 4.16: Distribution of respondent households (%) by overall benefits other than agriculture-related benefits 31

Figure 4.17: Distribution of respondent households (%) by well-being satisfaction rates 31

Workshop 1 | a: Northern Regional Workshop (New Delhi, CWC Head Office, 2 February 2026): Stakeholder consultations on irrigation efficiency, agricultural productivity, and socio-economic outcomes 76

List of Annexures

Annexure A3.1: List of Command Village Sample 113
Annexure A3.2: List of Non-Command Village Sample 123
Annexure A3.3: Village Questionnaire for Command and Non-Command Villages 129
Annexure -A3.4: Household Listing Questionnaire 136
Annexure A3.5: Questionnaire for the Officials 139
Annexure A3.6: Questionnaire for the Command Areas 144
Annexure A3.7: Questionnaire for the Non-Command Areas 154
Annexure A3.8: Focus Group Discussion Questionnaire: Irrigation Project Benefits 164
Annexure A4.1: Impact of Irrigation projects on Command vs Non-Command (%) 167
Table A4.1: Comparison between command and non-command 167
Table A4.2: Project-wise market value of land owned and change in land value (%) 168
Table A4.3: Project-wise changes in irrigation system of land in last 5 years (%) 170
Table A4.4: Project-wise changes in agriculture productivity (%) 172
Table A4.5: Project-wise changes in market linkages and agricultural trade (%) 174
Table A4.6: Project-wise changes in household income (%) 176
Table A4.7: Project-wise employment and business opportunities (%) 178
Table A4.8: Project-wise reduction in migration and contribution to local agri-business development (%) 180
Table A4.9: Project-wise improvement in education/ healthcare facilities & women participation (%) 182
Table A4.10: Project-wise benefits in environmental conditions (%) 184
Table A4.11: Project-wise tourism development (%) 186
Annexure 5: Exploratory Assessment of Tourism-related Effects in Irrigation Project Areas 188
Table A.5.1: List of irrigation projects with reported tourism-related activities 188
Table A.5.2: Estimates of marginal benefits from tourism at national level 189
Table A.5.3: Comparative Estimates with and without Tourism Effects 189
Annexure A6.1 Validation Exercise (Hypothetical Example) 190
Table A6.1 Validation steps 190
Annexure A6.2 Validation Exercise (Project-based Illustration) 190
Table A6.2 Agricultural income difference per hectare (Rs.) 191
Table A6.3 Estimated composite index value 191
Table A6.4 Estimated monetised value of indirect benefits per household 191
Table A6.5 Estimated monetised value indirect benefits per hectatre 192
Table A6.6 Indirect benefits as a percentage of total benefits 192
Annexure A7.1: Ranking of each parameter for all the Irrigation Projects 193
Table A7.1: Ranking of each parameter for all the Irrigation Projects 193
Table A7.2: Project-level FGD insights 197

Executive Summary

E1: BACKGROUND AND CONTEXT

The National Council of Applied Economic Research (NCAER), commissioned by the Central Water Commission (CWC) under the Ministry of Jal Shakti (MoJS), undertook an all-India evaluation titled *"Assessment of Indirect and Intangible Benefits from Irrigation Projects in the Command/Local/ Vicinity Area."* The study represents a significant advancement in irrigation policy analysis by moving beyond conventional assessments focused primarily on crop productivity and water-use efficiency. Instead, it examines the broader developmental outcomes of irrigation, including its indirect and intangible benefits.

This study constitutes one of the first systematic and data-driven attempts in India to quantify irrigation's multidimensional impacts—covering economic progress, social inclusion, environmental sustainability, and institutional strengthening—within a unified analytical framework designed specifically to estimate indirect benefits.

Using a rigorous "with-and-without" comparative approach, the study evaluates 57 major irrigation projects across 20 states, representing diverse agro-climatic regions, river basins, and institutional contexts. The extensive field coverage—spanning nearly 600 villages and about 10,000 households—provides a rich empirical basis for comparing outcomes between command and non-command areas. This approach captures not only improvements in agricultural productivity but also broader impacts such as reduced migration, employment generation, improved market linkages, better health and education outcomes, enhanced women's participation, and environmental improvements.

The findings provide a strong empirical foundation for reinterpreting irrigation as more than a sectoral agricultural intervention. Rather, irrigation emerges as a critical driver of rural transformation, supporting livelihoods, strengthening local institutions, and contributing to long-term socio-economic and environmental resilience in India's rural economy.

E2: RATIONALE AND OBJECTIVES

Evaluations of irrigation infrastructure in India have traditionally focussed on metrics such as irrigation potential created, area irrigated, and gains in agricultural productivity. However, irrigation influences rural economies in far broader and more interconnected ways. Beyond farm-level outcomes, it generates a wide spectrum of secondary and spillover benefits—expanded employment opportunities, improved access to education and health services, reduction in seasonal migration, localised recreational and landscape-related effects (where observed), groundwater recharge, better market linkages and stronger social cohesion through collective water management.

Despite their significance, these indirect and intangible effects remain largely absent from conventional cost–benefit and project appraisal frameworks. As a result, the full developmental value of irrigation investments is systematically undercounted.

Against this backdrop, the study was designed with the following key objectives:

1. To quantify the indirect and intangible benefits of irrigation projects across multiple socio-economic, institutional, and environmental dimensions;
2. To develop a composite index and associated coefficients that translate these benefits into measurable and comparable values across projects and states; and
3. To integrate quantitative indicators with qualitative community insights to understand the

pathways through which irrigation contributes to inclusive and sustainable rural development.

Taken together, these objectives aim to reposition irrigation from a narrowly defined agricultural intervention to a strategic catalyst of rural transformation. By systematically measuring benefits that were previously considered intangible or difficult to quantify, the study provides policymakers with a more holistic and evidence-based foundation for investment decisions. This expanded analytical lens not only helps uncover hidden value within existing and completed projects but also equips the Central Water Commission (CWC), Ministry of Jal Shakti (MoJS), and the state governments with tools to design, prioritise, and finance irrigation systems that maximise social, economic, and environmental returns. Ultimately, the framework developed through this study lays the groundwork for more inclusive, nationally consistent, and forward-looking water resource planning in India.

E3: METHODOLOGICAL FRAMEWORK

The study adopted a three-stage stratified sampling framework to ensure representation of irrigation systems across diverse agro-climatic, hydrological, and institutional contexts in India.

1. Project Selection:

   Irrigation projects were selected from the national database of completed major and medium irrigation projects provided by CWC. Projects were first stratified by Cultural Command Area (CCA) and period of completion to capture variation in both scale and historical phases of irrigation development. The final sample of 57 projects across 20 states was drawn using a circular systematic Probability-Proportional-to-Size (PPS) sampling method, ensuring that larger projects with wider beneficiary coverage had proportionately higher probability of selection.

2. Village Selection:

   A GIS-based spatial mapping approach was used to identify villages within and outside the command area of each project. Command villages were selected to represent head, middle, and tail reaches of the canal network, while non-command villages were chosen at a safe distance from the irrigation influence zone to serve as control locations for comparative analysis.

3. Household Sampling:

   Within each selected village, households were identified through a comprehensive listing exercise and stratified primarily by landholding size, while ensuring representation across social categories and women-headed households.

To ensure robustness of findings, the study adopted a mixed-method approach, combining:

- Household and village surveys for Quantitiative and Qualitative,
- Focus Group Discussions (FGDs) to capture community-level perceptions and institutional dynamics, and
- Key informant interviews with irrigation officials and local stakeholders.

Together, this integrated methodology enabled a comprehensive assessment of the indirect and intangible benefits of irrigation across multiple regions and socio-economic contexts.

E4: ANALYTICAL MODEL AND DERIVATION OF COEFFICIENTS

The analytical framework developed for the study integrates household-level survey data with project-level composite indicators in order to quantify the indirect and intangible benefits generated by irrigation projects.

a) Composite Index of Indirect Benefits

A Composite Index was constructed to capture the multidimensional impacts of irrigation beyond agricultural output. The index incorporates ten socio-economic and environmental parameters, including employment generation, reduction in distress migration, groundwater recharge, improvements in education and health conditions, women's participation, and community cooperation.

Each parameter was normalised on a 0–1 scale using a methodology similar to the UN Min–Max transformation, enabling consistent comparison between command and non-command areas across projects. The average of the ten normalised parameters was then computed to obtain the project-level Composite Indexes, representing the overall magnitude of indirect benefits.

b) Income Differentials

For each irrigation project, the average annual household income difference (Δ Income) between command and non-command areas was estimated. This was calculated using a weighted mean, where weights were derived from the distribution of landholding categories within the command area. The resulting income differential serves as a monetary proxy for the aggregate incremental benefits generated by irrigation.

c) Regression Modelling

The relationship between the composite index and income differentials was estimated using regression analysis based on primary survey data.

Regression 1:

$$\Delta \text{ Income}_i = \beta \text{ (Composite Index)} + \varepsilon_i$$

Where:

- β (beta) represents the marginal contribution of improvements in the composite index to annual household income.
- ε_i captures the residual effects of other factors influencing income difference.

This regression enables the estimation of the monetised value of indirect and intangible benefits arising from irrigation.

Regression 2:

$$\text{Composite Index}_i = \alpha \text{ (}\Delta \text{ Agri-Income}_i\text{)} + v_i$$

Where:

- α (alpha) represents the marginal contribution of agricultural income gains to improvements in the composite index.
- v_i captures the residual effects of other socio-economic influences.

This relationship allows the Composite Index to be estimated for new irrigation projects using observed agricultural income gains, thereby enabling application of the model without requiring a full primary survey.

d) Regression Results

The regression analysis produced the following national-level coefficients:

- Beta (β): Rs. 81,227 representing the estimated annual household income equivalent associated with a one-unit increase in the composite index.
- Alpha (α): 0.00000837 This figure represents the addition in composite index from an increase of one rupee in the annual agricultural income.

These coefficients are derived from a pan-India dataset covering 57 irrigation projects and therefore provide a nationally applicable benchmark for estimating the indirect and intangible benefits of irrigation investments.

These coefficients provide a practical tool for incorporating indirect and intangible benefits into irrigation appraisal. The estimated beta value indicates an average annual household income equivalent of approximately over Rs. 81,000 per household (at 2025–26 prices) associated with improvements in the composite index, highlighting the substantial socio-economic gains generated by irrigation beyond direct agricultural income.

E5: KEY FINDINGS

E5.1: Economic Transformation and Livelihood Diversification

Irrigation access has fundamentally altered rural income structures. In command areas, 68 per cent of households reported higher productivity and incomes, while land values more than doubled, signalling both enhanced productivity and risk reduction. In contrast, 67 per cent of households in non-command areas experienced stagnation or decline.

Improved irrigation strengthened market linkages, with 76 per cent of command households reporting better access to input and output markets. Employment diversification followed, as local agri-service enterprises, dairies, and repair shops proliferated—generating a 'rural multiplier effect' beyond crop cultivation.

FGDs reinforced this trend: farmers consistently cited greater livelihood security and resilience, noting that irrigation allows "farming to become predictable again," while non-command areas reported seasonal distress migration and growing dependence on informal credit.

E5.2: Social Development, Education, Gender Empowerment, and Migration Reduction

Irrigation also yielded significant social dividends. Educational outcomes improved markedly—83 per cent of command households reported better schooling infrastructure, and secondary school attendance increased sharply. Women's participation in the workforce rose to 61 per cent, reflecting both time savings from reduced drudgery and expanded local economic opportunities.

Migration declined substantially—from 46 per cent in non-command to 34 per cent in command areas—indicating enhanced livelihood stability. FGDs revealed that irrigation reduces the 'push factors' for migration by ensuring predictable returns from farming and enabling investment in education and home-based enterprises.

In regions such as Telangana, Gujarat, and Maharashtra, women's self-help groups (SHGs) and farmer producer organisations (FPOs) have leveraged irrigation infrastructure to initiate collective enterprises—demonstrating irrigation's role in institutional empowerment and social cohesion.

E5.3: Environmental and Health Outcomes

Command areas displayed substantial environmental recovery: 45 per cent of households reported groundwater improvement, 44 per cent reported soil quality enhancement, while 63 per cent observed that increased vegetation cover resulted in an improved environment. Dependence on rainfall declined by more than 50 per cent, reflecting irrigation's climate-adaptation role.

The FGDs highlighted improvements in water quality, a reduction in waterborne diseases, and enhanced environmental aesthetics—particularly in the canal and reservoir zones of Odisha, Telangana, and Gujarat. These outcomes indicate that irrigation contributes significantly to ecological regeneration and public health resilience.

E5.4: Localised Recreational and Tourism-linked Effects

Field observations and stakeholder consultations indicate that irrigation infrastructure—particularly reservoirs and associated water bodies—may give rise to localised recreational and tourism-related activities in select project areas. These include boating, fisheries-based recreation, and small-scale hospitality services, typically concentrated in the immediate vicinity of reservoirs and headworks.

However, such effects are spatially limited and not uniformly observed across all irrigation projects or across command areas. Their occurrence depends on a combination of factors including proximity to reservoir sites, availability of supporting infrastructure, and local entrepreneurial responses.

In view of these considerations, tourism-related effects have been treated as context-specific and non-generalisable outcomes, and are therefore not included in the core econometric estimation of indirect benefits presented in this report. A detailed exploratory analysis of such effects is provided separately for reference.

These findings suggest that while irrigation infrastructure can, under certain conditions, support diversification into recreational and tourism-linked activities, such outcomes should be interpreted as supplementary and project-specific, rather than as systematic components of indirect benefit estimation.

E5.5: Reduction in the Burden of Water Collection

The scope of the study was further enhanced by incorporating an assessment of the indirect benefits arising from the reduction in households' water-collection burden. This dimension captures the often-overlooked time and labour savings—particularly for women—that accompany improved irrigation facilities. Across the irrigation projects assessed, nearly 55 per cent of command-area households reported a significant decline in the time and physical effort required for water collection.

To quantify this benefit, the study applied a dummy-variable regression framework, using binary indicators to estimate the annual income equivalent of time saved from reduced water-collection activities. The analysis indicates that this translates into approximately Rs. 2,587 of additional annual income per household, reflecting the economic value of labour-hours that can now be redirected toward productive or welfare-enhancing activities.

E6: Comparative Project Insights

The top-performing projects—Uderusthan,

Kakrapar, Ukai, Karjan, and Hirakud—exhibit a distinctive convergence of strong performance with effective institutional and social linkages. Evidence from FGDs indicates higher community trust in local governance systems, a noticeable growth in tourism-related activities in some parts, and more equitable and reliable water distribution across command areas. These projects demonstrate how technical adequacy, when coupled with participatory institutions and responsive management, can generate broad-based rural development outcomes.

In contrast, low-performing projects such as Kanchi, Mayurakshi, and Harishchandra Sagar face persistent structural constraints, including irregular canal water supply, limited modernisation of irrigation assets, and weak user participation in water governance. These shortcomings highlight that irrigation performance is shaped not only by engineering design but also by the vitality of institutional arrangements, operation and maintenance practices, and the extent of community engagement.

E7: Groundwater Analysis

As part of the assessment of indirect and intangible benefits, the NCAER study also examined groundwater sustainability as an important environmental outcome associated with major irrigation projects. Using household-level evidence from the primary survey, supplemented by groundwater-level observations published by the Central Ground Water Board (CGWB), the study undertook a comparative assessment across selected irrigation projects representing different regions of the country. The analysis indicates that while groundwater outcomes vary across hydrogeological and agro-climatic settings, command areas generally exhibit relatively more favourable groundwater conditions than comparable non-command areas in several irrigation systems. The findings suggest that canal irrigation may contribute to moderating groundwater stress by reducing dependence on groundwater extraction, although the magnitude of this benefit remains region-specific and influenced by local climatic, geological, and agricultural conditions. These results reinforce the importance of recognising groundwater sustainability as an indirect environmental benefit of major irrigation projects and highlight the need for integrated management of surface water and groundwater resources.

E8: Policy Implications

The study demonstrates that the influence of irrigation extends well beyond agricultural production. By improving water reliability and stabilising farm incomes, irrigation generates broader rural multiplier effects, stimulating consumption, employment, asset formation, and community-level investments. However, the magnitude of these spillovers varies across projects, depending on factors such as governance quality, institutional engagement, equity in water distribution, and integration with local infrastructure, markets, and ecological systems.

To translate these insights into actionable policy directions, the study proposes the following recommendations:

1. Institutionalise Valuation of Indirect Benefits

Project appraisal frameworks under the Central Water Commission (CWC) and the Ministry of Jal Shakti (MoJS) should systematically incorporate the valuation of indirect and intangible benefits, including income stabilisation, reduction in distress migration, women's time savings, environmental improvements, and community-level development outcomes. Integrating these dimensions will enable more comprehensive and evidence-based investment decisions.

2. Strengthen Participatory Water Governance

Strengthening Water User Associations (WUAs), self-help groups (SHGs), and local panchayats is essential for equitable and efficient water distribution. Capacity building, financial support, and adoption of digital monitoring tools can significantly improve operation, maintenance, and long-term sustainability of irrigation systems.

3. Promote Integrated Water Resource Management

Irrigation planning should promote conjunctive use of surface and groundwater, groundwater recharge measures, and nature-based solutions to enhance ecological resilience. Integrating irrigation management with watershed development and climate adaptation strategies will be critical for sustaining water security in the long term.

4. Leverage Irrigation-linked Tourism and Rural Enterprises

Irrigation infrastructure may, in certain contexts,

support recreational and tourism-linked activities, particularly in reservoir-adjacent areas. While these may contribute to local economic diversification, such effects are context-specific and are not part of the core valuation framework adopted in this study.

5. Introduce National Benchmarking Using Composite Indices

A national framework for benchmarking irrigation projects using composite indices should be developed to assess engineering performance, agricultural outcomes, socio-economic spillovers, and environmental sustainability. Such benchmarking can guide funding priorities, modernisation strategies, and accountability across states while fostering knowledge-sharing and healthy competition among irrigation systems.

E9: ECONOMIC VALUATION AND FUTURE ANALYTICAL USE

The NCAER study introduces a practical and rigorous approach for assigning economic value to the indirect and intangible benefits of irrigation—benefits that are often overlooked in conventional project evaluations. These include improvements in health and education, expanded employment and non-farm opportunities, reduced distress migration, stronger community institutions, and enhanced environmental conditions. By comparing household incomes in irrigated (command) and non-irrigated (non-command) areas, the study demonstrates that these broader improvements in living conditions translate into measurable economic gains for rural households.

At the core of this framework is a regression-based valuation model that links the Composite Index of Indirect Benefits with household income differentials. The estimated alpha and beta coefficients translate improvements in multidimensional development indicators into corresponding income equivalents. This allows the broader developmental impact of irrigation—beyond increases in crop production or irrigation potential—to be captured in a consistent, transparent, and scalable manner.

The resulting analytical framework provides a foundation for next-generation irrigation appraisal tools. It enables policymakers in the Central Water Commission (CWC), Ministry of Jal Shakti (MoJS), and state governments to systematically incorporate indirect and intangible benefits into economic evaluations of irrigation projects. By linking improvements in well-being, resilience, and environmental quality to measurable economic outcomes, the NCAER framework helps ensure that irrigation planning reflects the full spectrum of developmental benefits and supports more informed and balanced investment decisions.

E10: SUMMING UP

A key contribution of this study is the development of a robust analytical framework for estimating—and economically valuing—the indirect and intangible benefits of irrigation. By systematically capturing the broader socio-economic and environmental outcomes associated with irrigation investments, the framework introduces an important new dimension to water resource planning in India, strengthening the basis for more comprehensive and evidence-based policy decisions.

The findings demonstrate that irrigation functions not only as an agricultural input but also as a catalyst for wider rural development. Beyond increasing agricultural productivity, irrigation contributes to income stability, livelihood diversification, improved health and education outcomes, women's empowerment, strengthened community institutions, and enhanced environmental conditions. These results underscore the importance of evaluating irrigation projects not only in terms of engineering performance or irrigated area, but also in terms of their broader developmental and social impacts.

By integrating indirect benefit valuation into irrigation appraisal, the study bridges a long-standing gap between infrastructure performance and development outcomes. The proposed framework—combining primary field evidence, composite indicators, and regression-based valuation coefficients—offers a scalable and practical tool for incorporating these broader impacts into future irrigation planning and evaluation.

Overall, the NCAER framework provides a forward-looking approach to irrigation assessment, recognising water not only as a factor of agricultural production but also as a driver of inclusive growth, environmental sustainability, and long-term rural resilience. As India faces increasing pressures on its water resources, such evidence-based approaches will be critical for guiding investments toward irrigation systems that generate the greatest overall developmental returns.

CHAPTER 1

Background

1.1 INTRODUCTION AND CONTEXT

Water is a fundamental resource essential for agriculture, urban development, industry, and ecological sustainability. In India, where a large share of the population depends on agriculture, efficient water management is critical for enhancing productivity, ensuring food security, and strengthening resilience to climate variability.

The Central Water Commission (CWC), under the Ministry of Jal Shakti, plays a central role in the development, regulation, and evaluation of water resources and irrigation projects across the country. Sustainable and equitable use of water is vital to balance competing demands among agricultural, urban, and industrial sectors while safeguarding natural ecosystems. Therefore, evaluating irrigation projects must go beyond direct agricultural outcomes to encompass their wider social, economic, environmental, and institutional implications.

1.2 IRRIGATION AND ECONOMIC DEVELOPMENT

Since the launch of India's Five-Year Plans in 1951, irrigation has been a cornerstone of the nation's agricultural and rural development strategy. It has significantly contributed to achieving food self-sufficiency, improving rural incomes, and reducing poverty.

The Pradhan Mantri Krishi Sinchai Yojana (PMKSY), launched in 2015–16, consolidated several existing initiatives, including the Accelerated Irrigation Benefits Programme (AIBP), to expedite project completion and improve water-use efficiency. As of now, AIBP has supported 297 major and medium irrigation projects, creating an irrigation potential of over 2.4 million hectares. The government's continued investment—such as the Rs. 93.1 billion allocations for the PMKSY (2021–26)—demonstrates a strong commitment to modernising irrigation infrastructure through technologies like Supervisory Control and Data Acquisition (SCADA) systems and micro-irrigation.

1.3 RECOGNISING THE INDIRECT BENEFITS OF IRRIGATION PROJECTS

Conventional evaluations of irrigation projects focus primarily on direct agricultural benefits, often expressed through yield gains, cropping intensity, or benefit-cost ratios. However, irrigation also generates a range of indirect and intangible benefits that contribute to long-term socio-economic and environmental well-being. These include:

1. Tourism and beautification: The creation of scenic reservoirs and canal systems promotes tourism and local enterprise.
2. Public health improvements: Reliable and clean water supply helps reduce waterborne diseases and improve sanitation.
3. Employment generation: Expanded agricultural and service activities create additional livelihood opportunities.
4. Groundwater recharge: Improved water tables enhance sustainability and reduce salinity.

5. Reduced migration: Steady access to water stabilises rural populations and mitigates distress migration.

6. Education and social development: Enhanced household income and community stability support better educational outcomes and social well-being.

Recognising these dimensions is essential for capturing the complete developmental impact of irrigation investments.

1.4 CLASSIFICATION OF INDIRECT BENEFITS

The indirect impacts of irrigation projects can be broadly categorised into economic, social, environmental, and institutional benefits:

- ***Economic Benefits:*** Irrigation stabilises agricultural output, supports crop diversification, and enhances income generation. It strengthens rural supply chains, raises land values, and promotes agro-based industries such as food processing, dairy, and horticulture.
- ***Social Benefits:*** Improved irrigation enhances food and nutritional security, reduces distress migration, and strengthens access to health and education. It also fosters the inclusion and empowerment of women and marginalised communities.
- ***Environmental Benefits:*** Efficient irrigation practices contribute to groundwater recharge, soil conservation, and afforestation along canals. The use of technologies like micro-irrigation and SCADA-based systems promotes water-use efficiency and ecological balance.
- ***Institutional Benefits:*** Irrigation projects strengthen governance frameworks and coordination between central and state agencies. Capacity-building initiatives for farmers and local institutions promote sustainable practices and informed decision-making.

1.5 CHALLENGES IN VALUING INTANGIBLE BENEFITS

Quantifying non-market benefits—such as improved health, education, and social stability—remains methodologically challenging. These impacts evolve gradually and are influenced by multiple socio-economic factors beyond agricultural output.

To address this complexity, the study employs a comparative field-based approach involving both command areas (CAs) and non- command areas (NCAs). This with-and-without analysis enables the assessment of irrigation's broader impacts on livelihoods, productivity, health, and social well-being.

1.6 OBJECTIVE OF THE STUDY

The primary objective of this study is to assess the indirect and intangible socio-economic, environmental, and institutional impacts of selected irrigation projects implemented under the Central Water Commission. Specifically, the study seeks to:

1. Quantify changes in agricultural income and employment associated with irrigation;
2. Evaluate the secondary impacts on health, education, migration, and community resilience;
3. Examine environmental and resource sustainability outcomes such as groundwater recharge and biodiversity enhancement;
4. Strengthen the evidence base for incorporating indirect benefit valuation into project appraisals; and
5. Provide policy insights for improving irrigation planning, governance, and monitoring systems.

1.7 STUDY RATIONALE AND POLICY RELEVANCE

While irrigation has been central to India's agricultural progress, its broader developmental contributions often remain undervalued in conventional assessments. This study bridges that gap by systematically examining both direct and indirect benefits, offering a multidimensional understanding of irrigation's role in promoting sustainable and inclusive growth.

By comparing command and non-command areas, the study captures how irrigation influences livelihoods, productivity, and ecological sustainability. The findings aim to inform the integration of indirect benefit assessment into national evaluation frameworks and enhance the effectiveness of future irrigation investments. The insights generated will guide the Central Water Commission and the Ministry of Jal Shakti in strengthening evidence-based irrigation planning, optimising resource use, and promoting inclusive and sustainable water governance in India.

CHAPTER 2

Review of Literature

2.1 BACKGROUND

Irrigation has been central to India's strategy for agricultural growth, poverty alleviation, and rural transformation since the inception of planned development. While successive investment plans and evaluations—ranging from the Five-Year Plans to recent reviews by the NITI Aayog and the Central Water Commission (CWC)—have traditionally emphasised the direct gains from irrigation in terms of crop productivity, irrigation intensity, and water-use efficiency, an emerging policy consensus recognises that such metrics capture only a part of the total impact. Irrigation systems, by altering the local hydrological, economic, and institutional environment, generate a wide spectrum of indirect or secondary benefits—including enhanced rural employment, income diversification, asset creation, reduced migration, improved education and health outcomes, strengthened local governance, and ecological spillovers.

However, these indirect benefits have seldom been quantified in a systematic or comparable manner across projects. The present CWC evaluation thus aims to fill an important empirical and policy gap by developing composite indices of indirect benefits and linking them to observed livelihood and welfare outcomes. Such an approach aligns with contemporary policy imperatives under the National Water Policy (2020)[1] and the FAO's Water–Energy–Food Nexus framework, both of which emphasise integrated water governance and sustainability.

Against this backdrop, the following section reviews key theoretical and empirical contributions from global and national literature on irrigation's indirect impacts. It synthesises findings in the economic, social, environmental, and institutional dimensions to situate the present study within the broader research landscape and inform its analytical framework.

2.2 EXPANDING THE SCOPE OF IRRIGATION BENEFITS

Historically, irrigation investments have been justified primarily on their capacity to increase agricultural productivity, stabilise food supplies, and mitigate the effects of rainfall variability. However, a growing body of interdisciplinary literature demonstrates that the impacts of irrigation extend far beyond direct yield increases. Irrigation interventions influence a complex web of economic, social, environmental, institutional, and even tourism-related processes, generating indirect benefits—or spillovers—that often rival or exceed the direct on-farm gains (Giordano et al., 2023; World Bank, 2023).[2]

[1]https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1782283&reg=3&lang=2

[2]Bassini, Elisabeth; Giordano, Mark Frank; Namara, Regassa Ensermu.
The Impacts of Irrigation: A Review of Published Evidence (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/099514502242320808Giordano et al., 2023; World Bank, 2023

These indirect impacts operate through multiple channels; by enhancing market linkages, catalysing non-farm employment, strengthening local governance, and reshaping rural landscapes. The scale and sustainability of such effects are strongly conditioned by project design, water governance mechanisms, and the degree of integration with complementary infrastructure and services. The literature thus argues for a system-level understanding of irrigation that goes beyond engineering performance to encompass broader socio-ecological outcomes.

2.3 ECONOMIC SPILLOVERS AND RURAL MULTIPLIER EFFECTS

The most consistently documented indirect benefit of irrigation is its stimulus to rural economies. Irrigation reduces production risk and facilitates a shift toward higher-value, multi-crop systems, which in turn generate forward and backward linkages across the rural economy.

Giordano et al. (2023)[3] find that irrigation investments frequently trigger non-farm employment growth by expanding demand for input supply, agro-processing, and transport services, resulting in income multipliers that extend well beyond agriculture. Mupaso et al. (2023)[4] corroborate this pattern in sub-Saharan Africa and South Asia, showing that small-scale irrigation reduces poverty primarily through labour market spillovers and local consumption linkages.

Empirical evidence from India supports these findings. Butler and Reddy's (2023)[5] study 'Watering the Seeds of the Rural Economy' demonstrates that access to groundwater irrigation not only boosts farm output but also induces positive consumption spillovers in nearby non-irrigated areas. Earlier general equilibrium analyses likewise highlight irrigation's role in raising rural wages, enhancing land values, and improving resilience to climatic shocks. However, several reviews caution that infrastructure alone is insufficient; complementary market access, price incentives, and institutional coordination are critical to translating irrigation into sustained regional growth.

2.4 SOCIAL AND WELFARE OUTCOMES

Beyond measurable economic gains, irrigation contributes indirectly to social welfare and human development. Alcon (2021)[6] conceptualises irrigation water as a form of social well-being capital, arguing that improved water security enhances life satisfaction, reduces vulnerability, and encourages household investments in education, housing, and health.

Empirical studies substantiate these pathways. Gizaw (2025)[7] finds that small-scale irrigation significantly improves household food security, dietary diversity, and asset accumulation in Ethiopia. Similarly, Saha (2025)[8] documents that irrigation in India reduces seasonal migration, stabilises schooling among children, and supports livelihood diversification within farm households.

Gendered impacts, however, are more nuanced. While rising incomes and market participation can empower women, increased irrigation-related workloads without mechanisation or labour redistribution can exacerbate time poverty (Gizaw, 2025).[9] The literature increasingly advocates gender-sensitive irrigation design, emphasising inclusive extension services, equitable access to water user associations (WUAs), and labour-saving technologies to ensure that women share equitably in the indirect social gains of irrigation.

---

[3]The Impacts of Irrigation A Review of Published Evidence

[4]Smallholder irrigation and poverty reduction in developing countries: a review

[5]Butler, D., & Reddy, V. R. (2021). Watering the seeds of the rural economy: Evidence from India. Agricultural Economics, 52(5), 745–760. (AndreButler.pdf)

[6]Alcon, F. (2021). Water for well-being: The social dimensions of irrigation and water security. Journal of Rural Studies, 88, 34–45. (Alcon, 2021), https://www.researchgate.net/publication/357417086_The_social_wellbeing_of_irrigation_water_A_demand-side_integrated_valuation_in_a_Mediterranean_agroecosystem

[7]Gizaw, T. (2025). Household food security and welfare impacts of small-scale irrigation: Evidence from Ethiopia. Agricultural Water Management, 286, 109812. (Gizaw 2025)

[8]Saha, P. (2025). Irrigation, migration, and schooling: Socioeconomic effects of water access in rural India. Indian Journal of Agricultural Economics, 80(1), 112–130. (Saha, et.al)

[9]Gizaw, T. (2025). Household food security and welfare impacts of small-scale irrigation: Evidence from Ethiopia. Agricultural Water Management, 286, 109812. (Gizaw 2025)

2.5 ENVIRONMENTAL AND ECOLOGICAL DIMENSIONS

The environmental literature portrays irrigation as both a potential ecological enabler and a source of risk. On the one hand, well-managed irrigation systems can reduce pressure on forests and marginal lands by intensifying production on existing farmland (Scanlon et al., 2012[10]; Tarolli, 2024[11]). On the other, poor water management can cause groundwater depletion, salinisation, and waterlogging, undermining long-term productivity and ecosystem health (Nyika, 2024).[12]

Recent reviews present a more nuanced picture. Fišer et al. (2025)[13] argue that when irrigation systems incorporate conjunctive use of surface water and groundwater and enforce environmental flow safeguards, they can sustain local wetlands and groundwater-dependent ecosystems. The consensus emerging from recent syntheses is that the net environmental effect of irrigation hinges on governance quality—particularly the integration of efficiency, equity, and sustainability principles into project planning, operation, and maintenance frameworks.

Thus, the ecological dimension of irrigation is not inherently negative but conditional on design and oversight, reinforcing the need for adaptive management and continuous monitoring.

2.6 TOURISM-RELATED ASPECTS OF RURAL DIVERSIFICATION

A relatively recent but expanding area of inquiry links irrigation to rural diversification through agritourism and landscape-based amenities. Phillip, Hunter, and Blackstock (2010)[14] established an influential typology connecting aesthetically enhanced irrigated landscapes to tourism potential. Building on this foundation, recent bibliometric analyses (2024–25) suggest that irrigation facilitates diversification into floriculture, orchards, and horticultural enterprises, which often underpin farm-based or peri-urban tourism ventures.

However, these outcomes are highly context-dependent, requiring accessibility, rural infrastructure, and marketing support. Irrigation thus functions as an enabler rather than a driver of tourism-led rural transformation. Its contribution lies in providing the biophysical and aesthetic base upon which diversified, service-oriented rural economies can evolve.

2.7 INSTITUTIONAL AND GOVERNANCE IMPACTS

Institutional transformations arising from irrigation projects constitute another category of indirect benefits that traditional cost-benefit analyses often overlook. The establishment of Water User Associations (WUAs)[15] has been shown to enhance efficiency, cost recovery, and conflict resolution in irrigation management (Roman et. al, 2025)[16]. These institutions frequently develop into platforms for broader collective action and local governance, strengthening social capital and participatory decision-making.

Parajuli (2024)[17] traces how farmer-managed irrigation systems evolve in response to technological modernisation and market integration, illustrating

[10]Scanlon, B. R., Jolly, I., Sophocleous, M., & Zhang, L. (2012). Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity versus quality. Water Resources Research, 48(7), W07502. (Scanlon, et.al)

[11]Tarolli, P. (2024). Irrigation intensification and land use trade-offs: Global evidence and sustainability challenges. Environmental Reviews, 32(1), 85–104. Tarolli (2024)

[12]Nyika (2024) Nyika, J. (2024). Soil salinization and waterlogging in intensively irrigated basins: Lessons for sustainable water management. Land Degradation & Development, 35(2), 223–240. Nyika (2024)

[13]Fišer, J., Novak, L., & Doležal, T. (2025). Balancing irrigation and ecosystem sustainability: A synthesis of ecological irrigation management. Environmental Research Letters, 20(3), 301–322. (Fišer et al. (2025)

[14]Phillip, S., Hunter, C., & Blackstock, K. (2010). A typology for defining agritourism. Tourism Management, 31(6), 754–758. Phillip, Hunter, and Blackstock (2010)

[15]An Empirical Examination on the Role of Water User Associations for Irrigation Management in Rural China

[16]Kuryltsiv, R., Stańczuk-Gałwiaczek, M., & Łuczyński, R. (2025). Water User Associations in Drained and Irrigated Areas for More Sustainable Land and Water Management: Experiences from Poland and Ukraine. Sustainability, 17(15), 7100.

[17]Parajuli, R. (2024). Adaptive governance in farmer-managed irrigation systems. Water Policy, 26(1), 65–84. Parajuli (2024)

adaptive governance at the community level. Vallury et al. (2022)[18] extend this argument by describing irrigation systems as "multiple action situations" that foster coordination, negotiation, and learning among diverse stakeholders. Such institutional spillovers—enhanced rule enforcement, transparency, and accountability—represent significant, though often intangible, long-term benefits of irrigation investments.

2.8 SYNTHESIS AND EMERGING RESEARCH DIRECTIONS

The literature converges on a critical insight: irrigation's indirect benefits are multifaceted, cross-sectoral, and contingent on governance and complementary infrastructure. Economic spillovers manifest through employment and market linkages; social welfare gains arise via food security, education, and reduced vulnerability; environmental outcomes depend on sustainability safeguards; and institutional effects reinforce local governance and cooperation.

Recent studies advocate for integrated assessment frameworks that combine socio-economic, institutional, and environmental indicators to capture these interlinkages holistically. Quantifying and valuing such indirect benefits remain an empirical challenge but are essential for a more accurate appraisal of irrigation's true contribution to rural transformation and resilience.

2.9 CONCLUDING REFLECTIONS AND LINKAGES TO THE PRESENT STUDY

The reviewed literature consistently underscores that irrigation's developmental impact extends well beyond direct gains in agricultural output, influencing income diversification, employment generation, women's participation, migration dynamics, and social well-being. However, much of the evidence remains fragmented, project-specific, or descriptive, often constrained by the absence of robust counterfactuals. The dominance of before–after or beneficiary–nonbeneficiary comparisons in past evaluations has limited the ability to disentangle irrigation's unique contribution from concurrent policy and market influences.

The present CWC evaluation seeks to address these limitations through a with-and-without comparative framework that contrasts outcomes across command and non-command villages. By constructing composite indices—covering the economic, social, educational, market, health, and environmental dimensions—the study provides a systematic measure of irrigation's indirect benefits and their variations across projects and regions. Furthermore, the integration of both quantitative household data and qualitative field evidence enables a nuanced understanding of the pathways through which irrigation influences livelihoods and welfare. In doing so, the study contributes to a more comprehensive evidence base for policy appraisal and investment prioritisation in India's water resource sector.

[18]Vallury, K., Bhat, S., & Sen, A. (2022). Multiple action situations in irrigation governance: Toward adaptive institutions. Water Alternatives, 15(2), 311–329. Vallury et al. (2022)

CHAPTER 3

Sampling Methodology

3.1 STUDY COVERAGE AND SCOPE

To ensure a representative selection of irrigation units and effectively capture the diverse impacts of irrigation interventions across varied agro-climatic and hydrological conditions, a three-stage stratified sampling design has been adopted with projects, villages, and households as the units in the first-stage, second-stage, and third-stage respectively. This approach enables a comprehensive assessment of the indirect and intangible benefits of irrigation projects, encompassing both short-term and long-term effects.

In the first stage, the sampling frame was constructed using a comprehensive list of irrigation projects provided by the Central Water Commission (CWC). The projects in this list were not pre-classified by regions; hence, the selection process was carried out directly from the national-level database to avoid any regional bias and to ensure systematic representation. The selection was guided by criteria that ensured inclusion of projects from diverse agro-climatic zones, capturing variations in irrigation potential, water availability, and cropping intensity.

In the second stage, projects were categorised according to their plan period of completion in order to incorporate a temporal dimension into the sampling framework. This classification enabled the inclusion of both older projects, which provide insights into sustained impacts over time, and more recently completed projects, which reflect emerging outcomes and ongoing benefits.

In the third stage, the irrigation projects were stratified based on their command area (CCA), measured in thousand hectares. Projects were arranged in descending order of command area size, and the selection followed the Probability-Proportional-to-Size (PPS) or Command-Area-Proportion-to-Size method. This ensured that larger irrigation projects, which typically have a broader socio-economic and environmental footprint, had a proportionately higher probability of inclusion.

Based on this stratified and systematic procedure, a total of 57 irrigation projects were selected from the CWC-provided list. The final selection was made through an iterative screening and consultation process with the Central Water Commission and relevant project authorities to ensure that the chosen projects adequately represent the different types, scales, and operational contexts of irrigation systems in India. These projects collectively capture the diversity of irrigation impacts across distinct ecological, institutional, and developmental settings. A detailed sample-selection process is narrated below.

3.1.1 Selection of Irrigation Projects Across States

As noted earlier, the first stage of the sampling design involved the selection of irrigation projects from a national database of completed major and medium irrigation projects obtained from the CWC. The database includes irrigation projects across multiple states and river basins and provides information on their CCA as well as the year of completion.

In order to ensure that the selected sample adequately represents irrigation systems of different

historical phases of development as well as variations in project scale, a stratified PPS sampling procedure was adopted.

First, a temporal stratification was introduced by grouping irrigation projects according to their period of completion. Incorporating this temporal dimension into the sampling design allows the study to capture irrigation systems with varying levels of maturity and impact. Accordingly, projects were broadly classified into three groups:

- Projects completed during earlier planning periods (for example, during the early Five-Year Plans),
- Projects completed during intermediate periods of irrigation expansion, and
- Projects completed during the most recent decade.

This classification ensured that the sample includes both long-established irrigation systems, where the impacts of irrigation have evolved over several decades, and more recently completed projects where irrigation benefits and associated outcomes are still emerging.

Following temporal stratification, projects within each category were arranged in descending order of their CCA. The CCA serves as an appropriate measure of project size, as irrigation systems with larger command areas typically influence a greater number of agricultural holdings, beneficiary households, and cropping systems. Consequently, using CCA as the size measure enables the sampling design to adequately reflect the relative scale and potential economic impact of different irrigation projects.

After organizing projects according to period of completion and project size, irrigation projects were selected using a Circular Systematic PPS sampling method, with CCA serving as the measure of size. Under this method, the probability of selecting a project is proportional to its command area, implying that irrigation projects covering larger command areas—and therefore representing a larger population of potential beneficiaries-have a proportionately higher probability of being included in the sample.

In the circular systematic PPS procedure, projects are first arranged in a list ranked by CCA. A sampling interval is then computed by dividing the total cumulative command area of all projects in the sampling frame by the desired number of projects to be selected. A random start point is selected within the first interval, and subsequent projects are chosen systematically by moving through the cumulative CCA distribution at fixed sampling intervals. When the end of the list is reached, the selection continues from the beginning of the list, thereby forming a circular selection process and ensuring that all projects have a non-zero probability of selection.

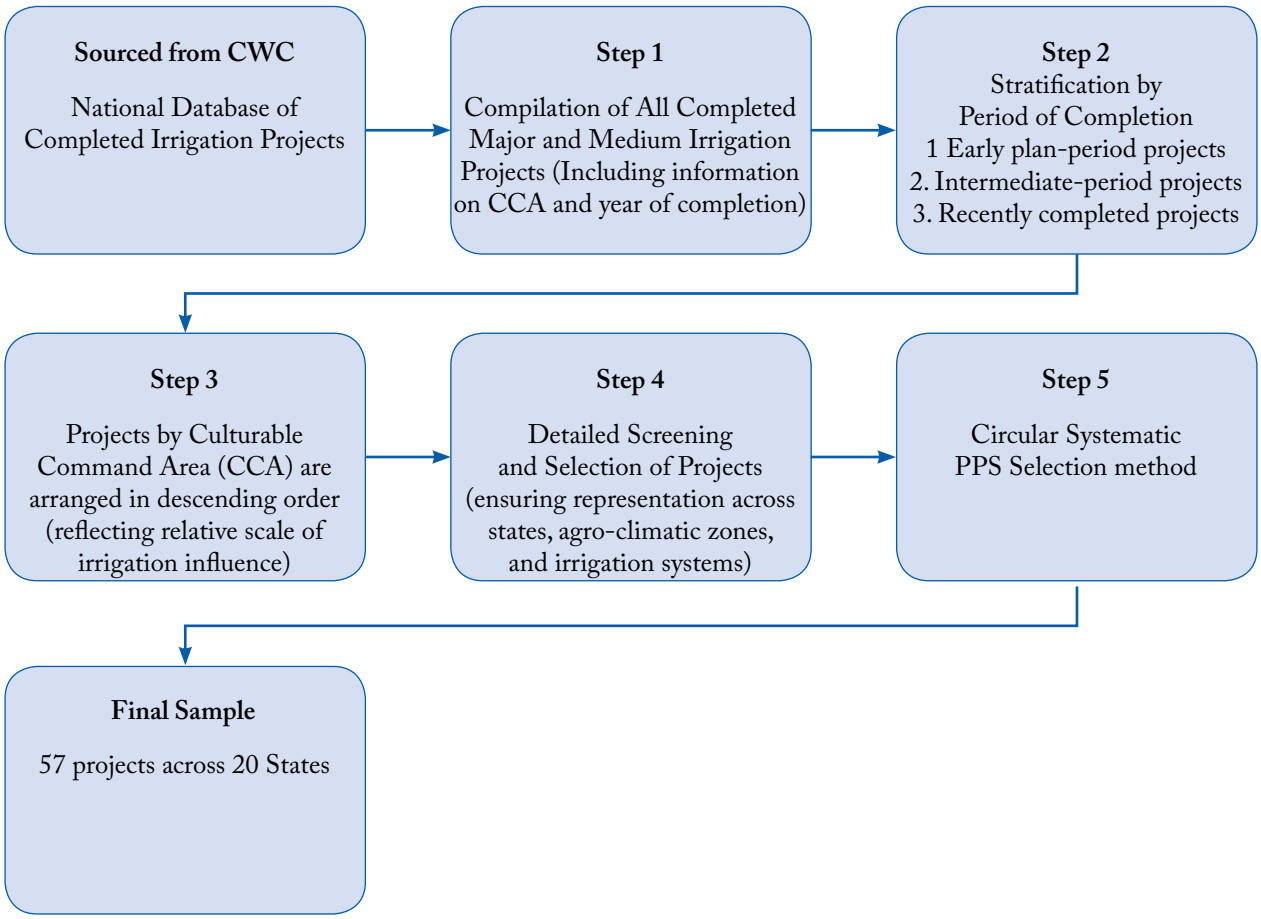
This sampling approach ensures that irrigation projects of different scales are represented in the sample while maintaining statistical efficiency and minimizing selection bias. The PPS method is widely used in large-scale surveys where sampling units differ substantially in size.

Using this combined temporal stratification and CCA-based PPS selection procedure, irrigation projects were identified iteratively in consultation with the Central Water Commission to ensure adequate representation across different states, agro-climatic zones, and stages of irrigation development. The final sample consists of 57 irrigation projects across 20 states, representing a diverse mix of large and medium projects as well as both older and recently completed irrigation systems.

Overall, the selected projects span multiple agro-climatic regions and river basins, ensuring broad national coverage and enabling the study to capture the diverse contexts in which irrigation systems operate in India.

The project selection procedure is summarised in Figure 3.1

Figure 3.1: Project selection process (Flow diagram illustrating the multi-stage procedure used to select irrigation projects from the national database provided by the Central Water Commission)



The irrigation projects along with their CCAs (in thousand hectares) and their respective states, are listed in Table 3.1.

Table 3.1: Projects selected for the study

Northern Region			
S. No	**Projects**	**State**	**CCA (in 000' Ha.)**
1	Sharda Sahayak Canal	Uttar Pradesh	1,522.0
2	Western Yamuna Canal	Haryana	1,076.0
3	Upper Ganga Irrigation Canal	Uttar Pradesh	924.0
4	IGNP Irrigation Canal (1 and 2)	Rajasthan	525.0
5	Matatila Irrigation Canal	Madhya Pradesh	427.0
6	Sir hind Irrigation Canal	Punjab	360.0
7	Chambal Irrigation Project	Rajasthan	229.9
8	Sidmukh Irrigation Canal	Rajasthan	80.0
9	Rewari Irrigation Project	Haryana	32.9
10	Tanda Pump Canal	Uttar Pradesh	32.0
11	Hindon Krishi Irrigation Project	Uttar Pradesh	31.4
12	Deokali Pump Canal	Uttar Pradesh	28.4
13	Ravi Irrigation Canal	Jammu & Kashmir	26.6
14	Adwa Irrigation Canal	Uttar Pradesh	21.8

15	Makhu Canal System	Punjab	20.6
16	Harishchandra Sagar Canal	Rajasthan	18.0
17	Haripur Reservoir	Uttarakhand	11.0
Southern Region			
S. No.	**Projects**	**State**	**CCA (in 000' Ha.)**
1	Hemavathy Irrigation Canal	Karnataka	283.3
2	Tungabhadra Irrigation Canal	Andhra Pradesh	323.8
3	Sri Ram Sagar Irrigation Canal	Telangana	317.1
4	Nagarjuna Sagar Irrigation Canal	Telangana	900***
5	Nagarjuna Sagar RBC Canal	Andhra Pradesh	
6	Nagarjuna Sagar LBC Canal	Andhra Pradesh	
7	Penna Irrigation Project	Andhra Pradesh	24.0
8	Lower Bhavani Irrigation Canal	Tamil Nadu	83.8
9	Kallada Irrigation Project	Kerala	53.6
10	Kuttiyadi Irrigation Project	Kerala	14.6
Eastern Region			
S. No.	**Projects**	**State**	**CCA (in 000' Ha.)**
1	Mayurakshi (JH) Irrigation Canal	Jharkhand	234.0**
2	Eastern Sone Canal Project	Bihar	139.0*
3	Eastern Sone High Level Canal	Bihar	
4	Western Sone and Chausa Command	Bihar	
5	Western Sone High Level Command	Bihar	
6	Hirakud Irrigation Canal	Odisha	157.8
7	Potteru Irrigation Canal	Odisha	61.8
8	Uderusthan Irrigation Canal	Bihar	41.1
9	Sakri Lower Valley Project	Bihar	33.0
10	Ajoy Barrage Irrigation Canal	Jharkhand	22.9
11	Kanchi Irrigation Project	Jharkhand	17.9
12	Ong Diversion Weir	Odisha	9.9
Western Region			
S. No.	**Projects**	**State**	**CCA (in 000' Ha.)**
1	Kakrapar Irrigation Project	Gujarat	204.0
2	Jayakwadi (Stage 1) Project	Maharashtra	183.3
3	Ukai Irrigation Project	Gujarat	127.5
4	Upper Wardha Canal	Maharashtra	83.3
5	Krishna Irrigation Canal	Maharashtra	82.2
6	Girna Irrigation Project	Maharashtra	79.3
7	Shetrunji Irrigation project	Gujarat	57.1
8	Karjan Irrigation Project	Gujarat	51.0
9	Ghod Irrigation Project	Maharashtra	41.5
10	Itiadoh Irrigation Project	Maharashtra	22.8
11	Wan Irrigation Project	Maharashtra	22.5
12	Gangapur Irrigation Project	Maharashtra	21.9
13	Hathmati Irrigation Project	Gujarat	17.5
14	Meshwo Irrigation Project	Gujarat	17.2
15	Salauli Irrigation Project	Goa	14.4

North-Eastern Region			
S. No.	**Projects**	**State**	**CCA (in 000' Ha.)**
1	Jamuna Irrigation Canal	Assam	27.7
2	Loktak Lift Irrigation Canal	Manipur	23.4
3	Integrated Kollang Canal	Assam	21.5

Notes: ***: CCA for Mayurakshi covers all states (WB and Jharkhand)*: CCA for Sone Canal covers all projects of Sone. ***: CCA for Nagarjuna Sagar is combined for both states of Andhra Pradesh & Telangana*

Source: *Data sourced from CWC Publications, DoWR, MoJS (https://nwic.gov.in/)*

3.2 SAMPLING FRAMEWORK AND GIS-BASED VILLAGE SELECTION

To ensure that the study captures the full range of irrigation impacts-both direct and indirect-a Geographic Information System (GIS)-based approach was adopted for selecting villages under each irrigation project. The GIS method enabled accurate identification of command and non-command areas, ensuring a balanced representation across all selected projects.

3.2.1 Command and Non-Command Areas

The study distinguishes between two main categories of villages:

- **Command Area (CMD):** Villages located within the reach of the irrigation network, including main canals, distributaries, and field channels. These villages benefit directly from canal irrigation and are expected to experience improvements in agricultural productivity, income, and livelihood opportunities.
- **Non-Command Area (NCMD):** Villages situated outside the influence of the canal system. These rely primarily on rainfall or groundwater for cultivation, and serve as control villages to assess irrigation impacts relative to non-irrigated conditions.

3.2.2 Development of a Project-Wise Village Database

A comprehensive project-wise village database was developed by integrating information from multiple sources - Census 2011 village directories, Central Water Commission project documents, and GIS layers showing administrative boundaries, reservoir locations, canal alignments, and drainage networks.

This integrated spatial database enabled precise mapping of each irrigation project's area of influence, allowing accurate classification of villages into command and non-command categories. The approach ensured consistency, comparability, and spatial accuracy across all 57 selected irrigation projects.

3.2.3 GIS Methodology for Village Selection

The village selection process involved several steps using GIS tools and datasets:

1. **Mapping Project Boundaries:** Official shapefiles and maps provided by the CWC and State Irrigation Departments were used to delineate command area boundaries for each project. These boundaries defined the zones directly benefitting from canal irrigation.
2. **Overlay of Census Villages**: The Census 2011 village boundary layer was superimposed on project maps to identify which villages fall within (command) or outside (non-command) the canal service area.
3. **Zoning Within Command Areas:** To capture variations in irrigation intensity and water access, command areas were divided into three zones -— head, middle, and tail — corresponding to the starting, middle, and end stretches of the canal system. This zoning ensured representation of areas with differing water availability.
4. **Selection of Command Villages:** From each irrigation project, eight villages were selected within the command area - typically distributed as three from the head, three from the middle, and two from the tail zone. In cases where a middle zone was absent, five villages were selected (three from the head and two from the tail).

5. **Selection of Non-Command Villages:** For each project, four non-command villages were selected based on distance criteria. These villages were located at least 15 km and at most 50 km away from the nearest command village. The minimum distance avoided spillover or indirect benefits from irrigation, while the maximum distance ensured similarity in agro-climatic and socio-economic characteristics.

6. **Field Verification:** The list of GIS-identified villages was shared with state-level agencies and designated nodal officers for field verification. The nodal officers validated whether command villages indeed received canal irrigation and that non-command villages were outside the irrigated zone.

Based on their feedback, necessary corrections were made to account for any discrepancies between mapped and actual boundaries.

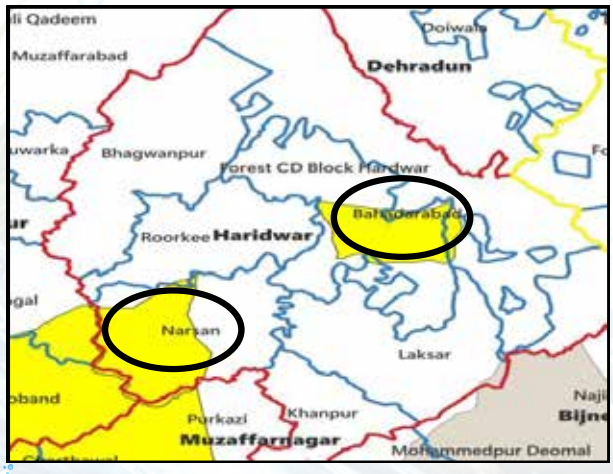
The final list of sample villages, verified and approved by the nodal officers, served as the foundation for household and stakeholder surveys. This spatially robust and field-validated methodology ensured accurate and representative coverage of diverse irrigation contexts across all regions. A final list of selected command and non-command villages is given in Annexures A3.1.1 and A3.1.2.

3.2.4 Illustration Sample

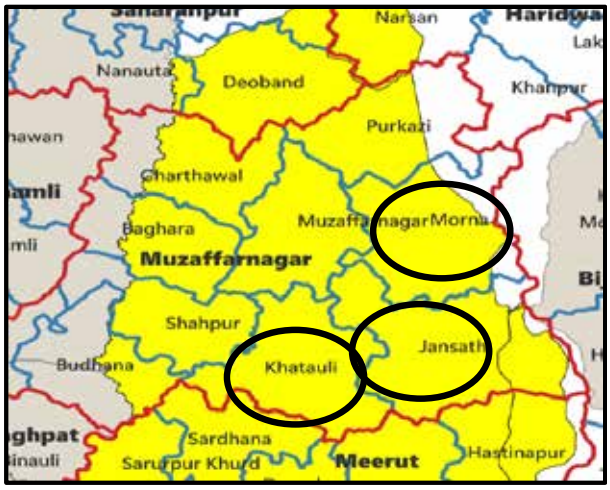
GIS Screenshots for the Upper Ganga Irrigation Project: For reference, GIS screenshots for the Upper Ganga Canal irrigation project are attached here to provide a visual representation of the block and village selection process.

3.2.4.1 Example of the Upper Ganga Irrigation Project

A. Block shelection

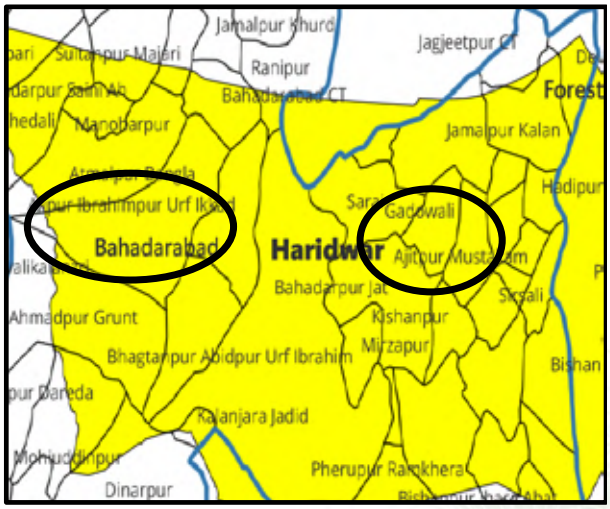


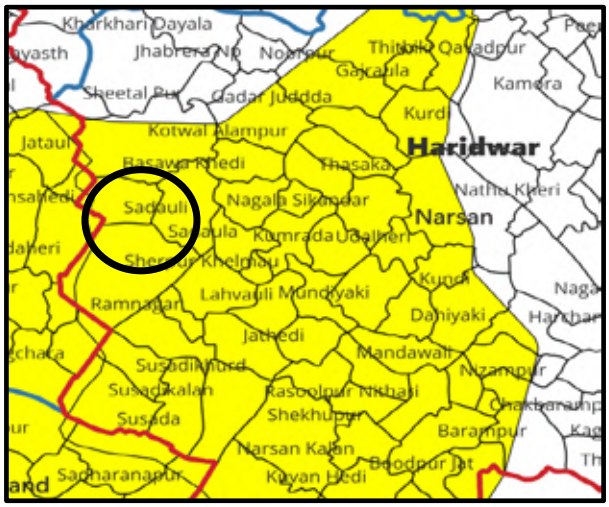
Head District	
District	**Block**
Haridwar	Narsan
Haridwar	Bahdrabad



Middle District	
District	**Block**
Muzaffarnagar	Khatauli
Muzaffarnagar	Jansath
Muzaffarnagar	Morna

B. Command village selection

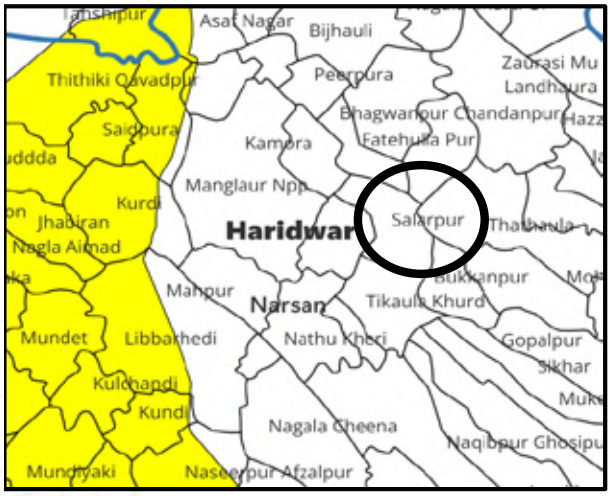


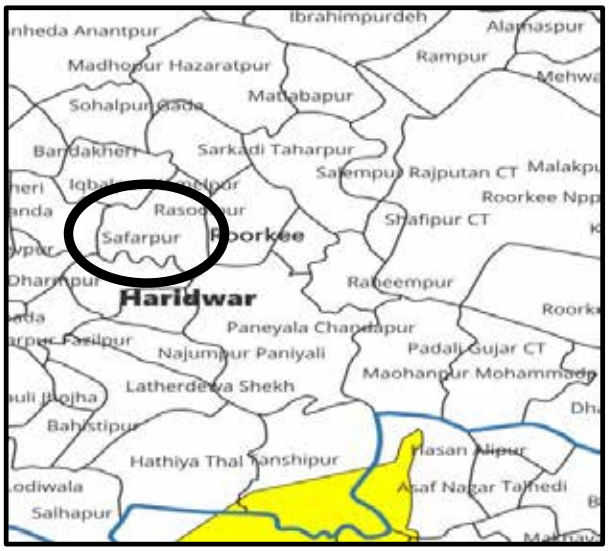


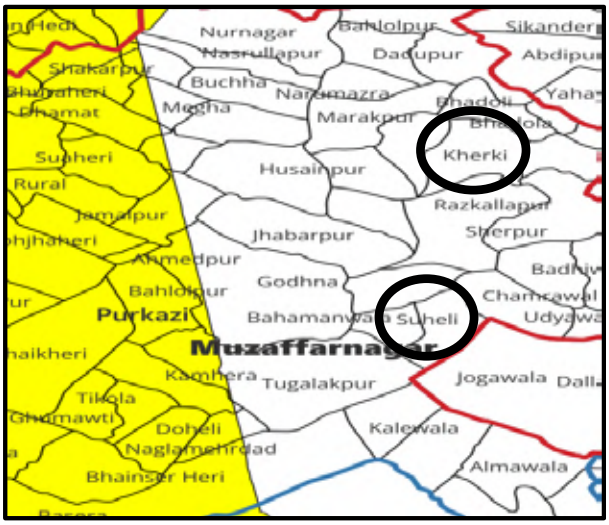
Head Villages	
Block	**Village**
Narsan	Sadauli
Bahdrabad	Alipur Ibrahimpur
Bahdrabad	Gadowali

Tail Villages	
Block	**Village**
Firozabad	Nargapur
Shikohabad	Indumai

C. Non-Command village selection







Non-Command Villages	
Block	**Village**
Narsan	Salarpur
Roorkee	Safarpur
Purkasi	Suheli
	Kherki

3.3 HOUSEHOLD LISTING AND SAMPLING STRATEGY

After finalising the selection of the project (command) and control (non-command) villages, the next stage involved household-level sampling to assess the indirect and intangible benefits of irrigation. A two-step procedure was followed: (i) a village-level listing exercise; and (ii) a stratified random selection of households.

3.3.1 Listing Exercise

Before starting the household survey, a comprehensive listing exercise was conducted in each selected village to prepare an updated sampling frame. Enumerators listed all resident households, noting key information such as:

- Land ownership and operational holding size,
- Primary occupation and income source,
- Gender of the household head, and
- Social category (SC/ST, OBC, General).

This detailed listing ensured that the household selection reflected the true structure of the village economy and livelihood conditions.

3.3.2 Household Stratification

Based on the household listing data, households in the study area were stratified into four categories representing differences in landholding size, livelihood strategies, and potential patterns of water use:

Landless laborers, who owned no agricultural land and were primarily dependent on agricultural wage labour;

Marginal farmers, owning less than 1 hectare (<2 acres) of agricultural land;

Small farmers, owning between 1 and 2 hectares (2–5 acres) of land; and

Medium and large farmers, owning more than 2 hectares (>5 acres) of land.

Study also selected Women-Headed Households, regardless of land size.

This landholding-based stratification ensured that the sample captured the major agrarian groups within the village, which differ in their access to productive resources, farming practices, and likely interaction with irrigation systems.

Women-headed households were not treated as a separate sampling stratum. Instead, such households were considered a cross-cutting household characteristic, as they may occur within any of the landholding categories described above. During the listing process, women-headed households were identified in order to ensure that they were not inadvertently excluded from the sample.

For the household survey, a total sample of 20 households was selected from the four strata. The sample design aimed to include 16 male-headed households and 4 female-headed households to ensure that households headed by women were represented in the study. However, the primary objective of the survey was not to conduct gender-specific or gender-disaggregated statistical analysis. Rather, the inclusion of female-headed households was intended to ensure that the diversity of household structures present in the village was reflected in the sample.

Female-headed households were therefore selected from within the existing landholding strata wherever possible. In cases where female-headed households were not available within a particular category, they were replaced by male-headed households from the same stratum, while maintaining the overall sample size of 20 households.

3.3.3 Social Representation

To ensure social inclusiveness, households from Scheduled Castes/Scheduled Tribes (SCs/STs), Other Backward Classes (OBCs), and General categories were proportionately represented within each stratum. Higher selection weights were assigned to SC/ST households to capture their livelihood improvements under irrigation projects, while OBC and General households were limited to one each per stratum for balanced representation.

Household is defined as a group of persons usually living together and sharing meals from a common kitchen[19]. It includes temporary stay-aways (with an expected absence of less than six months) but excludes temporary visitors and guests. Unrelated individuals living in the same dwelling but not sharing a common kitchen were not treated as a household.

3.3.4 Sample Selection

The final sampling of households was carried out randomly within each stratum:

- In project (command) villages, four households per stratum were selected, resulting in 20 households per village. These households were interviewed in detail to assess irrigation-related improvements in water security, agriculture, income, and livelihoods.

[19]Household Definition, MoSPI

- In control (non-command) villages, two households per stratum were sampled, making 10 households per village. These served as comparison groups to evaluate the differential effects of irrigation.

This design ensured that the analysis could effectively compare households exposed to irrigation benefits with those in non-irrigated conditions.

Box 3.1: Why un-weighted income estimation

In principle, income estimates for the entire command area should be scaled using an area-based weight derived from the Cultural Command Area (CCA). Multiplying the total income of households in the sample villages by this weight yields an estimate of the overall income in the command area. This weight is given by:

Weight = Total CCA of the project / Area of the sampled villages

And,

Estimated total income = Total village income × Weight

However, the study focuses on average household income rather than total income. To compute the average household income within the CCA, the estimated total income derived above must be divied by the estimated number of households within the CCA. Total households within the command area can, in turn, be computed by multiplying the same CCA based weight to the total number of households within the sampled villages.

Estimated total households within the CCA = Total households in sample villages × Weight

But, when both total income and total households are scaled using the same weight, the weight cancels out. Mathematically the same can be illustrated as:

Average income per household = Total village income × weight /Total sample households ×weight

Therefore, the average household income calculated from the sampled villages remains unchanged, even if the estimates were scaled to the full command area. For this reason, additional weighting was not required for estimating average household income.

Furthermore, for non-command areas, no equivalent irrigated boundary such as the CCA exists. The objective was therefore to estimate the average household income under non-irrigated conditions rather than to scale income to a defined geographical area. Accordingly, average income was calculated directly from the surveyed households in the four control villages. This approach ensures a consistent and unbiased comparison between command and non-command areas while maintaining methodological simplicity and transparency.

3.3.5 Summary of Household Selection and Total Sample Size

Table 3.2.1: Selection criteria of sample households through listing

Strata	Government Definition (Hectares)	SC/ST	OBC	General	Total per Project Village	Total per Control Village
Landless Labourers	Not applicable	2	1	1	4	2
Marginal Farmers	< 1 hectare	2	1	1	4	2
Small Farmers	1 – 2 hectares	2	1	1	4	2
Medium & Large Farmers	> 2 hectares	1	1	2	4	2
Total per Village	—	**7**	**4**	**5**	**16**	**8**

Table 3.2.2: Additional gender representation

Category	Number per Project Village	Number per Control Village
Women-Headed Households*	4	2

Table 3.2.3: Final sample per village

Type	Households
Project (Command) Village	20
Control (Non-Command) Village	10

Note: ** Women-headed households were treated as a cross-cutting analytical category rather than a mutually exclusive stratum. Such households may belong to any landholding category. To ensure adequate gender representation, women-headed households were purposively included within the sampled households across strata.*

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Table 3.3: Total sample size of the study

S. No.	Parameter	Total
1	No of Irrigation Projects	57
2	Total Villages	594
3	Total Command Villages	366
4	Total Non-Command Villages	228
5	Total Command Villages Households	7,320
6	Total Non-Command Villages Households	2,280
7	Total Households	9,600

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

3.4 WHY IS THE COMMAND-AREA SAMPLE SUBSTANTIALLY LARGER THAN THE NON-COMMAND SAMPLE?

The study adopted a stratified sampling framework within the command area to adequately capture spatial variations in the benefits arising from irrigation interventions. For larger irrigation projects, eight command villages were selected, comprising three villages from the head region, three from the middle region, and two from the tail region of the canal system. For smaller projects, five command villages were selected, consisting of three villages from the head region and two from the tail region. A uniform sample of 20 households was surveyed in each selected village, resulting in a total command-area sample of 160 households for larger projects and 100 households for smaller projects.

For comparative purposes, four non-command villages were selected for each irrigation project, with 10 households surveyed in each village. This resulted in a total non-command sample of 40 households per project, which served as the benchmark against which outcomes observed in the command area were assessed.

The rationale for adopting this differentiated sampling framework is summarised below.

1. **Need to Capture Spatial Heterogeneity within Command Areas**

   A key objective of the study was to assess how the indirect and intangible benefits of irrigation vary across different sections of the canal system. Since irrigation performance and associated socio-economic outcomes often differ between the head, middle, and tail reaches of a canal network, it was necessary to ensure adequate representation from each of these sub-regions. Consequently, a larger sample was allocated to command villages to facilitate meaningful comparisons across these distinct geographical segments.

2. **Greater Analytical Focus on Irrigation-Induced Benefits**

   The principal objective of the study was to assess and quantify the indirect benefits arising from irrigation interventions. Since such benefits are expected to accrue predominantly within command areas, a larger share of the sample was intentionally allocated to command villages to enable more robust estimation of irrigation-induced outcomes and to capture variations across different beneficiary groups.

3. **Role of the Non-Command Area as a Comparison Group**

   The non-command area primarily serves as a counterfactual or comparison group against which outcomes in the command area can be benchmarked. Accordingly, while sufficient observations were collected to establish a reliable reference baseline, a substantially larger sample in the non-command area was not necessary for achieving the objectives of the study. Instead,

survey resources were allocated in a manner that maximised analytical depth within the command area while maintaining an adequate comparison group.

4. **Efficient Allocation of Survey Resources**

   The adopted sampling allocation is consistent with the principle of efficient resource utilisation in impact evaluation studies. Given that the command area was further stratified into multiple analytical categories (head, middle, and tail reaches), additional observations were required to support disaggregated analysis. In contrast, the non-command area was intended primarily to provide a reference benchmark and did not require a comparable level of stratification. The resulting allocation therefore achieved an appropriate balance between statistical efficiency, analytical requirements, and resource constraints.

5. **Adequacy of the Non-Command Sample for Comparative Analysis**

   Although smaller in absolute size, the non-command sample remained sufficiently large to provide a stable and reliable benchmark for comparative assessment. The sampling design ensured that adequate observations were available to establish counterfactual conditions and facilitate meaningful command–non-command comparisons across all study indicators.

Implications for Composite Index Estimation

The implications of this sampling design can be illustrated through the composite index methodology, which compares the proportion of command and non-command households across ten distinct indicators. Since the non-command sample comprises 40 households, each respondent influences the estimated proportion by 2.5 percentage points (1/40), whereas each respondent in the command sample of 160 households influences the corresponding proportion by only 0.625 percentage points (1/160).

Consequently, changes in responses among non-command households are more readily reflected in the benchmark proportions used for comparison. This feature ensures that the outcomes observed in the comparison group remain clearly visible in the analytical framework and provides a transparent basis for evaluating differences between command and non-command areas.

Overall, the adopted sampling design reflects the dual objectives of the study: (i) generating a sufficiently detailed understanding of irrigation-induced impacts within command areas, including variations across the canal system, and (ii) maintaining an adequate and reliable non-command benchmark for comparative analysis. Similar disproportionate sampling allocations are commonly employed in impact assessment studies where the treatment group is stratified into multiple analytical categories, while the comparison group is intended primarily to serve as a reference baseline.

3.5 QUESTIONNAIRE SCOPE AND DESIGN

The primary survey was implemented using a comprehensive set of pre-tested questionnaires administered across multiple stakeholder levels to ensure representativeness and depth. Data were elicited from beneficiary households, villages heads, and project management functionaries, enabling triangulation of perspectives from end-users and implementing agencies. To capture the full spectrum of irrigation impacts, distinct survey instruments were deployed for different respondent categories, including:

1. Village Schedule Questionnaire, to collect contextual information on infrastructure, demographics, and public services (questionnaire references are given in Annexure A3.2);
2. Listing Questionnaires, to generate household rosters for stratified sampling and ensure representation across social and landholding categories (questionnaire references are given in Annexure A3.3);
3. Questionnaires for Officials, focusing on governance mechanisms, project implementation processes, and fund utilisation (questionnaire references are given in Annexure A3.4).
4. Command and Non-Command Household Questionnaires, designed to facilitate household-level comparisons between beneficiary and control areas under the 'with-and-without' framework (questionnaire references are given in Annexures A3.5 and A3.6); and
5. Focused Group Discussion (FGD) Questionnaires, conducted specifically in command areas to explore community-level

perceptions, institutional participation, and qualitative dimensions of change (questionnaire references are given in Annexure A3.7).

The use of this multi-instrument design allowed for a holistic and layered understanding of irrigation outcomes—capturing not only the quantifiable economic benefits experienced by households but also the less tangible improvements in social cohesion, local governance, environmental conditions, and community well-being. This methodological architecture thus ensured that the assessment of irrigation projects extended beyond conventional performance metrics to encompass their broader developmental significance.

3.6 CONCLUDING REMARKS

This chapter has outlined the sampling design and data collection framework adopted for the study. A multi-stage stratified sampling approach was used to ensure that the selected irrigation projects, villages, and households adequately represent the diversity of irrigation systems across India. At the first stage, irrigation projects were selected from the national database provided by the Central Water Commission using stratification based on project size (Cultural Command Area) and period of completion, followed by a circular systematic Probability-Proportional-to-Size selection procedure. This ensured representation of irrigation systems of different scales as well as projects developed across different phases of India's irrigation expansion.

At the second stage, a GIS-based methodology was used to identify and select command and non-command villages within each project area. This spatial approach ensured balanced representation across head, middle, and tail reaches of canal systems, while control villages were selected outside the command influence zone to facilitate robust with-and-without comparisons.

Finally, at the household level, a structured listing and stratified sampling process was implemented to capture variations across landholding categories, social groups, and gender dimensions. The resulting sample of 9,600 households across 594 villages provides a comprehensive and geographically diverse dataset for analysing the indirect and intangible benefits of irrigation projects.

Together, this integrated sampling framework ensures statistical robustness, spatial representativeness, and socio-economic diversity, thereby providing a strong empirical foundation for the subsequent analysis presented in the following chapters.

CHAPTER 4

Impact of Irrigation Projects on Rural Livelihoods: A With–Without Comparative Perspective in a Geo-Physical and Socio-Economic Framework

4.1 BACKGROUND AND CONTEXT

The present study on the impact of irrigation adopts a 'with-and-without' analytical framework, a robust approach widely used in development evaluation to capture the differential outcomes attributable to project interventions. Under this framework, while command areas represent the 'with-project' scenario, non-command areas serve as the 'without-project' or baseline control, thereby offering a realistic cross-sectional assessment of irrigation's incremental contributions to rural development in the absence of any baseline data.

In an ideal scenario, impact evaluation studies typically employ the difference-in-differences (DID) method, which requires four sets of data: pre-intervention, post-intervention, intervention area, and control (non-intervention) area. However, in this case, the projects were implemented several decades ago, during the 1950s and 1960s, resulting in a very long recall period. Due to this limitation, the DID approach was not feasible for the present study. Instead, a 'with–without' comparison was found to be the most appropriate method. By systematically comparing outcomes between command and non-command areas, the study presents a comprehensive and evidence-based understanding of irrigation's multifaceted impacts—economic, social, and environmental.

The comparison of parameters between command and non-command regions may not exclusively represent the impacts of the irrigation projects in the region, as it includes the impacts of external factors as well. However, to control this limitation to the maximum extent possible, the questions have been framed in such a way that they capture the changes in various scenarios due to the presence of irrigation projects in command areas and the absence of irrigation projects in non-command areas. The exclusive impacts of irrigation projects on intangible benefits are discussed in Chapter 5.

With this background, the present chapter seeks to empirically examine whether and to what extent such differences exist across command and non-command regions, and how irrigation contributes to broader socio-economic outcomes such as education, healthcare access, women's participation, and migration patterns. The latter part of the chapter delves into project-wise comparisons, offering a granular view of how irrigation interventions perform across diverse agro-climatic and socio-economic contexts.

Collectively, the findings underscore the transformative potential of irrigation infrastructure, not merely as an agricultural input but as a catalyst for holistic rural development. Improved water management, when coupled with institutional and community-level participation, emerges as a cornerstone for achieving sustainable growth, poverty reduction, and social inclusion in India's agrarian landscape.

4.2 COMPARATIVE ASSESSMENT BETWEEN COMMAND AND NON-COMMAND AREAS

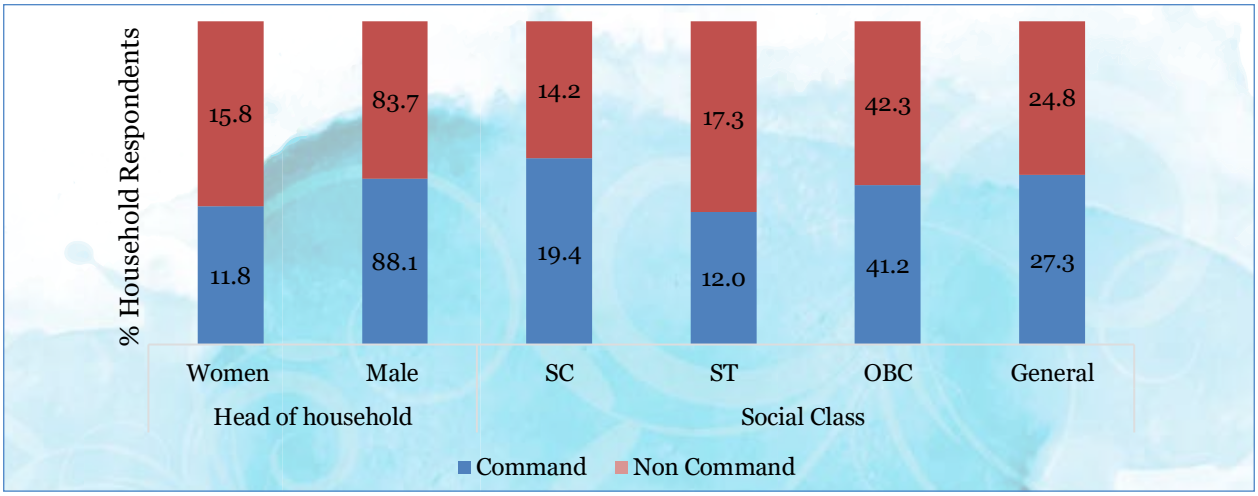
4.2.1 Household Social Profile

In command areas where irrigation infrastructure is in place, there are improvements in various socio-economic indicators.

The gender profile for head of the households in command areas shows a higher proportion of males—by about 4.4 per cent—compared to non-command areas (Figure 4.1).

The social composition indicates that the share of Scheduled Castes (SCs) and General category respondents is slightly higher in command areas, whereas the proportion of Scheduled Tribes (ST) and Other Backward Classes (OBC) is relatively lower (Figure 4.1).

Figure 4.1: Distribution of respondent households (%) by social characteristics

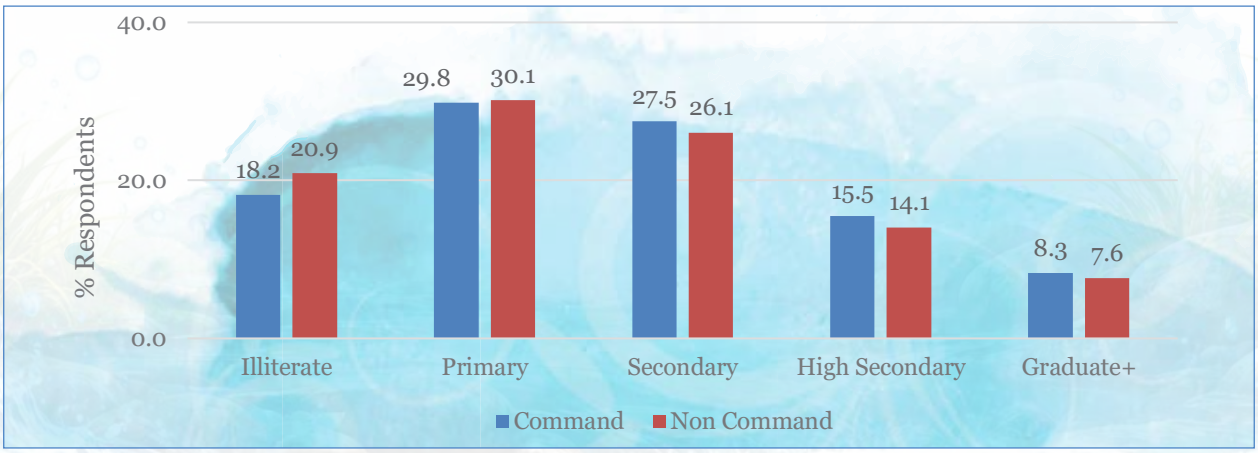


Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to assess Indirect Benefits of Irrigation Projects*, 2025

In terms of educational profile, command areas have fewer respondents in the categories of illiteracy and primary education, and a slightly higher proportion with secondary and above education levels compared to non-command areas (Figure 4.2).

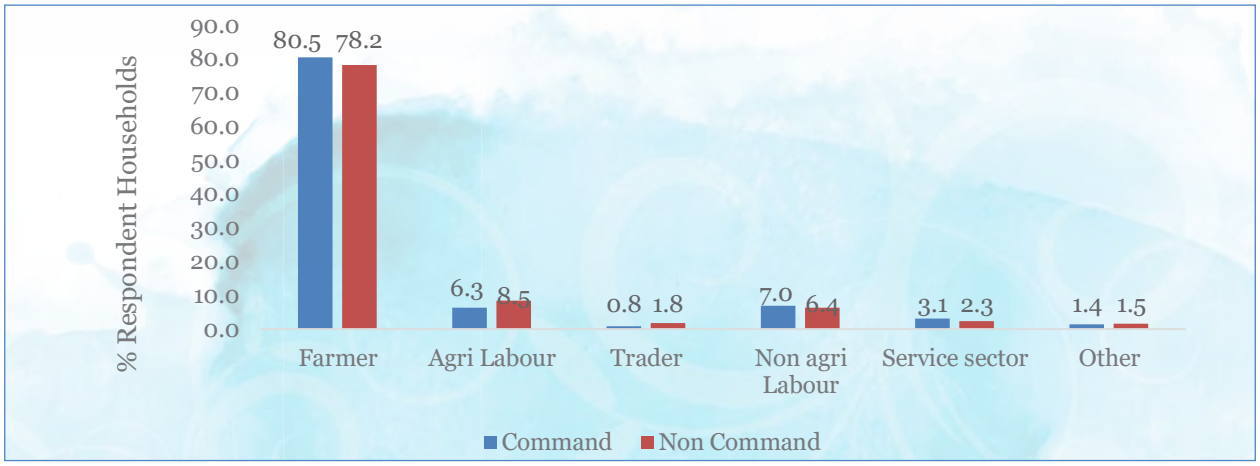
The livelihood profile reveals that the proportion of agricultural labourers, traders, and others is lower in command areas, while the share of farmers, non-agricultural labourers, and those employed in the service sector is somewhat higher (Figure 4.3), showing better educational outcomes, with higher literacy rates and access to schooling.

Figure 4.2: Distribution of respondent households (%) by highest educational attainment



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Figure 4.3: Distribution of respondent households (%) by source of earning

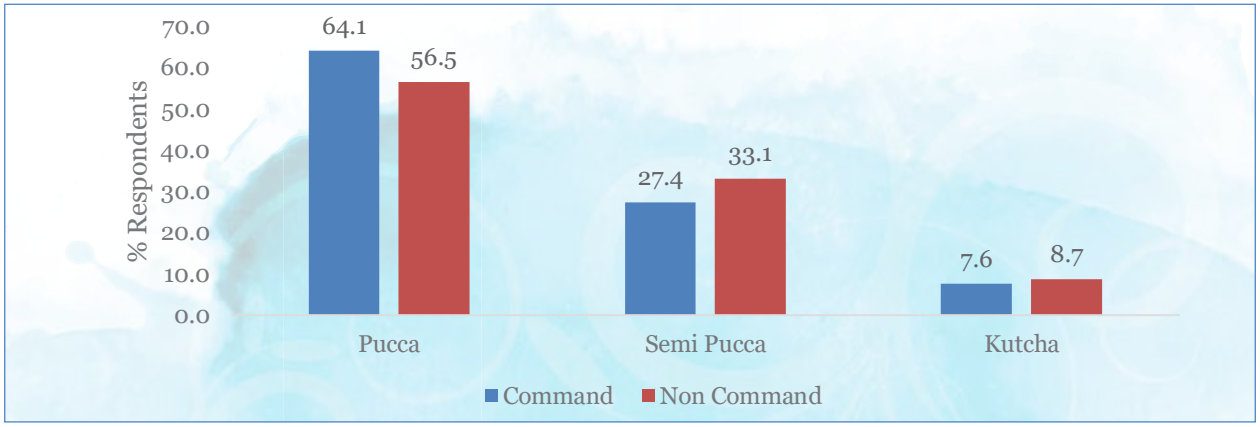


Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Note: "Agriculture" includes crop cultivation and allied farm activities; "Trade" refers to small-scale buying and selling activities including retail and wholesale; "Services" include wage employment and self-employment in non-trade services such as transport, construction, repair services, education, and personal services; "Others" include pensions, remittances, and miscellaneous sources. Responses are based on households' primary source of earning.

Housing conditions in command areas are noticeably better than in non-command areas, showing a lower proportion of semi-pucca and kutcha houses, with a relatively higher proportion of pucca houses compared to non-command areas (Figure 4.4).

Figure 4.4: Distribution of respondent households (%) by type of house



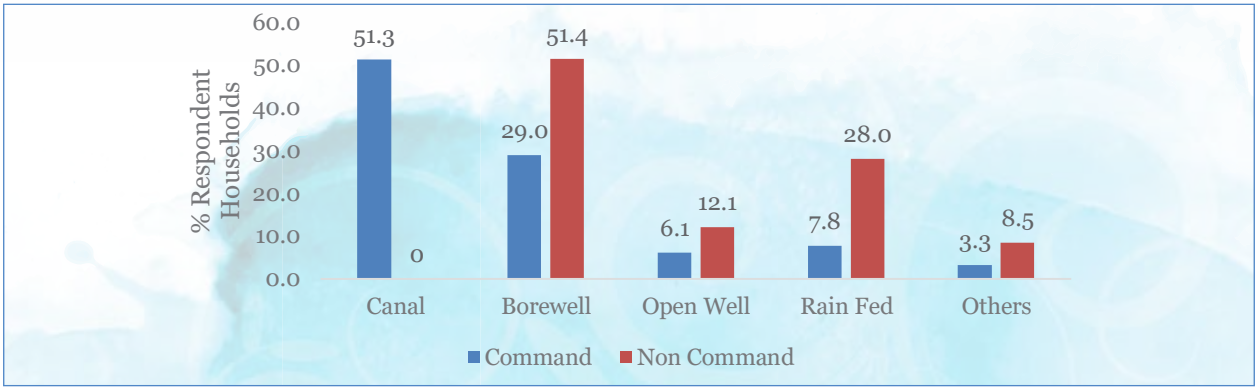
Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

These findings suggest that irrigation, while primarily intended to support agriculture, also plays a significant role in supporting social empowerment, with positive indirect effects on education, housing quality, and women's empowerment, contributing to an overall improvement in the quality of life across all social and economic categories.

4.2.2 Land and Irrigation

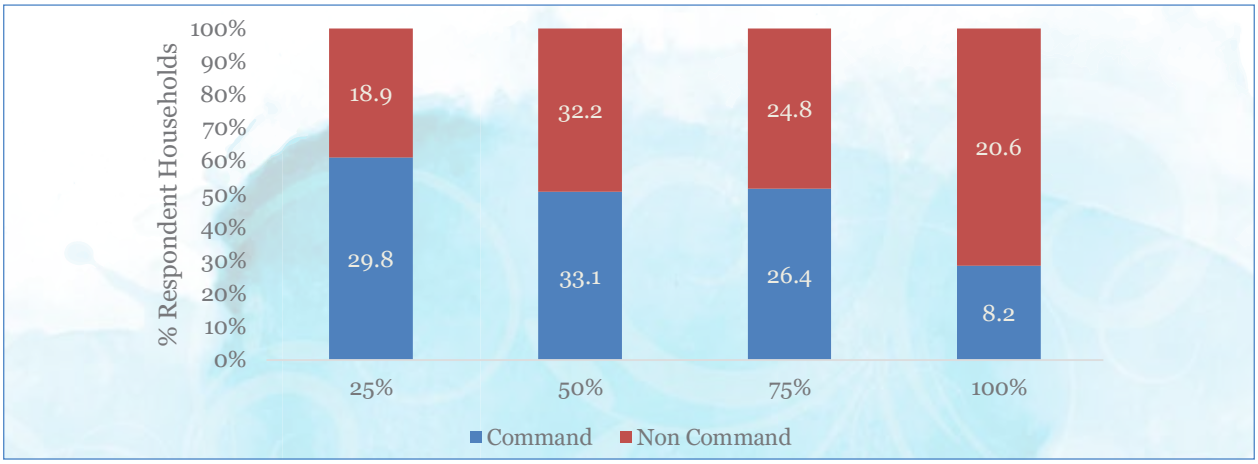
In non-command areas, the majority of farmers are more dependent on borewells and rainfall, whereas the majority of farmers in command areas are more dependent on canal water and borewells, and far less on rainfall, and thus face no uncertainty of irrigation water (Figure 4.5). Among those who are dependent on rainfall for agriculture, the extent of dependence is higher in the case of non-command areas, where more than 45 per cent of households have mentioned that the extent of their dependence on rainfall is up to 75 per cent and above. This proportion is nearly one-third in command areas (Figure 4.6).

Figure 4.5: Distribution of respondent households (%) by type of irrigation facilities used



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

Figure 4.6: Distribution of respondent households (%) by dependence on rainfall for agriculture

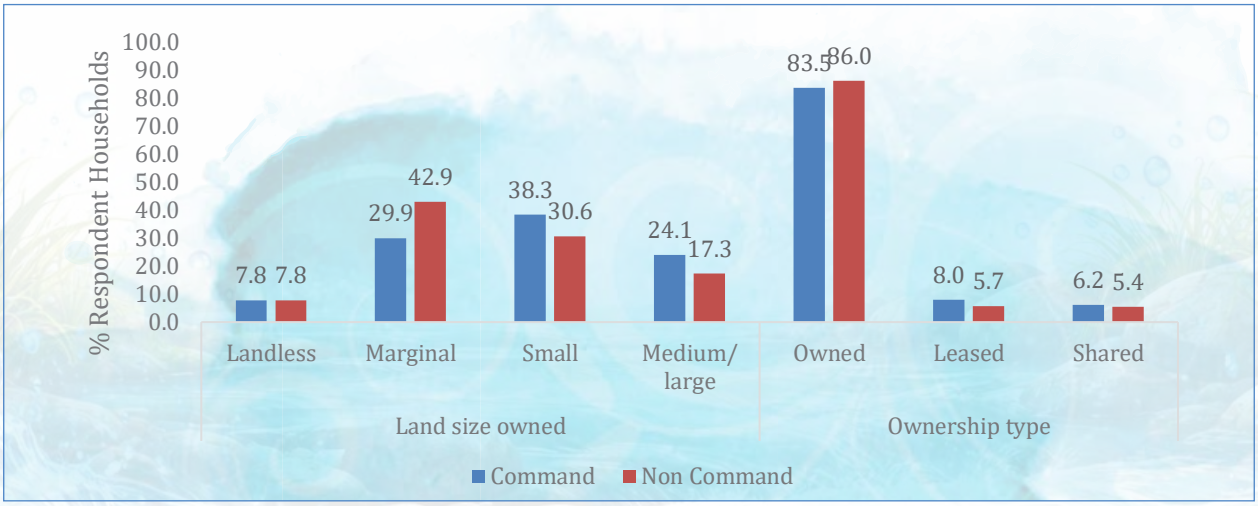


Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Furthermore, 43 per cent of farmers in non-command areas are marginal, cultivating smaller landholdings, which make them more vulnerable to climatic variations and agricultural uncertainties.

In contrast, command areas show a shift towards a higher proportion of small and medium/large farmers (Figure 4.7).

Figure 4.7: Distribution of respondent households (%) by size of land owned and ownership type



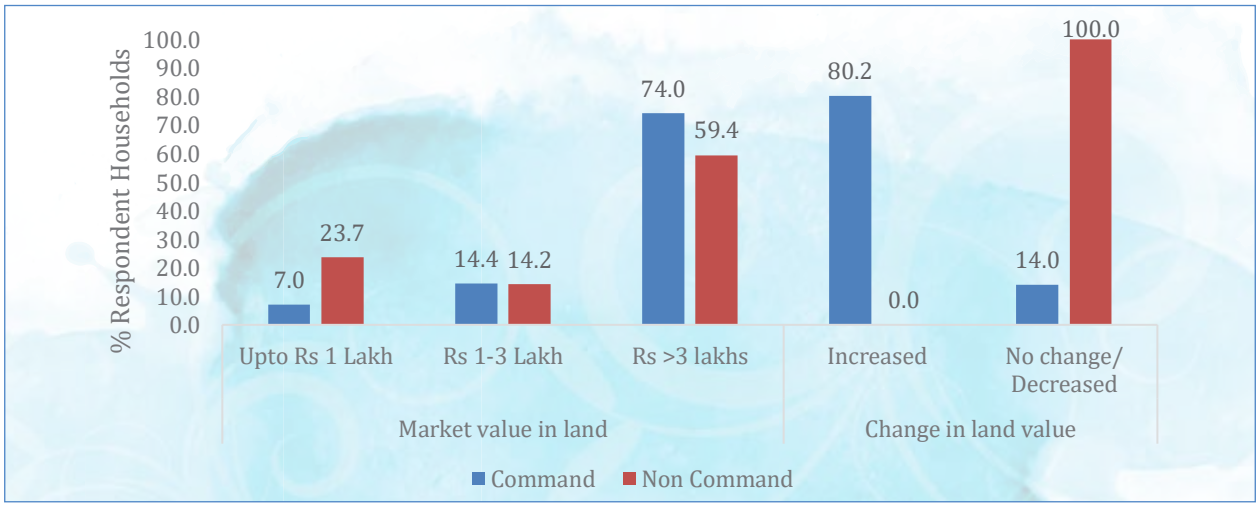
Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to assess Indirect Benefits of Irrigation Projects*, 2025

Overall, irrigation access has effectively transformed farming conditions, moving farmers away from vulnerable rainfed or marginal agricultural systems to more secure, irrigated systems that allow for greater land-use efficiency and diversification of irrigation methods.

4.2.3 Economic Outcomes

The economic impact of irrigation is starkly illustrated when comparing land and income values between command and non-command areas. In non-command areas, land values are typically low, with 38 per cent of households reporting land values below Rs. 3 lakh (Figure 4.8). Agricultural productivity in these areas is in decline, with 70 per cent of farmers experiencing reduced yields (Figure 4.9). Additionally, 67 per cent of households report a decline in income, reflecting the negative economic spiral caused by low productivity and poor market linkages.

Figure 4.8: Distribution of respondent households (%) by market value of land and change in land value



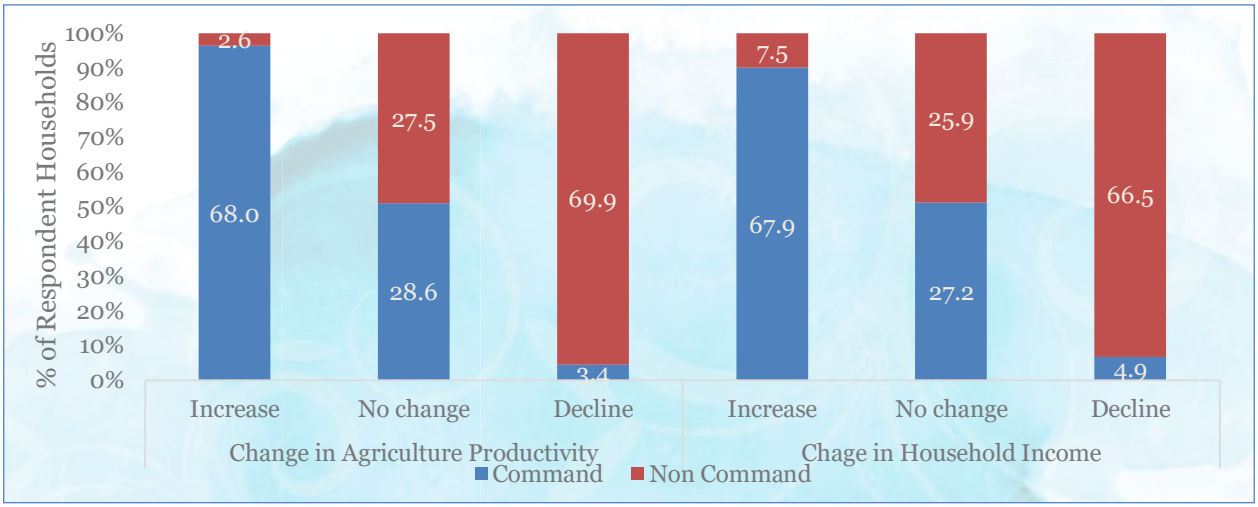
Note: *Cases where the total percentage does not equal 100 are due to non-responses*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

On the other hand, command areas show significant improvements in land values, with 74 per cent of households reporting land values greater than Rs. 3 lakhs. Irrigated land sees further value increases, with 80 per cent of households in command areas reporting rising land values. Productivity also shows a marked improvement, with 68 per cent of farmers in command areas experiencing higher yields, and 68 per cent of households reporting increased incomes (Figure 4.9). Among those households which mentioned increased agriculture productivity in command areas, for nearly half of them this increase is between 11-20 per cent, while for another 30 per cent it is above 20 per cent. In contrast, in non-command areas, among those households which mentioned a decline in agriculture productivity, for 76 per cent of them the decline is moderate (between 20-50%), for the remaining it is above 50 per cent. These statistics demonstrate the powerful economic boost that irrigation can provide, increasing both the land's financial value and the income of farming households.

These results are broadly consistent with the earlier impact evaluation study conducted by DMEO and IIM Lucknow for the Programme Evaluation Organization (PEO) of the Planning Commission, which confirms that assured irrigation plays a transformative role in improving agricultural productivity, household incomes, and overall rural development. Supporting evidence from Hussain and Hanjra (2003)[20] similarly indicates that access to irrigation increases farmers' production by raising crop yields through a more reliable and stable water supply. Irrigation enables farmers to shift from traditional subsistence crops to more market-oriented varieties, thereby fostering agricultural diversification (Binswanger & Von Braun,[21] 1991; Smith, 2004[22]).

[20]https://iwaponline.com/wp/article-abstract/5/5-6/429/19637/Does-irrigation-water-matter-for-rural-poverty?redirectedFrom=fulltext
[21]https://documents1.worldbank.org/curated/en/966261468739230729/pdf/multi-page.pdf
[22]https://exaly.com/paper-pdf/37317063/citation-report.pdf

Figure 4.9: Distribution of respondent households (%) by agricultural productivity and change in household income



Source: *NCAER Study to assess Indirect Benefits of Irrigation Projects*, 2025

Irrigation projects directly contribute to wealth creation and economic resilience, enhancing agricultural productivity and significantly raising land and income values in comparison to outcomes in non-command areas.

4.2.4 Market and Business Linkages

The presence or absence of irrigation infrastructure also plays a crucial role in market linkages and rural enterprise development. In non-command areas, farmers face weak market connections and a declining farm business environment, and 100 per cent of the households' report shrinking employment opportunities against seven per cent in command areas (Table 4.1). These findings suggest that without access to irrigation, agricultural productivity stagnates, making it difficult for farmers to engage in larger markets or expand their businesses.

Conversely, command areas show a notable improvement in market linkages, with 76 per cent of farmers reporting better access to markets against 28.7 per cen in non-command area. This enhanced connectivity is critical for integrating farmers into broader supply chains and improving profitability. It has resulted in 33 per cent of farmers reporting business improvements, and 52 per cent seeing an increase in employment opportunities. Figure 4.10 indicates that about half the respondents perceive that input markets (for seeds, fertiliser, equipment, etc.) have developed in the area, and 37 per cent have even mentioned the development of agro-processing units in the region. This demonstrates that irrigation projects help connect farmers to markets, foster rural entrepreneurship, and create new jobs and business opportunities, in contrast to the stagnation observed in non-command areas.

The findings indicate that irrigation facilitates stronger market connections and supports rural business development, providing greater economic opportunities and reducing rural poverty. The findings are in line with the available literature that gives evidence of the benefits of irrigation in terms of increased market access (Gidwani, 2002[23], and increased demand for labour resulting in higher wages (Narayanamoorthy & Deshpande, 2003; Von Braun, 1995).

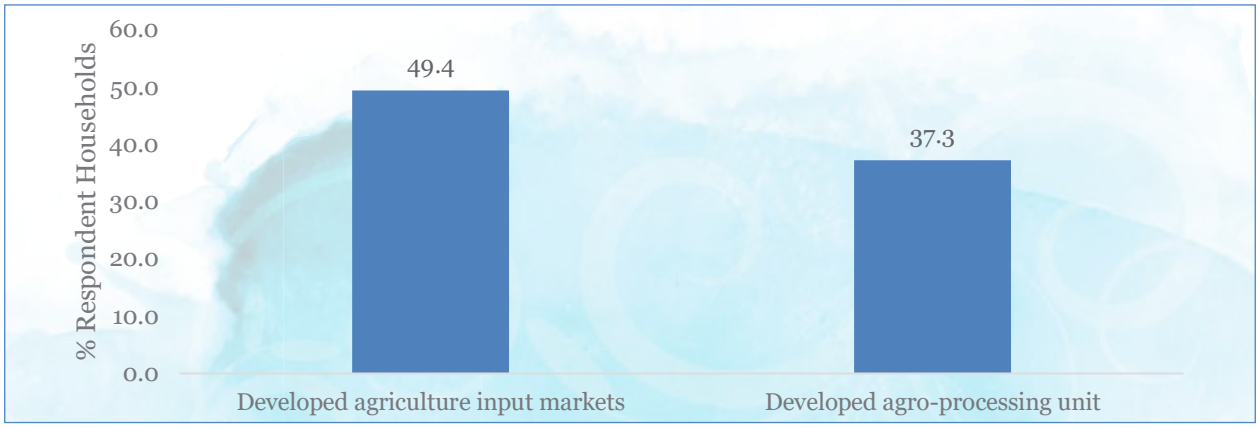
[23]https://www.sciencedirect.com/science/article/abs/pii/S030590060200017X

Table 4.1: Distribution of respondent households (%) by market and business linkages

	Command	Non-Command
Market Linkages		
Increased linkage	76.4	28.7
Declined linkages	20.0	68.3
Limited bargaining	3.7	3.0
Employment Opportunities		
Increase	51.9	0
No change	40.7	0
Decline	7.4	100
Impact on Farm Business		
Improved	32.6	1.4
Improved but limited	26.2	25.3
No change	34.8	34.4
Decline	4.1	38.9
Total	**100.0**	**100.0**

Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Figure 4.10: Distribution of respondent households (%) by development of agriculture input markets and agro-processing units in command areas

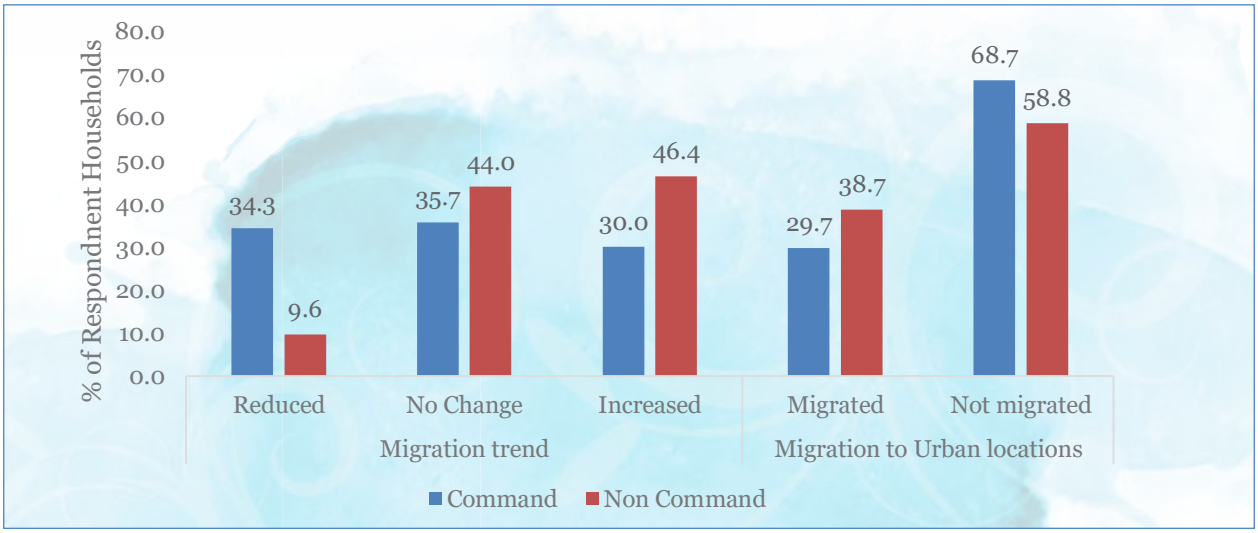


Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

4.2.5 Migration and Livelihoods

Migration patterns offer further insight into the socio-economic impacts of irrigation. In non-command areas, 46 per cent of households' report increasing migration, with urban migration being particularly high (39%) (Figure 4.11). This is indicative of distress migration, where households are forced to move due to limited agricultural opportunities and lack of employment in rural areas. Non-agricultural jobs are often negative or limited in these regions, pushing many to migrate in search of better livelihoods.

Figure 4.11: Distribution of respondent households (%) by migration trends



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

However, in command areas, the trend is reversed. Migration decreases to 34 per cent, as irrigation provides more stable and diverse livelihood opportunities. The study conducted by DMEO and IIM Lucknow also indicates a reduction in migration and an increase in nonfarm activities in some states due to irrigation projects.[24] The presence of irrigation has also fostered the development of non-agricultural businesses and improved local economic conditions, further reducing the need for rural populations to migrate (Table 4.2). Contribution in terms of jobs creation in non-agricultural sectors and local agri-business development have been reported at 30 per cent and 40 per cent, respectively, in command areas, compared to 17 per cent and 32 per cent, respectively, in non-command areas.

Table 4.2: Distribution of households (%) by opportunities in non-agriculture and agriculture business development

Indicators	Command	Non-Command
Job opportunities in non-agriculture		
New business and service sectors	30.2	17.4
Non-agriculture jobs	28.3	30.2
No impact	36.5	40.2
Negative impact	2.5	9.3
Contribution to local agri-business development		
Contributed	39.6	32.0
No contribution	58.6	68.0
Total	**100.0**	**100.0**

Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Irrigation plays a key role in reducing distress migration, providing rural communities with better livelihood options and helping to diversify income sources beyond agriculture.

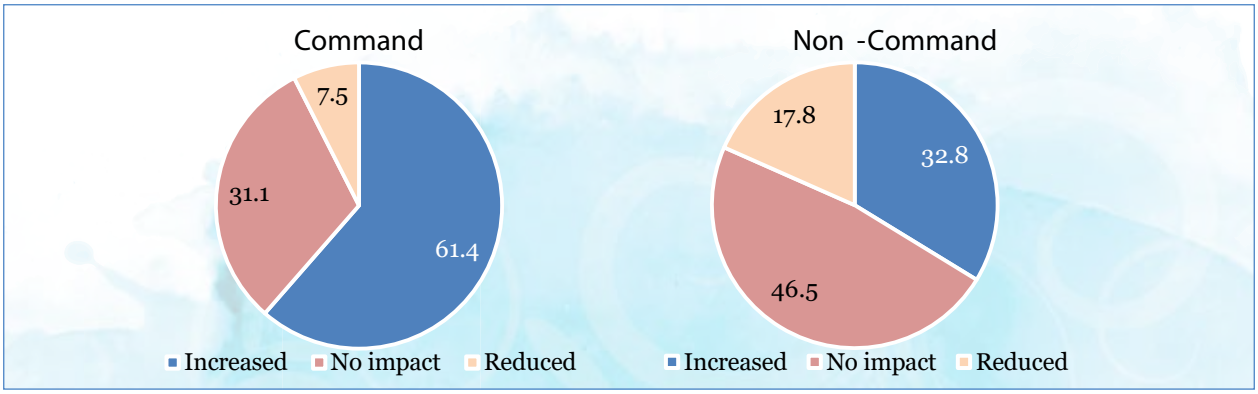
4.2.6 Social Development

Social development indicators also improve with the introduction of irrigation infrastructure. In non-

[24]Evaluation study on Accelerated Irrigation Benefits Programme (AIBP), 2010, https://dmeo.gov.in/reports-working/evaluation-study-accelerated-irrigation-benefits-programme-aibp

command areas, there are limited improvements in schooling, and higher education is often unaffordable. Women's participation in the workforce increased in 61 per cent of households in command areas, against an increase in only 33 per cent of households in non-command area, indicating that irrigation results in strengthening of women participation and empowerment (Figure 4.12).

Figure 4.12: Distribution of households (%) by change in women participation



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

In contrast, command areas see substantial improvements in social development: a remarkable 83 per cent of households report better schooling facilities, and higher education becomes more affordable for many families (Table 4.3). Higher women's participation in workforce indicates a positive shift towards gender equality and empowerment. The available literature also supports these findings where irrigation projects have led to an increase in educational outcomes such as an increase in literacy levels is the region (DMEO and IIM Lucknow Report, 2010). Additionally, 72 per cent of households in command areas report a reduction in the burden of water collection, which had previously been a time-consuming and physically taxing task (Table 4.3).

Table 4.3: Distribution of households (%) by improvements in social development indicators

Indicators	Command	Non-Command
Educational facilities		
Improved	82.7	42.6
No change	17.3	32.5
Deteriorated	-	24.9
Impact on higher educational opportunities for youth		
Improved/more affordable	40.1	29.7
No change	36.9	29.8
Deteriorated/unaffordable	15.2	24.5
Engaged in farm activity	5.4	0.0
Migration for education	-	16.0
Burden of water collection		
Reduced	72.1	48.8
Increased	25.5	51.2
Total	**100.0**	**100.0**

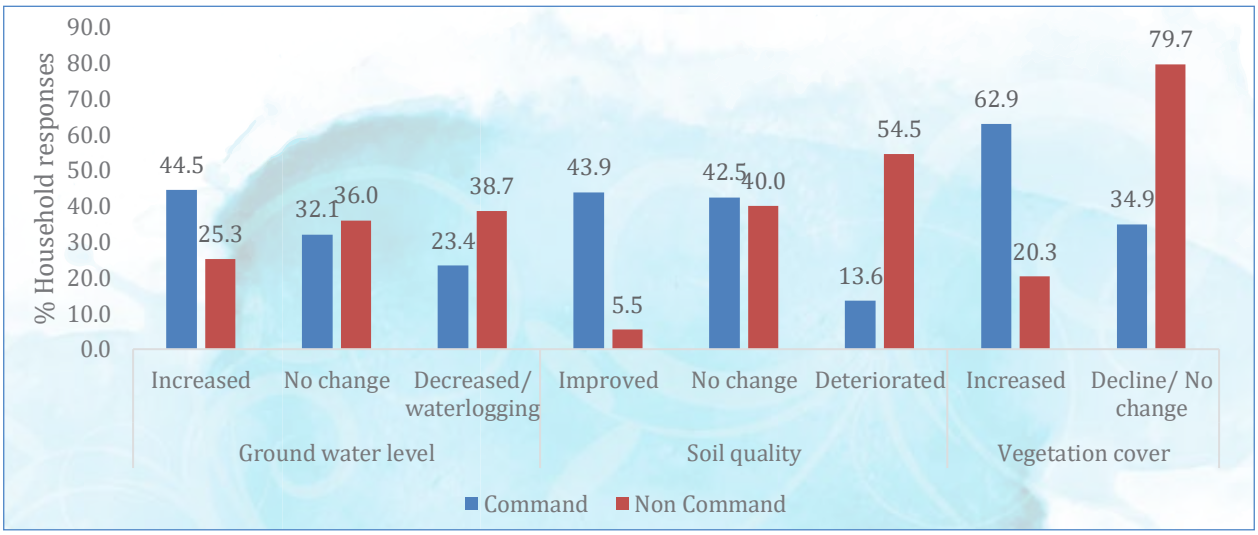
Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Irrigation not only enhances economic conditions but also leads to substantial improvements in education and gender equality, and reduces social burdens, particularly for women and children.

4.2.7 Environmental Outcomes

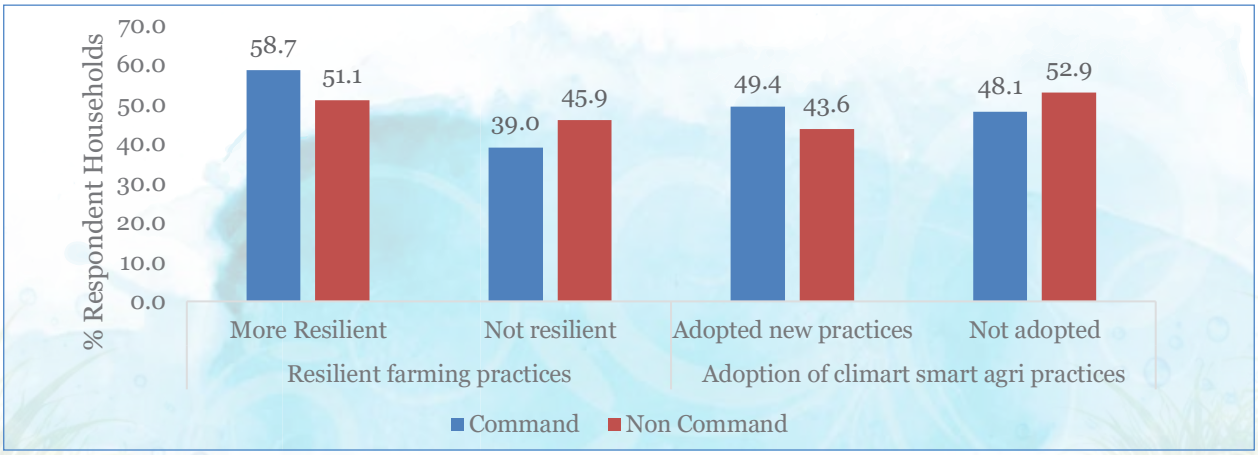
Environmental sustainability is another key benefit of irrigation (such as adoption of better water management and more resilient and sustainable farming practices)[25] (Figure 4.14). In command areas, groundwater levels, soil quality, and vegetation cover have improved as reported by 44.5 per cent, 44 per cent and 63 per cent, respectively, of respondents; this is in comparison with 25 per cent, 5.5 per cent, and 20 per cent, respectively, in non-command areas (Figure 4.13). These findings resonate with the available literature which confirm that canal irrigation, managed recharge structures, and intensified cropping systems can contribute to localised groundwater recovery, improved soil organic carbon retention, and enhanced vegetative greenness, particularly where resource conserving practices are adopted.[26]

Figure 4.13: Distribution of households (%) by environmental improvements



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Figure 4.14: Distribution of respondent households (%) by resilient and climate-smart agriculture practices



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

25Resilient and climate-smart agriculture practices aim to increase productivity and income while adapting to climate change impacts, like droughts, floods, and reducing greenhouse gas emissions. These practices involve diversifying crops, improving water and soil management, and using climate-resilient crop varieties. Key examples include precision irrigation, conservation agriculture, agroforestry, and integrated pest management.

[26]Central Ground Water Board, Ground Water Year Book – India 2022–23. CGWB, Ministry of Jal Shakti. Central Ground Water Board; Central Ground Water Board, National Compilation on Dynamic Ground Water Resources of India (GWRA), 2022/2024. CGWB. Central Ground Water Board+1; ICAR–National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), soil survey publications and maps. (NBSS&LUP website). icar-nbsslup.org.in.

Irrigation helps mitigate environmental degradation, promoting sustainability and resilience. Without irrigation, environmental conditions continue to deteriorate, further exacerbating challenges in non-command areas.

4.2.8 Infrastructure and Access to Services

Command areas have shown strong improvement in water availability in the last five years, as 66.2 per cent of respondents reported increased assured water availability, compared to just 14.1 per cent in non-command areas (Table 4.4). Conversely, water availability has declined for 59 per cent in non-command areas, but for only 33.8 per cent in command areas, indicating that the latter appear to have benefitted from better water management and supply stability. On access to potable water, marginally higher access to potable water is noticed in command areas, though the differences are not very stark. Command areas are substantially better off in terms of water reliability and quality, with better healthcare improvements reflecting irrigation or infrastructure advantages. These findings are consistent with the IIM Bangalore study,[27] which not only indicates improvements in water availability and access in rural systems, but also that these changes have further reduced women's burdens of water collection, and contributed to broader socioeconomic benefits. As far as investment in farm infrastructure is concerned, the trends are almost identical: an increase reported by 47.5 per cent (in command areas) vs. 43.9 per cent (non-command areas) (Table 4.4).

Table 4.4: Distribution of respondent households (%) by infrastructure development and access to various services

Indicator	Command	Non-Command
Water availability in last 5 years		
Assured water availability increased	66.2	14.1
Water availability declined	33.8	59.0
No change		24.1
Access to potable water		
<25%	7.5	8.6
25-50%	26.1	32.6
51-75%	33.2	27.1
>75%	31.2	29.4
Drinking water access		
Improved	59.5	14.8
No change	30.0	32.0
Scarcity/ quality deteriorated/dependence on natural resources	10.5	53.1
Healthcare services access		
Increased	35.2	8.5
No change	26.8	39.4
Declined/limited access	38.0	52.1
Investment in farm infrastructure		
Increased investment	47.5	43.9
Decline in investment	50.1	53.1
Total	**100**	**100**

Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: NCAER *Study to Assess Indirect Benefits of Irrigation Projects*, 2025

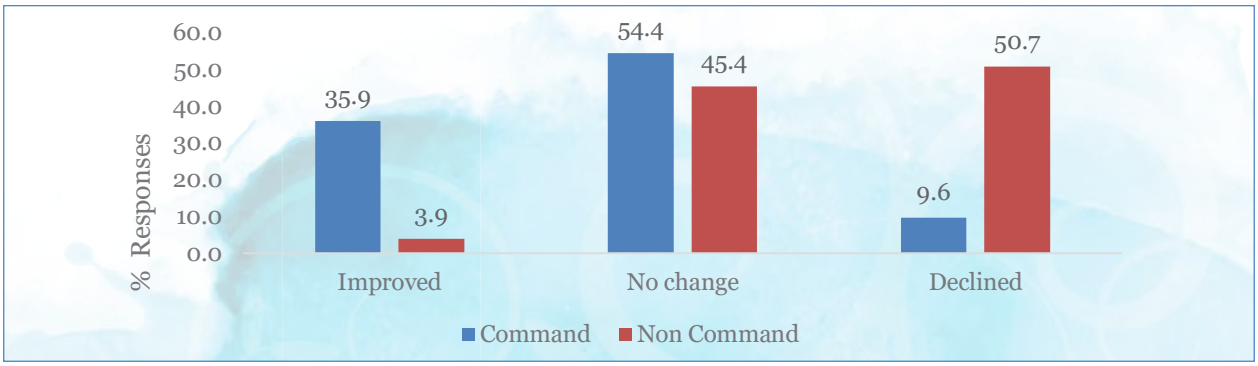
[27]Singh, A., & Naik, G. 2024. 'Rural Drinking Water Supply Program and Societal Development: Evidence from the Early Implementation Phase of India's Jal Jeevan Mission (JJM)'. PLOS ONE, 19(11), e0312144. https://doi.org/10.1371/journal.pone.0312144

Command areas consistently outperform non-command areas in water availability, quality, and healthcare access, implying tangible benefits from irrigation and resource management interventions. Non-command areas face greater scarcity and a service decline, highlighting the need for targeted infrastructure and water management support.

4.2.9 Tourism-related Activities in the Project Areas

A noticeable difference is observed in the reporting of tourism-related or recreational activities between command and non-command areas. Nearly 40 per cent of respondents in command areas reported the presence of such activities (Figure 4.15), compared to about 4 per cent in non-command areas.

Figure 4.15: Distribution of respondent households (%) reporting tourism-related or recreational activities in the area



Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

However, field interactions suggest that these activities are typically concentrated in locations proximate to reservoirs, headworks, or major canal structures, and are not uniformly distributed across the entire command area.

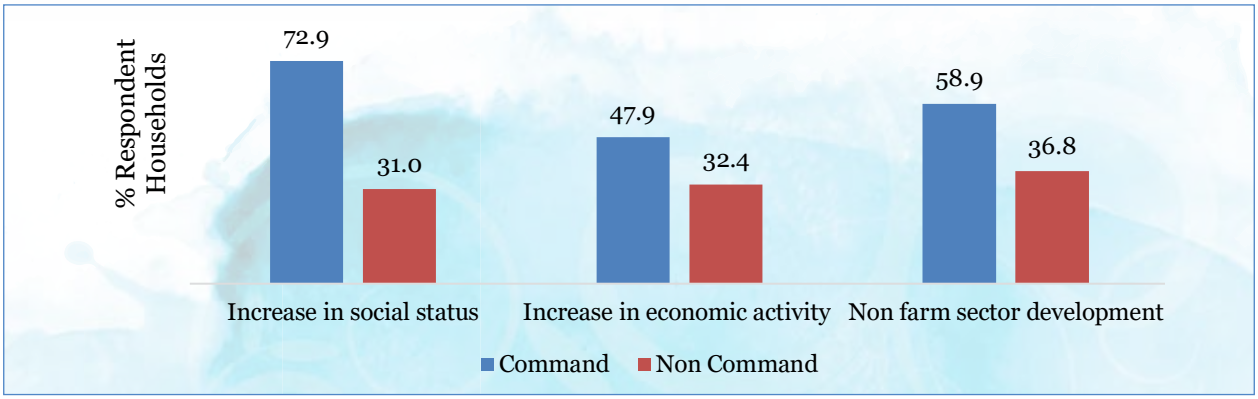
Among respondents who reported such developments, around 22.5 per cent indicated the presence of boating and water-based recreational activities, 23.3 per cent reported farm-based or agri-tourism initiatives, and nearly 30 per cent observed the emergence of roadside shops and small eateries catering to visitors.

These findings indicate that irrigation infrastructure, under certain conditions, may be associated with the emergence of localized economic activities linked to recreation and visitor inflows. However, such outcomes are context-specific and dependent on factors such as location, accessibility, and supporting infrastructure, and therefore should not be interpreted as uniform impacts across all command areas.

4.2.10 Overall Well-being

When asked about overall benefits, other than agriculture benefits for households, a significantly higher share of households in command areas (compared to non-command areas) reported an improvement in social status (Figure 4.16). By enabling more agricultural and allied activities in command areas, irrigation projects have led to higher levels of economic engagement, reflecting a positive difference in command areas. Further, it is found that more non-farm opportunities (e.g., shops, services, small enterprises) have been developed in command areas as indicated by nearly 60 per cent of the respondent households. Overall, irrigation projects play a substantial role in promoting higher social status, greater economic activity, and better non-farm sector development in command compared to non-command areas.

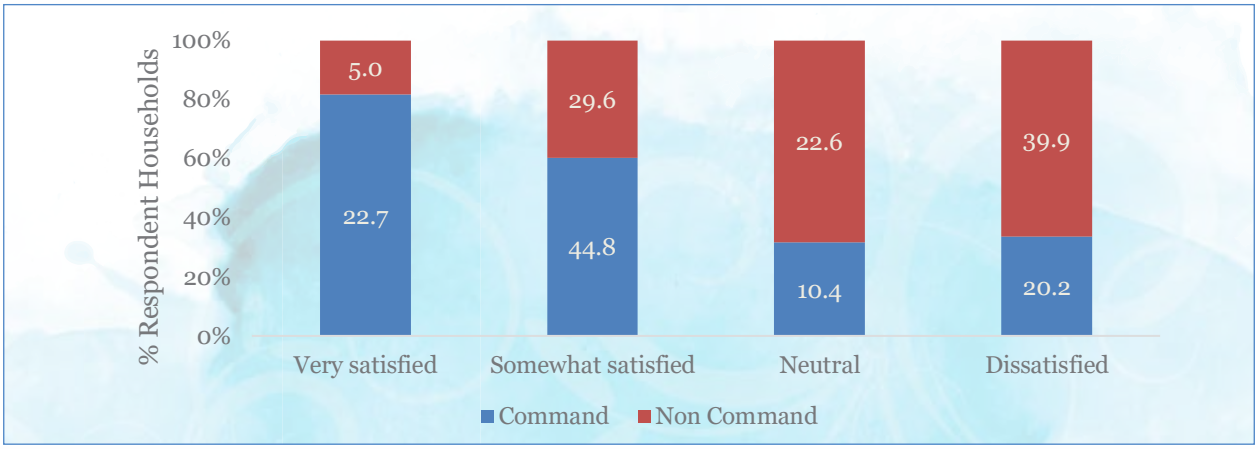
Figure 4.16: Distribution of respondent households (%) by overall benefits other than agriculture-related benefits



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

The overall wellbeing of households is significantly impacted by the presence of irrigation infrastructure. In non-command areas, 40 per cent of households' report being dissatisfied with their living conditions, and only a small fraction (5%) is 'very satisfied' with their overall situation (Figure 4.17). In command areas, however, satisfaction levels are much higher: about 23 per cent of households' report being 'very satisfied,' while the majority are somewhat satisfied; dissatisfaction falls to just 20 per cent, indicating a clear improvement in overall life satisfaction.

Figure 4.17: Distribution of respondent households (%) by well-being satisfaction rates



Note: *Cases where the total percentage does not equal 100 are due to non-responses.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Irrigation projects lead to a significant improvement in the overall well-being of rural communities, increasing satisfaction levels and contributing to a more positive outlook on life.

For the impacts on additional indicators, refer to Annexure Table A4.1.

4.3 COMPARATIVE ASSESSMENT OF IRRIGATION PROJECTS

This section presents a comparative assessment of key parameters at the irrigation project-level between command and non-command areas. The project-wise analysis indicates a mixed impact of irrigation interventions, with several parameters showing notable improvements in command areas. A significant outcome is the increase in land value, which has risen across nearly all 57 projects, with around 48 reporting market values exceeding Rs.3

lakh per acre. Assured water availability has also improved in most projects, with more than 80 per cent of respondents in about 24 projects reporting consistent water supply.

The impact of irrigation is further reflected in enhanced groundwater levels (38 projects), better soil quality (55 projects), and reduced dependence on rainfall (49 projects). Agricultural productivity has improved across all projects, alongside gains in employment opportunities, market linkages, and farm business, contributing to higher household incomes in almost all cases. Additionally, several irrigation projects have also led to the development of tourism opportunities in the region, highlighting the broader socio-economic benefits of irrigation development.

For detailed information refer to Annexure Tables A4.2 to A4.11.

4.4 CONCLUDING REMARKS

The findings from the NCAER study highlight a marked contrast between non-command areas—treated as the control or baseline scenario—and command areas benefitting from irrigation infrastructure. By using non-command areas as a reference, the study approximates a 'without-irrigation' scenario, enabling a clear assessment of the changes attributable to irrigation projects in a quasi-experimental, with-and-without framework.

Non-command areas remain highly vulnerable. Agriculture in these regions is predominantly rainfed, making it heavily dependent on seasonal rainfall and highly sensitive to climatic variability. This results in declining crop yields and limited opportunities for agricultural diversification. Poor soil and water quality further constrain productivity. These structural vulnerabilities are compounded by socio-economic pressures, including rising rates of seasonal and permanent migration (as households seek alternative sources of income), limited access to education, and constrained livelihood opportunities. Overall, these areas exemplify the baseline challenges facing rural communities in the absence of irrigation support.

In contrast, command areas with reliable irrigation infrastructure show significant improvements across multiple dimensions. Land values and household incomes are higher, reflecting enhanced agricultural productivity and stronger market linkages. Reduced migration allows households to remain rooted in their communities, supporting local development. Educational outcomes improve, with higher enrollment and lower dropout rates, while women experience greater empowerment through active participation in agricultural work, income generation, and decision-making. Environmental conditions also show positive trends, including better soil and water management and more sustainable natural resource use.

These findings underscore the transformative impact of irrigation projects. Beyond boosting crop yields, irrigation catalyses broader rural development by stabilising incomes, strengthening local markets, empowering women, improving education, and enhancing environmental resilience. By comparing command areas with non-command controls, the study demonstrates that irrigation projects are a critical lever for achieving sustainable and equitable development in farming communities.

CHAPTER 5

Analytical Framework for Estimating the Indirect Benefits of Irrigation Projects

5.1 INTRODUCTION

This chapter presents the analytical framework and model formulation used to estimate the indirect benefits arising from irrigation interventions. Beyond their direct impacts on agricultural productivity and water availability, irrigation projects generate a wide range of indirect effects—such as improved livelihoods, enhanced health outcomes, better access to services, and strengthened rural infrastructure. The proposed model integrates economic, social, institutional and environmental indicators within a structured valuation framework to capture these multidimensional benefits. It also outlines the methodological approach, variables, and data requirements necessary to quantify and assess the broader development outcomes of irrigation investments.

The analytical framework adopted in this chapter is grounded in established practices within development evaluation and project appraisal literature. The construction of the composite index follows established principles of multidimensional indicator aggregation, including normalisation and scaling procedures consistent with the United Nations' Min–Max methodology and the OECD Handbook on Constructing Composite Indicators (OECD, 2008). These approaches emphasise transparency, internal consistency, and interpretability in transforming heterogeneous indicators into a unified evaluative metric.

The use of with–and–without comparisons at the project level aligns with standard applied development evaluation techniques in contexts where baseline data are unavailable or where interventions have long implementation histories (Ravallion, 2008; Deaton, 2010). By defining the dependent variable as the income differential between command and non-command areas, the framework adopts a difference-based structure that mitigates location-specific confounders while preserving cross-project variation relevant for policy analysis.

Further, the regression-based monetisation of multidimensional benefits is consistent with integrated valuation approaches used in irrigation and water-resource appraisal literature (Alcon et al., 2021; Giordano et al., 2023), as well as with applied cost–benefit frameworks commonly employed in infrastructure evaluation (World Bank, 2016; World Bank, 2020). The present study integrates these methodological elements into a coherent and operational framework tailored specifically for irrigation appraisal in the Indian context. Against this conceptual backdrop, the methodological stages are outlined below.

5.1.1 Stages of Model Formulation

Building on this foundation, a systematic and transparent methodological framework was formulated to assess the indirect and intangible benefits arising from irrigation projects. The framework was designed in a structured and staged manner, enabling refinement, validation, and

triangulation of findings at successive analytical levels. Each stage served a distinct analytical purpose—progressively adding conceptual depth, empirical rigour, and interpretive clarity to the overall assessment of irrigation impacts.

The six interlinked stages of the framework are as follows:

1. Identification of Relevant Parameters
2. Computation of Normalised Scores
3. Calculation of Income Difference
4. Computation of National-level Beta Coefficients
5. Accounting for Time-Saving Benefits

The subsequent sections provide a detailed discussion of each stage undertaken during the formulation of the methodology.

5.2 STAGE 1: IDENTIFICATION OF RELEVANT PARAMETERS

The first stage involved measurable and un-measurable parameters that effectively capture the multidimensional impacts of irrigation projects. These parameters were derived from the *NCAER- Study to Assess Indirect Benefits of Irrigation Projects*, 2025, and reflect critical domains such as economic well-being, employment generation, environmental quality, social inclusion, health outcomes, educational attainment, and institutional participation. The selection procedure involved detailed discussions with the Consultancy Management Committee (Project Review Committee of the CWC) and insights from pilot testings. The parameters selected for this study are given in Table 5.1.

These ten parameters ensure that the assessment captures the maximum possible indirect benefits of irrigation projects in a comprehensive yet measurable manner. Irrigation does not only increase crop production; it also influences economic activities, social conditions, environmental sustainability, and community dynamics. Therefore, the parameters were chosen to represent these multiple dimensions in a balanced way.

First, economic impacts are captured through parameters such as Improvement in Market Linkages, Dependence on External Finance, and Improvement in Local Agri-Businesses. These reflect how irrigation strengthens farmers' connection to markets, reduces financial vulnerability, and stimulates local economic activity beyond farming. Together, they indicate whether irrigation contributes to broader rural economic development.

Second, employment and income security are reflected in Increased Employment Opportunities and Reduction in Migration. Irrigation enables multiple cropping and allied activities, which generate local jobs and reduce distress migration. These parameters show whether irrigation creates stable livelihood opportunities within the region.

Third, social development outcomes are captured through Increased School Attendance and Improvement in Community Cooperation. When agricultural income improves, households are better able to invest in education. At the same time, irrigation systems often require collective water management, which can strengthen cooperation and social cohesion within communities.

Fourth, health and environmental benefits are measured through Reduction in Water-borne Diseases, Reduction in Soil Degradation, and Ground Water Recharge. These parameters reflect improvements in environmental sustainability and public health conditions that arise from better water availability and management practices.

Each selected parameter represents a distinct, non-overlapping indirect benefit of irrigation, chosen to capture the multifaceted impacts of irrigation projects on the above-mentioned critical domains.

The column 'Significant (Yes/No)' in Table 5.1 indicates whether the difference between the Command and Non-Command areas is statistically significant. A 'Yes' means that the observed difference is unlikely to have occurred by chance and can reasonably be associated with the presence of irrigation. A 'No' indicates that the difference between the two areas was not statistically strong enough to establish a clear irrigation-related impact.

Under a two-tailed two-sample proportional difference hypothesis testing framework (5 per cent significance level), nine of the ten pre-specified indicators exhibit statistically significant differences between command (irrigated) and non-command areas. Statistically significant proportional differences are observed for market linkages, dependence on external finances, employment beyond agriculture, development of local agri-

businesses, community cooperation, and reduced migration ($p < 0.05$). These results indicate that the observed differences in proportions between the two groups are unlikely to have arisen by random variation. Collectively, the evidence suggests that irrigation is associated with measurable differences across multiple dimensions of rural economic and institutional outcomes.

Among environmental and social indicators, statistically significant proportional differences are also observed for soil degradation, reduction in school attendance, and incidence of water-borne diseases.

Table 5.1: List of selected parameters

S. No	Parameter	Significant (Yes/No)
1	Improvement in Market Linkages***	Yes
2	Dependence on External Finance***	Yes
3	Improvement in Local-Agri Businesses***	Yes
4	Reduction in Soil Degradation***	Yes
5	Increased Employment Opportunities***	Yes
6	Increased School Attendance***	Yes
7	Ground Water Recharge	No
8	Reduction in Water-borne Diseases***	Yes
9	Reduction in Migration***	Yes
10	Improvement in Community Cooperation***	Yes

Note: With *** indicating 99% level of significance
Source: *NCAER- Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Table 5.1 also reveals that out of the ten parameters selected, only one, i.e., Ground Water Recharge is statistically insignificant. However, we have decided to keep it within the comparison framework due to its theoretical and logical relevance.

Overall, the results demonstrate that irrigation is associated with statistically distinguishable outcomes across most economic, social, and environmental indicators examined, while also underscoring the importance of complementary groundwater management, drainage planning, and public health safeguards to ensure sustainable and inclusive irrigation development.

Each irrigation project was evaluated across these ten distinct parameters, with each parameter assigned equal weight in the analysis to ensure a balanced assessment of the project's overall impact. A detailed summary of each parameter, along with the corresponding questions used to derive the results, is presented in Table 5.2.

Table 5.2: Detailed summary of selected parameters along with their questionnaire references

No	Parameter	Command Questionnaire Reference	Non-Command Questionnaire Reference	Rationale
1	Improvement in Market Linkages	Question used: (Q34) Have you observed an increase in market linkages and agricultural trade due to irrigation? Response used: 1. Yes, increased access to markets and better prices 2. Some improvement, but market challenges remain	Question used: (Q32) Have you observed changes in market linkages and agricultural trade due to the lack of irrigation? Response used: 2. Some improvement via government	Irrigation stabilises output, improving access to organised markets
2	Dependence on External Finances	Question used: (Q 33) How has irrigation affected your dependency on external financial assistance (loans, subsidies, etc.)? Response used: 1. Decreased dependency on loans	Question used: (Q31) How has the lack of irrigation affected your dependency on external financial assistance? Response used: 3. Decreased due to reduced farming	Stable income reduces need for informal credit
3	Employment Beyond Agriculture	Question used: (Q44) Has irrigation led to job creation beyond agriculture? Response used: 1. Yes, new businesses and service sectors have emerged 2. Some increase in non-agricultural jobs	Question used: (Q42) Has the lack of irrigation led to a shift towards non-agricultural jobs? Response used: 1. Yes, new businesses have emerged 2. Some shift in job opportunities noted	Irrigation stimulates rural non-farm jobs
4	Migration Patterns	Question used: (Q45) How has irrigation influenced migration patterns in your area? Response used: 1. Reduced migration to urban areas	Question used: (Q43) How has the lack of irrigation influenced migration patterns in your area? Response used: 3. Decreased migration	Income stability reduces distress migration
5	Local Agri-Businesses	Question used: (Q48) Has irrigation contributed to the development of local agribusinesses (e.g., milling, storage)? Response used: 1. Yes	Question used: (Q46) Has the lack of irrigation limited development of local agribusinesses? Response used: 2. No	Irrigation catalyses processing, storage, input supply
6	Groundwater Levels	Question used: (Q54) How has irrigation influenced groundwater levels in your area? Response used: 3. Depleted groundwater levels	Question used: (Q52) How has the lack of irrigation influenced groundwater levels? Response used: 1. Decline due to extraction	Irrigation interacts with aquifers
7	Soil Degradation	Question used: (Q55) Has irrigation influenced soil quality? Response used: 3. Declining soil fertility due to over-irrigation	Question used: (Q53) Has lack of irrigation influenced soil quality? Response used: 1. Low fertility	Irrigation affects fertility and sustainability
8	Access to Education	Question used: (Q49) Has irrigation influenced your children's access to education? Response used: 5. No, reduced school attendance due to greater participation in family farming activities	Question used: (Q47) Has the lack of irrigation influenced children's access to education? Response used: 1. Yes, fewer attend school	Stable incomes support schooling

No	Parameter	Command Questionnaire Reference	Non-Command Questionnaire Reference	Rationale
9	Incidence of Water-borne Diseases	Question used: (Q61) Has irrigation caused any health-related issues in your area? Response used: 1. Yes, increase in waterborne diseases	Question used: (Q62) Have you observed health-related issues due to the lack of irrigation? Response used: 1. Waterborne diseases	Quality of irrigation water can have health implications
10	Community Cooperation	Question used: (Q74) Has irrigation strengthened community cooperation? Response used: 1. Yes, increased cooperation for water management	Question used: (Q73) How has the lack of irrigation affected community cooperation? Response used: 1. Increased cooperation	Shared water fosters or undermines cooperation

Source: *NCAER- Study to Assess Indirect Benefits of Irrigation Projects*, 2025

The responses obtained from both command and non-command areas for each of the ten parameters were systematically analysed to derive comparable performance indicators. These responses were then utilised to compute a normalised score, ensuring that variations across parameters and projects were measured on a common scale. The detailed procedure for computing these normalised scores is explained in section 5.3.

5.3 STAGE 2: COMPUTATION OF COMPOSITE SCORE

To systematically evaluate project performance across multiple dimensions, individual indices were developed for each parameter identified in the preceding section. Each index captured the relative standing of a project's command area with respect to its non-command area, in a particular dimension of indirect benefit, such as economic diversification, employment generation, environmental sustainability, or social well-being. The use of parameter-specific indices ensured that performance variations across different aspects of irrigation impact could be assessed independently, allowing for a nuanced understanding of each project's strengths and weaknesses.

To obtain an integrated measure of overall performance, these individual indices were subsequently aggregated into a composite index. The composite index provides a consolidated representation of how effectively an irrigation project contributes to generating indirect and intangible benefits beyond direct agricultural outcomes. This approach not only facilitates inter-project comparison but also helps identify projects that demonstrate balanced performance across multiple dimensions, thereby serving as benchmarks for sustainable and inclusive irrigation development.

5.3.1 Normalisation Formula

To promote consistency and enable meaningful analysis, all collected responses from command and non-command areas underwent normalisation to a standardised 0–1 scale, applying a method similar to the United Nations min–max method.[28]

The formulae used for calculating normalised index values were tailored to the specific characteristics of each parameter. Since the direction of improvement varied across indicators, the computation method was adjusted accordingly.

This distinction ensured that all indices were expressed on a uniform scale, with higher scores consistently reflecting better performance. Such standardisation allowed meaningful aggregation across parameters and enhanced the comparability of results across irrigation projects.

5.3.1.1 Improvements Associated with Higher Command Responses

For parameters where a higher proportionate response in the command area indicates better performance—such as employment generation or school attendance—the index was computed using the following formula:

$$\text{Normalised Value} = \frac{\text{Command Proportion} - \text{Non Command Proportion}}{\text{Maximum Value (100)} - \text{Non Command Proportion}} \quad [5.1]$$

In this framework, the denominator represents the maximum potential benefit attainable under ideal conditions, serving as the upper bound or reference point for evaluation. It enables the index to capture the extent to which the project's observed performance approaches its full potential. The value 100 denotes the ideal benchmark, while the Non-Command Proportion reflects the share of benefits that exist even in the absence of irrigation interventions.

Accordingly, the numerator—Command Proportion minus Non-Command Proportion—captures the actual incremental benefit attributable to the irrigation project. This difference quantifies the realised improvement in outcomes that can be directly linked to the availability and effective use of irrigation infrastructure.

5.3.1.2. Improvements Associated with Lower Command Responses

For parameters where improvement is reflected through a lower proportionate command response—such as migration or water-borne diseases—the index was computed using the following formula:

$$\text{Normalised Value} = \frac{\text{NonCommand Proportion} - \text{Command Proportion}}{\text{NonCommand Proportion} - \text{Minimum Value(0)}} \quad [5.2]$$

In this formulation, the denominator represents the maximum potential benefit achievable through irrigation. Since a lower value indicates better performance, the minimum or ideal value is considered 0. The difference between the Non-Command Proportion and this ideal benchmark thus signifies the total scope for improvement if irrigation interventions were to be introduced.

The numerator—Non-Command Proportion minus Command Proportion—captures the actual reduction in the adverse outcome attributable to irrigation. This difference quantifies the realised improvement or benefit resulting from the project's influence.

The resulting index is expressed as an index of the maximum attainable reduction, thereby standardising the measure on a 0-1 scale. A value of 0 indicates no observable reduction in the adverse outcome due to irrigation, while a value approaching 1 signifies that the command area has nearly eliminated the gap relative to the ideal condition.

Mathematically, when the Command Proportion equals the Non-Command Proportion, the index becomes 0, indicating no project-induced improvement. When the Command Proportion approaches 0, the index approaches 1, reflecting the maximum theoretical reduction achievable.

This normalised structure ensures comparability across negatively oriented indicators and maintains consistency with the methodology applied to positively oriented parameters. Implicitly, the formulation assumes that differences between command and non-command areas primarily reflect the impact of irrigation, holding other external influences constant.

5.3.2 Computation of Normalised Scores

5.3.2.1 Min-Max Normalisation Approach

The computation formulae outlined above yield index values ranging from 0 to 1, where '0' represents no benefit realised and '1' indicates the attainment of maximum potential benefit from the irrigation project. Thus, a higher index value indicates stronger project performance in delivering the specific indirect benefit associated with a given parameter.

Using this normalisation approach, ten parametric indices were derived for each irrigation project, corresponding to the ten parameters identified for assessing indirect and intangible benefits. This ensured a standardised scale across all indicators, facilitating meaningful comparison both within and across projects.

5.3.2.2 Treatment of Negative Index Values

In certain cases, the computed index values may turn negative, indicating that outcomes in non-command areas surpass those in command areas. Since such values did not carry meaningful interpretation within the normalised 0–1 scale and could have disproportionately distorted the composite score, all negative index values were truncated to zero prior to aggregation. This adjustment ensures that the resulting composite index remains both robust and interpretable, accurately reflecting relative project performance.

5.3.2.3 Computation of the Composite Index

After standardising individual parameter indices and setting negative values to zero, the composite index for each project was calculated as the simple arithmetic mean of all the ten parameter indices indicated above. This aggregation method provides

an intuitive measure of overall project performance in generating indirect and intangible benefits. However, it also implicitly penalises projects where improvements are concentrated in only a few dimensions rather than being evenly distributed across parameters, thereby encouraging balanced progress across all aspects of irrigation impact.

All projects' composite index values are presented in Table 5.3.

Table 5.3: Composite scores of all selected irrigation projects

S. No.	Irrigation Projects	Composite Index	CCA (000' Ha.)
1	Adwa Canal Irrigation Project	0.218	21.8
2	Chambal Irrigation Project	0.431	229.9
3	Deokali Irrigation Project	0.268	28.4
4	Haripur Reservoir Irrigation Project	0.434	11.0
5	Harishchandra Sagar Irrigation Project	0.147	18.0
6	Hindon Krishi Irrigation Project	0.314	31.4
7	IGNP Irrigation Projects	0.305	525.0
8	Makhu Irrigation Project	0.370	20.6
9	Matatila Irrigation Project	0.369	427.0
10	Ravi Canal Irrigation Project	0.325	26.6
11	Rewari or JNP Project	0.218	32.9
12	Sharda Sahayak Irrigation Project	0.271	1522.0
13	Sidmukh Irrigation Project	0.134	80.0
14	Sri Hind Irrigation Project	0.404	360.0
15	Tanda Pump Canal Project	0.225	30.0
16	Upper Ganga Irrigation Project	0.651	924.0
17	Western Yamuna Irrigation Project	0.360	1076.0
18	Ajoy Barrage (Siktia) Irrigation Project	0.042	22.9
19	Eastern Sone Command Irrigation Project	0.250	139*
20	Eastern Sone High Level Command Project	0.206	139*
21	Hirakud Irrigation Project	0.710	157.8
22	Kanchi Irrigation Project	0.021	17.9
23	Mayurakshi (JH) Irrigation Project	0.027	234.0**
24	ONG Diversion Weir	0.375	9.9
25	Potteru Irrigation Project	0.225	61.8
26	Sakri Lower Valley	0.495	33.0
27	Uderusthan Irrigation Project	0.857	41.1
28	Western Sone High Level Irrigation Project	0.766	139*
29	Western Sone Chausa Irrigation Project	0.358	139*
30	Integrated Kollang Irrigation Project	0.241	21.5
31	Loktak Lift Irrigation Project	0.305	23.4
32	Jamuna Irrigation Project	0.273	27.7
33	Hemavathy Irrigation Project	0.197	283.3
34	Kallada Irrigation Project	0.173	53.6
35	Kuttiyadi Irrigation Project	0.439	14.6
36	Lower Bhavani Irrigation Project	0.152	83.8

S. No.	Irrigation Projects	Composite Index	CCA (000' Ha.)
37	Nagarjuna Sagar LBC	0.313	900***
38	Nagarjuna Sagar RBC	0.352	
39	Nagarjuna Sagar Telangana	0.538	
40	Penna Irrigation Project	0.486	24.0
41	Sri Ram Sagar Irrigation Project	0.357	317.1
42	Tungabhadra Irrigation Project	0.451	323.8
43	Gangapur Irrigation Project	0.349	21.9
44	Ghod Irrigation Project	0.381	41.5
45	Girna Irrigation Project	0.409	79.3
46	Hathmati Irrigation Project	0.238	17.5
47	Itiadoh Irrigation Project	0.520	22.8
48	Jayakwadi (Stage 1) Irrigation Project	0.412	183.3
49	Kakrapar Irrigation Project	0.846	204.0
50	Karjan Irrigation Project	0.832	51.0
51	Krishna Irrigation Project	0.416	82.2
52	Meshwo (Reservoir) Irrigation Project	0.397	17.2
53	Salauli Irrigation Project	0.384	14.4
54	Shetrunji Irrigation Project	0.666	57.1
55	Ukai Irrigation Project	0.811	127.5
56	Upper Wardha Irrigation Project	0.363	83.3
57	Wan Irrigation Project	0.263	22.5

Notes: **: CCA for Mayurakshi covers all states (WB and Jharkhand)
*: CCA for Sone Canal covers all projects of Sone.
***: CCA for Nagarjuna Sagar is combined for both states of Andhra Pradesh & Telangana
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

5.4 STAGE 3: CALCULATION OF INCOME DIFFERENCES

The third stage of the model formulation focused on calculating average annual income differences between command and non-command households, thereby providing the economic foundation for quantifying indirect irrigation benefits. The observed income differentials reflect not only direct agricultural gains but also a range of broader economic and welfare effects—such as improved livelihood stability, enhanced productivity, reduced vulnerability, and better access to services—that accrue indirectly due to irrigation availability.

By adopting a with-and-without comparative framework paired with the sample selection strategy explained in chapter 3, the analysis isolates the income advantage associated with irrigation access while abstracting from absolute income levels. This difference-based approach provides a robust basis for linking observed income gains to irrigation-induced indirect benefits.

5.4.1 Command Households' Annual Average Income

This stage began with the estimation of the annual average household income within the command areas. To ensure that differences in resource endowment and farm productivity were systematically captured, the 160 command households (or 100 households, depending on project coverage) were first categorised according to landholding size. The landholding size classifications used for this purpose are given in Table 5.4.

Table 5.4: Landholding category respective area

Landholding Category	Landholding Size (Ha.)
Marginal	< 1
Small	1 – 2
Medium/Large	> 2

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

The landholding categories presented above are consistent with the official definitions adopted by the Government of India.[29]

Within each landholding group, average household income was computed, and these group-specific averages were then combined to derive an overall measure of economic well-being for the command area. A weighted average approach was employed, with weights reflecting the proportional representation of each landholding category. This ensured that groups with greater presence in the command area exerted appropriate influence on the overall average income.

Example

Consider Krishna irrigation project with the following characteristics pertaining to the command area (Table 5.5).

Table 5.5: Example of income calculation in the command area

Landholding Category	Proportion of Landholding Category	Average Income (Rs.)
Marginal	0.24	203886.56
Small	0.48	343104.17
Medium/large	0.28	494018.76

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Based on the following parameters of the irrigation project within the command area, the estimated average annual household income is calculated as follows:

Average Household Income = (0.24) *203886.56 + (0.48) *343104.17 + (0.28) *494018.76

This figure turns out to be Rs. 350513

5.4.2 Non-Command Households' Annual Average Income

A parallel procedure was followed for households in the non-command areas, thus enabling a fair and unbiased comparison between irrigated and non-irrigated regions. Here, too, households were categorised by landholding size, average incomes were calculated for each category, and an overall weighted average was derived. Importantly, the weights applied were based on the command area distribution rather than the actual distribution in the non-command areas.

This uniform weighting scheme ensured that observed differences in household income could be attributed primarily to irrigation access rather than to variations in landholding composition. The approach rests on the assumption that differences in landholding structure between command and non-command areas are largely shaped by irrigation development.

Hence, maintaining a uniform weighting scheme helps isolate the true effect of irrigation access on household income, enabling a more accurate and unbiased comparison between command and non-command regions.

5.5 STAGE 4: COMPUTATION OF NATIONAL-LEVEL BETA COEFFICIENTS

5.5.1 Regression Framework and Interpretation

After computing composite scores and average annual income differentials between command and non-command households, the next step involved isolating the portion of income gains attributable specifically to indirect and intangible benefits of irrigation. To achieve this, a regression-based mapping approach was employed.

The objective of this regression is not to estimate a structural income determination equation, but rather to establish an empirical relationship that translates improvements in multidimensional indirect outcomes into corresponding income equivalents. This specification ensures that the estimated coefficient exclusively captures the income differential attributable to indirect benefits.

- Δ Average HH Income$_i$ denotes the average annual household income difference between command and non-command areas for project i;
- Composite Index$_i$ captures the relative improvement in indirect socio-economic outcomes attributable to irrigation;
- The coefficient β represents the monetisation coefficient, translating a unit increase in the composite index into an income equivalent.

The regression is estimated without an intercept. This deliberate specification was based on the underlying assumption that the command and non-command areas are structurally comparable, with differences in income emerging primarily due to the irrigation intervention in the command area. Including an intercept would have implied the existence of systematic baseline differences between the two regions independent of irrigation, which would contradict this foundational assumption.

As a consequence of this specification, the model could not be extended into a fixed effects framework, since fixed effects estimation inherently relies on the presence of intercept terms.

While this specification may raise concerns regarding simultaneity bias, since the composite index and income could potentially influence each other, this concern is somewhat mitigated by the nature of the irrigation projects examined in the study. The irrigation projects considered here are long-established projects, implying that the potential of mutual reinforcement between income levels and the composite index has been largely realised. Thus, studying the direction of causality under these circumstances is not applicable.

Thus, the current regression approach adequately serves the purpose of estimating the monetised value of indirect benefits leaving limited scope of simultaneity bias.

A composite index value of zero represents no incremental indirect benefit relative to the non-command benchmark. This normalisation allows the coefficient β to be interpreted as the marginal income gain associated with irrigation-induced indirect benefits, abstracting from baseline income differences that may arise from historical, geographic, or institutional factors unrelated to the indirect benefit mechanism.

5.5.2 National-level Beta Value

Using the above specification, a national-level beta coefficient was estimated by pooling data across all 57 irrigation projects. This approach provides a single, operational coefficient suitable for national-level appraisal and policy application.

Table 5.6: National estimated beta value

Beta Coefficient Value (Rs.)	Coefficient of Determination (R^2)
81,227***	0.36

Note: *** indicates 99% level of significance
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

The estimated beta value of Rs. 81,227 implies that a unit increase in the composite index—representing a substantial improvement across multiple indirect benefit dimensions—is associated with an average annual household income gain of approximately Rs. 81,227 in the command area.

While the coefficient of determination (R^2) appears modest, such values are typical in cross-sectional analyses using primary rural household data. As noted in the empirical literature on social science modelling, R^2 values in the range of 0.1–0.5 are considered acceptable when coefficients are statistically significant and theoretically consistent ('The Acceptable R-square in Empirical Modelling for Social Science Research'[30] Peterson K. Ozili).

The estimated coefficient in this model is statistically significant at the 99 per cent confidence level, indicating a robust and meaningful relationship.

5.5.3 Robustness Checks and Validation

To assess the sensitivity and robustness of the estimated regression coefficients, particularly the beta coefficient, additional robustness exercises were undertaken to examine whether the estimated coefficients remained stable under changes in sample composition. Specifically, the analysis evaluated the extent to which the regression estimates varied when observations were added to or excluded from the sample.

5.5.3.1 Inclusion Exercise

The inclusion exercise was conducted by introducing an additional hypothetical representative project, termed "Project AVG", into the sample. The Composite Index and Income Difference values

assigned to this project were computed as the arithmetic averages of the corresponding values across all sampled projects.

The regression model was subsequently re-estimated after incorporating this additional observation, yielding the following results.

Table 5.7: Sensitivity under inclusion

Inclusion Analysis	
Original Beta	81226.65
Beta Inc	81683.89
Difference	-457.24

Soruce: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

It is evident from Table 5.7 that the difference between the original beta coefficient and the revised beta coefficient obtained after inclusion of the representative project is only Rs. 457 per year. The relatively small magnitude of this variation indicates that the regression estimates remain stable even after augmentation of the sample, thereby supporting the robustness of the original model specification.

5.5.3.2 Exclusion Exercise – 1

To assess the implications of sample reduction on the estimated regression coefficient, a project exhibiting characteristics closest to those of "Project AVG" — in terms of Composite Index and Income Difference values — was excluded from the sample, following which the regression model was re-estimated.

Based on this criterion, the Nagarjuna Sagar RBC project was identified as the closest representative project and was therefore removed from the sample for the purpose of the sensitivity exercise.

Table 5.8: Sensitivity under closest exclusion

Exclusion Analysis	
Original Beta	81226.65
Beta Exc-1	80661.69
Difference	564.96

Soruce: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

The results indicate that the difference between the original beta coefficient and the revised coefficient obtained after exclusion of the selected project is approximately Rs. 565 per year. Such limited variation suggests that the exclusion of a representative observation does not materially influence the estimated regression outcomes, thereby reinforcing the stability and reliability of the original model.

5.5.3.3 Exclusion Exercise – 2

To further examine the robustness of the regression estimates, an additional sensitivity exercise was conducted by excluding the project whose Composite Index and Income Difference values deviated the most from those of "Project AVG". This exercise was intended to evaluate the sensitivity of the regression coefficient to the exclusion of the most extreme observation in the sample.

Based on the specified criterion, the Upper Wardha Irrigation Project was identified as the farthest observation from the sample average and was consequently excluded from the regression analysis.

Table 5.9: Sensitivity under farthest exclusion

Analysis	
Original Beta	81226.65
Beta Exc-2	82330.65
Difference	-1104

Soruce: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

The results indicate that the absolute deviation between the original beta coefficient and the revised coefficient obtained after exclusion of the extreme observation is approximately Rs. 1,104 per year. Given the magnitude of the original coefficient, this variation remains economically negligible and suggests that the regression results are not unduly influenced by extreme observations within the sample.

5.5.3.4 Overall Interpretation

Taken together, the inclusion and exclusion exercises indicate that the estimated regression coefficients remain broadly stable under alternative sample compositions. The relatively limited variation observed across all scenarios supports the robustness and consistency of the estimated relationship between the Composite Index and household income differential.

More specifically, the regression estimates exhibited only marginal changes when the sample was augmented through the inclusion of a representative project, as well as when observations

representing both near-average and extreme project characteristics were excluded from the analysis. This suggests that the estimated coefficient is not unduly driven by any single observation or by the particular composition of the sampled projects.

The results therefore provide additional confidence that the observed relationship between the Composite Index and income differential is systematic in nature rather than being an artefact of isolated observations or sample-specific effects. Overall, the sensitivity exercises reinforce the reliability, stability, and empirical validity of the regression framework adopted in the study.

5.5.3.5 Validation Check

The regression-based estimates were subjected to an explicit validation exercise (presented in Annexure A6), wherein the derived coefficients were applied to project-level data to assess the consistency and plausibility of the resulting benefit estimates. The validation results demonstrate that the estimated beta values reproduce observed project level income differentials with a high degree of consistency, thereby confirming the empirical stability of the monetisation coefficient and providing strong support for the robustness of the methodology.

Taken together, these checks indicate that the estimated beta coefficient is stable, interpretable, and suitable for valuation and policy application.

5.6: TREATMENT OF TOURISM-RELATED EFFECTS

During the course of the study, tourism-related or recreational activities were observed in select project areas, particularly in locations proximate to reservoirs and headworks. These include boating, small-scale hospitality services, and other visitor-oriented economic activities.

However, such effects were found to be spatially limited and not uniformly distributed across command areas, and their occurrence depended on factors such as accessibility, infrastructure availability, and local entrepreneurial responses.

In view of these characteristics, and to avoid issues of overlap with other economic indicators such as employment and income diversification, tourism-related effects have not been included in the core econometric framework for estimating indirect benefits.

A separate exploratory analysis of tourism-related effects has been undertaken and is presented in the Annexure 5 for reference.

5.7 STAGE 5: QUANTIFICATION OF BENEFITS FROM A REDUCTION IN THE WATER-FETCHING BURDEN

An additional dimension of the indirect benefits assessed in this study concerns the reduction in the time and physical burden borne by women for collecting household water. In many rural locations, women are primarily responsible for securing water for domestic use, often walking long distances and spending substantial time on this activity. The introduction of irrigation systems, whether through canal networks, lift irrigation, or improved groundwater recharge, can indirectly improve local water availability and thereby alleviate this burden.

To quantify this benefit, households in command area were asked the following question:

'Has the availability of irrigation reduced the burden on women for water collection?' Responses were coded as 1 = yes and 0 = no.

For analytical consistency across projects, a project was classified as having achieved a significant reduction in women's water-collection burden if at least 70 per cent of the surveyed households in the command area responded 'Yes.' The 70 per cent cut-off corresponds to the national average of affirmative response across all command areas of all irrigation projects.

This threshold-based approach ensures that only projects with widespread improvements in water access—not isolated household-level outcomes—are flagged as having meaningful gender-related benefits. Table 5.10 contains a list of projects where significant time was saved in water collection after the commencement of irrigation availability.

Table 5.10: List of projects with significant time-saving

Project Name	Region
Hirakud Irrigation Project	Eastern
Mayurakshi JH Irrigation Project	
ONG Diversion Weir	
Potteru Irrigation Project	

Project Name	Region
Chambal Irrigation Project	Northern
Haripur Reservoir Irrigation Project	
Harischandra Sagar Project	
IGNP Irrigation Project	
Makhu Irrigation Project	
Ravi Canal Irrigation Project	
Sri Hind Irrigation Project	
Upper Ganga Irrigation Project	
Hemavathy Irrigation Project	Southern
Kallada Irrigation Project	
Kuttiyadi Irrigation project	
Nagarjuna Sagar RBC	
Nagarjuna Sagar Telangana	
Penna Irrigation Project	
Sri Ram Sagar Project	
Tungabhadra Irrigation Project	
Gangapur Irrigation Project	Western
Ghod Irrigation Project	
Hathmati Irrigation Project	
Jayakwadi (Recovered)	
Kakrapar Irrigation Project	
Karjan Irrigation Project	
Krishna Irrigation Project	
Mesho Irrigation Project	
Salauli Irrigation Project	
Shetrunji Irrigation Project	
Ukai Irrigation Project	
Upper Wardha Irrigation Project	

***Note**: CCA for selected projects are mentioned in Table 3.1.*
***Source:** NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

5.7.1 Regression Framework

To examine whether irrigation projects that significantly reduce women's water-collection burden are associated with higher household income gains, a two-group dummy regression without a constant term was estimated.

A two-variable dummy regression without a constant term was estimated in the following form:

$$\Delta Y_i = \beta_1 * D_{1i} + \beta_2 * D_{2i} + u_i \qquad (5.7.1)$$

It is evident from equation 5.7.1 that two project-level dummy variables were created with the following properties:

ΔY_i denotes the average annual income differential between command and non-command households for project i;

Dummy 1 (D1) taking the value 1, where ≥70% of command area respondents reported reduced water collection burden from irrigation, 0 otherwise;

Dummy 2 (D2) taking the value 1 where < 70% of command area respondents reported reduced water collection burden from irrigation, 0 otherwise.

Table 5.11: Regression output linking income

Explanatory Variable	Coefficient (Rs.)	R^2
Dummy Yes ($D1Y_i$)	43,577***	0.52
Dummy No ($D2N_i$)	40,990***	

***Source:** NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025
Note: *** Indicates 99% significance level

The quantified additional gain generated from the reduction in the burden of water collection in the command area is given by the difference between $D1_i$ and $D2_i$. Thus, projects that achieve a significant reduction in women's water-collection burden report a higher average annual income gain of Rs. 43,577 – Rs. 40,990 = Rs. 2,587 compared to projects that do not achieve the threshold.

Although modest in magnitude, this Rs. 2,587 additional income gain is meaningful when viewed as an indirect co-benefit of improved water access. The mechanism likely operates through time savings for women, which can be reallocated toward:

- Increased participation in agricultural operations,
- Better livestock management,
- Engagement in income-generating activities, or
- Improved household well-being due to reduced physical drudgery.

The study results also align with findings from IIM-Bangalore-led studies,[31] which show that improvements in water availability and access in rural systems reduce women's burdens of water collection and contribute to broader socioeconomic benefits. This convergence of evidence underlines that irrigation investments with drinking water components ease domestic water-fetching burdens, and yield enhanced returns not only for agricultural productivity but also for gender equity and household welfare.

5.7.2 Review of Various Reports

While the survey findings indicate notable improvements in groundwater status, soil quality, and vegetation cover within the command areas of the assessed irrigation projects, the degree of certainty regarding irrigation as the primary driver must be interpreted with careful nuance. Cross-validation with authoritative national sources, including CGWB's *Ground Water Year Book* and *Dynamic Ground Water Resources Assessments*,[32] ICAR–NBSS&LUP soil evaluations and Soil Health Card datasets,[33] and the Forest Survey of India's ISFR, 2023,[34] shows that the direction of change observed in our sample is broadly consistent with documented trends across irrigated regions in India. These sources confirm that canal irrigation, managed recharge structures, and intensified cropping systems can contribute to localised groundwater recovery, improved soil organic carbon retention, and enhanced vegetative greenness, particularly where resource-conserving practices are adopted. However, the magnitude of these gains is shaped by multiple contextual factors, including groundwater-extraction pressure, nutrient-management practices, drainage and soil conditions, land-use choices, and broader hydrological settings such as deltaic zones, catchment characteristics, and drought- or flood-prone geographies. Consequently, while irrigation has demonstrably acted as a significant enabling factor in the environmental improvements observed in various command areas, it should not be regarded as the sole determinant of such outcomes. The evidence supports a conclusion of moderate-to-high confidence for vegetation improvements, moderate confidence for groundwater recharge, and conditional, practice dependent confidence for soil-quality enhancement, with variations across projects reflecting hydrological, agronomic, and operational and maintenance differences.

The findings of the present CWC study are also broadly consistent with the earlier impact evaluation conducted by IIM Lucknow for the Programme Evaluation Organization (PEO) of the erstwhile Planning Commission.[35] Both studies confirm that assured irrigation plays a transformative role in enhancing agricultural productivity, household incomes, and overall rural development. While the IIM Lucknow study, based on beneficiary versus non-beneficiary comparisons, reported higher cropping intensity, increased irrigated area, and improved farmer incomes under AIBP projects, the CWC's more extensive with-and-without analysis across 57 projects reinforces these outcomes by highlighting significant improvements in crop diversification, market engagement, and socio-economic conditions in command areas relative to non-command regions. Moreover, the CWC study captures a wider spectrum of indirect and intangible benefits including reduced vulnerability to climatic shocks, improved environmental conditions, lower distress migration, enhanced livelihood security, higher asset creation, increased women's participation in agricultural decision-making, growth in non-farm income, and better access to credit and health services, which were only partially captured in the earlier PEO evaluation. Together, the two studies strengthen the evidence base that irrigation investments generate substantial, multidimensional development impacts extending well beyond direct agricultural gains.

5.8 LIMITATIONS OF THE MODEL AND POSSIBLE WORKAROUNDS

The regression-based approach used to compute the national-level alpha and beta values, while robust and reasonably accurate, nonetheless carries certain methodological limitations. These limitations and their respective workarounds are as follows:

- **Limited Recall Value**

  Limitation

  Impact analysis of development interventions is typically undertaken using a difference-in-difference (DiD) approach, which relies on both pre-and-post as well as with-and-without intervention comparisons. This dual-layered structure allows isolation of the true impact of a project by controlling for time-related changes and external factors that may influence outcomes.

  The sample selected for this study also includes several irrigation projects developed as early as the First Five-Year Plan. Because these projects are several decades old, many beneficiaries have limited or no recollection of conditions before the project's implementation, making it impossible to conduct a reliable pre-and-post intervention analysis.

[28] ldc-handbook-2021.pdf

Workaround

To work around this limitation, we relied exclusively on with-and-without intervention data, comparing outcomes between command and non-command areas. The study adopted a novel regression-based index quantification approach to accurately identify and quantify various indirect benefits accruing to beneficiaries of irrigation interventions.

- **Accuracy Decay of Model Coefficients**

Limitation

The national-level beta values derived in this study are grounded in primary survey-based findings and therefore reflect the prevailing economic conditions as of FY26 shaped by inflation, cost, income levels, and other macroeconomic factors.

However, these values are not entirely immune to accuracy decay as economic conditions evolve over time. While they remain reasonably robust for the next five years, consistent with typical quinquennial planning cycles, their reliability gradually diminishes thereafter. This underscores the importance of periodic recalibration to retain model reliability.

Workaround

One way to mitigate this issue is to periodically adjust the beta values, as they are more sensitive to evolving economic conditions like inflation. The alpha values, being relatively small and less volatile, may not require frequent adjustment.

Beta values can be periodically adjusted for inflation to preserve their representativeness and reliability as economic conditions evolve. The following section presents an illustrative example of how such an inflation-based adjustment can be carried out.

Preserving Model Reliability Through Indexation

To counter the accuracy decay in the national-level beta value (Rs. 81,227) and retain its reliability amid changing economic conditions, we index the beta value to the annual CPI inflation rate, which reflects the prevailing retail price environment. This inflation-linked adjustment ensures that the beta value remains representative, consistent, and aligned with real economic trends over time.

The following example illustrates how the indexation mechanism operates in practice:

Illustrative Indexation Exercise

Consider Table 5.12 which lists the set of inputs which form the basis for the subsequent analysis and calculations:

Table 5.12: Inputs required for indexation

Year	CPI	Indexed Beta Value (Rs.)
FY26	100	81,227
FY27	105	85,288
FY28	112	90,974

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Table 5.12 contains the current beta value of Rs. 81,227 as on FY26, which is also taken as the base year for the consumer price index (CPI). For illustration, assume that the CPI rises to 105 in FY27 and further to 112 in FY28. The formula for indexation of beta is given by:

$$\beta_t = \beta_0 * \frac{CPI\ (t)}{CPI\ (o)}$$

β_t= Indexed beta value in year t

β_0= Current beta value, i.e., Rs. 81,227

CPI (t) = CPI as in year t

CPI (0) = Base year CPI

Applying this formula results in indexed beta values of Rs. 85,228 for FY27 and Rs. 90,974 for FY28. These figures account for economic fluctuations and developments, ensuring that the values remain representative and relevant.

The Government of India produces and publishes a cost inflation index (CII)[36] which is used to adjust the original purchase price of an asset for inflation when calculating long-term gains.

Box 5.1: Methodological Note for Policymakers

Valuing the Indirect Benefits of Irrigation Projects

Traditional appraisal of irrigation projects has largely focused on direct agricultural outcomes such as increased irrigated area, crop yields, and cropping intensity. However, irrigation investments generate a broader set of indirect and intangible benefits—including improved income stability, reduced distress migration, better health and education outcomes, strengthened rural enterprises, enhanced groundwater interactions, and greater community cooperation. These outcomes are rarely incorporated systematically into conventional cost–benefit frameworks.

The methodology developed in this study provides a practical, transparent and evidence-based mechanism to quantify such indirect benefits in monetary terms. The approach is grounded in primary household survey data collected from both command and non-command areas across irrigation projects in India.

Core Elements of the Approach

1. **With–and–Without Comparison**

   Outcomes are compared between command and non-command areas within the same project geography. This within-project design isolates the contribution of irrigation while minimising the influence of broader regional, climatic or macroeconomic factors.

2. **Composite Index of Indirect Benefits**

   Multiple socio-economic, environmental and institutional indicators are combined into a single composite index. This captures multidimensional improvements attributable to irrigation, rather than relying on any single indicator.

3. **Difference-Based Monetisation**

   Income differentials between command and non-command households are statistically linked to differences in the composite index through a regression-based mapping. This enables translation of multidimensional indirect improvements into an average annual income equivalent per household.

4. **Transparent Normalisation and Interpretation**

   The composite index is normalised such that a value of zero represents no incremental indirect benefit relative to the non-command benchmark. The estimated coefficient therefore directly represents the monetised value of indirect benefits, ensuring clarity and ease of application in appraisal exercises.

5. **Validation and Robustness**

   Estimated coefficients are validated against observed project-level income differentials. Sensitivity checks confirm that results are stable and not driven by isolated parameters or modelling artefacts.

Policy Relevance and Application

The national-level monetisation coefficient provides a ready-to-use valuation parameter for both ex ante and ex post appraisal of irrigation projects.

The framework complements conventional cost–benefit analysis by explicitly incorporating indirect and intangible benefits.

Separate modules account for tourism-related gains and reductions in women's water-collection burden, ensuring that important co-benefits are not omitted.

The methodology is scalable, transparent, and can be periodically updated to reflect evolving economic conditions.

Why This Matters

By systematically capturing indirect benefits, this approach enables policymakers to:

More accurately assess the full developmental returns to irrigation investments;

Prioritise projects with strong inclusive, resilience-enhancing and sustainability outcomes;

Strengthen the economic justification of irrigation spending in planning and budgeting processes.

In doing so, the framework expands irrigation appraisal beyond narrow productivity metrics and recognises irrigation as a multidimensional driver of rural transformation and long-term economic resilience.

5.9 CONCLUSION

This chapter presents a comprehensive and operational framework for estimating the indirect and intangible benefits of irrigation projects. The central contribution of the methodology lies in systematically linking observed income differentials between command and non-command areas to a composite index that captures multidimensional indirect benefits—spanning economic diversification, employment generation, migration patterns, education, health, environmental interactions, and community-level outcomes. By grounding the analysis in a with-and-without comparative design, the framework isolates realised improvements associated with irrigation while minimising the influence of broader regional factors.

The resulting national-level beta coefficient provides a transparent, empirically derived and scalable mechanism for monetising these indirect benefits. Rather than relying on qualitative assessments or arbitrary multipliers, the approach translates multidimensional socio-economic improvements into a consistent income-equivalent measure that can be readily incorporated into project appraisal exercises. The framework is designed to balance methodological rigour with operational applicability, ensuring that it remains both analytically sound and practically deployable within institutional decision-making processes.

Reductions in women's water-collection burden are incorporated as additional component to account for context-specific spillovers that may not be fully captured within the core composite index. This layered structure allows the framework to reflect the diversity of indirect outcomes associated with irrigation investments, while maintaining internal coherence and transparency.

Together, these elements enable the Central Water Commission to integrate indirect and intangible benefits into irrigation appraisal in a consistent, evidence-based manner. By expanding the evaluative lens beyond direct agricultural productivity, the framework strengthens both the economic justification and the broader developmental relevance of irrigation investments—particularly in the context of rural transformation and climate resilience.

CHAPTER 6

Operationalisation of the Methodology – Application by the Central Water Commission

6.1 INTRODUCTION

The econometric regression analysis presented in Chapter 5 established a robust methodological foundation to quantify the indirect benefits arising from irrigation interventions. While traditional appraisal frameworks of the Central Water Commission (CWC) primarily focus on quantifiable agricultural gains, the analytical model developed in this study demonstrated that irrigation projects generate a wider spectrum of socio-economic benefits ranging from employment diversification and asset creation to tourism and livelihood resilience. However, capturing these indirect and intangible benefits through conventional data collection methods poses significant and practical operational challenges, including high survey costs, non-uniform reporting standards, and time constraints during project appraisal.

To bridge this gap, the study developed the alpha (α) coefficient, a statistically grounded parameter that bridges direct income gains and the composite index. This chapter first explains the conceptual and methodological rationale for α, and then provides a step-by-step framework for how the CWC can apply it together with the existing β parameters within its appraisal and benefit-cost ratio (BCR) system.

6.2 CONCEPTUAL FOUNDATION OF THE ALPHA COEFFICIENT

6.2.1 Why and How Alpha Was Developed

During the empirical phase, it became evident that the Composite Index of Indirect Benefits constructed from ten socio-economic and infrastructural indicators could not be feasibly calculated for every new project, given the data intensity of household-level surveys. Yet, the analysis revealed a consistent, statistically significant relationship between changes in per hectare Average annual agricultural income and the composite index across diverse regional samples.

To capture this linkage in a practical form, the alpha (α) coefficient was developed as a conversion factor enabling the estimation of the composite Index from readily available project-level information. In essence, 'α' expresses how much multidimensional welfare improvement is associated with a one-unit increase in agricultural income. In simpler terms, the α value obtained from the following regression (equation 6.1) represents the average change in the composite index corresponding to a one-rupee increase in the per hectare Average annual agricultural income difference.

Formally, the relationship is expressed as,

$$\text{Composite Index}_i = \alpha * \Delta (\text{Agricultural Income per hectare})_i + u_i \quad [6.1]$$

where Δ (Agricultural Income per hectare) represents the incremental per hectare income expected after project implementation.

6.2.2 Derivation of the National Alpha Coefficient

The alpha coefficient was derived through regression analysis linking the normalised composite index values (dependent variable) to the observed incremental agricultural income per hectare (independent variable) across multiple regional datasets.

The composite indexes across all projects were regressed on their respective per-hectare agricultural income differences, yielding the national-level α value (0.0000207) derived from equation 6.1. The national-level α coefficient is presented in Table 6.1.

Table 6.1: National-level alpha coefficient

Region	Alpha Value	R^2 Value
National	0.00000837***	0.418

Note: *** indicates 99% level of significance
Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

A higher α value implies that each unit of income gain leads to proportionally larger welfare enhancement, typically observed in regions where irrigation investments have strong multiplier effects.

6.3 PROCEDURE TO BE FOLLOWED BY THE CENTRAL WATER COMMISSION FOR USING ALPHA AND BETA COEFFICIENTS

To enable uniform estimation of the indirect benefits across future irrigation projects, the application of the alpha and beta coefficients at the national level is discussed in this section. The values of the β and α coefficients derived in earlier sections are given in Table 6.2.

Table 6.2: National-level alpha and beta coefficients

Region	Beta Value (Rs.)	Alpha Value
National	81,227	0.00000837

Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

These coefficients will therefore serve as standard inputs for appraising the indirect benefit component for all upcoming irrigation projects. The application of these inputs and their computational logic are detailed in the following subsections.

6.3.1 Required Inputs for the Assessment

To operationalise the methodology, each project appraisal should include the following data elements:

1. Culturable Command Area (CCA) – expressed in hectares;
2. Agricultural Income Before Irrigation – the baseline per hectare income of beneficiary farmers prior to project implementation;
3. Agricultural Income After Irrigation – the projected or observed per hectare income once irrigation facilities become operational; and
4. Number of Households Within the CCA – representing the total number of direct beneficiaries.

These variables are sufficient to derive all subsequent calculations and to integrate the results into the project's benefit-cost ratio (BCR) analysis.

6.3.2 Stages of Computation

The methodology unfolds in four sequential stages, each representing a distinct step in the estimation of indirect benefits.

6.3.2.1 Stage 1: Derivation of Change in Per Hectare Agricultural Income

The first stage involves determining the incremental agricultural income attributable to the project. This is obtained by subtracting the pre-irrigation project per-hectare income from the post-irrigation project per-hectare income

$$\text{Change in Agricultural Income} = \frac{\text{Agricultual Income After - Agricultural Income Before}}{\text{Cuturable Command Area (Hectare)}} \quad [6.2]$$

If income data is reported at the aggregate CCA level, this difference should be divided by the total area to obtain the per-hectare value. This variable serves as the primary driver of subsequent computations.

6.3.2.2 Stage 2: Calculation of Composite index from Aplha

The second stage converts the per hectare agricultural income difference into a composite index representing the multidimensional indirect benefits associated with irrigation. This is achieved by multiplying the income difference by the 'α' coefficient,

This figure will be computed by multiplying the per hectare agricultural income difference with the rnational-level alpha value.

Composite Index = ΔPer-hectare Average annual agricultural Income * Alpha coefficient [6.3]

This step embodies the conceptual role of α as a conversion factor linking observable agricultural gains with latent welfare improvements captured by the composite index. These α values serve as the first link in the operational chain. Once the composite index is estimated via α, the beta (β) coefficient translate this index into rupee-denominated per household income equivalents.

6.3.2.3 Stage 3: Computation of Per-Household Indirect Benefits

Once the composite index is determined, it is monetised using the national β coefficient. The resulting value expresses the estimated annual indirect benefit accruing to each household within the command area. The formula for monetising the indirect benefit is given in equation 6.4.

Per Household Indirect Benefit = Composite Index * Beta Coefficient [6.4]

This computation translates multidimensional welfare gains into a single monetary measure that can be integrated into standard economic appraisal frameworks.

6.3.2.4 Stage 4: Computation of Total Indirect Benefits

Finally, the total project-level indirect benefit is obtained by multiplying the per-household indirect benefit by the total number of households located within the CCA. The formula for calculating the total indirect benefit is given in equation 6.5.

Total Indirect Benefit = Per Household Indirect Benefit * Total Households [6.5]

The resulting figure represents the aggregate annual welfare enhancement attributable to the irrigation intervention. The above methodology ensures that every new irrigation project can be appraised within a unified analytical structure. Importantly, the computation is designed to be compatible with existing appraisal templates; it does not replace the direct benefit calculations but supplements them.

6.4 ASSESSMENT OF EXTENSION, RENOVATION, AND MODERNISATION (ERM) PROJECTS

While the methodology described above provides a unified national framework for assessing indirect benefits, extension, renovation, and modernisation (ERM) projects exhibit distinctive characteristics that necessitate certain analytical adjustments. Unlike new irrigation schemes that expand command areas and generate first-time access to irrigation, ERM projects typically focus on improving the efficiency, reliability, and equity of water distribution in already irrigated zones. Consequently, their benefits emerge through productivity enhancement and stabilisation rather than area expansion.

6.4.1 Nature of ERM Projects and Analytical Implications

ERM projects often involve interventions such as canal lining, rehabilitation of distributaries, modernisation of command structures, automation of control gates, and repair of storage or conveyance systems. These activities tend to yield incremental gains in water-use efficiency, cropping intensity, and yield stability, all of which contribute indirectly to household welfare through improved and more predictable agricultural outcomes. The economic manifestation of these improvements is typically a smaller but more immediate increase in per-hectare agricultural income, which in turn induces broader welfare effects captured by the composite index.

6.4.2 ERM-Specific Projects and their Coefficients

The selection of ERM projects was carried out in collaboration with the Central Water Commission (CWC). The final list was drawn from the national project sample to ensure the inclusion of schemes from all geographic regions of India.

Table 6.3: List of Projects Considered under ERM

S. No.	Irrigation Project	Region
1	Eastern Sone Canal Irrigation Project	Eastern
2	Ravi Canal Irrigation Project	Northern
3	Rewari or JNP Irrigation Project	
4	Sri Hind Irrigation Project	
5	Loktak Lift Irrigation Project	North-Eastern
6	Sri Ram Sagar Irrigation Project	Southern
7	Tungabhadra Irrigation Project	
8	Shetrunji Irrigation Project	Western
9	Kakrapar Irrigation Project	
10	Ukai Irrigation Project	

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

Based on the econometric estimations presented earlier, the following coefficients were estimated for ERM contexts (Table 6.4).

Table 6.4: Beta and alpha coefficients of ERM projects

Type of Coefficient	Coefficient
Beta Coefficient	57127*
Alpha Coefficient	0.00000203*

Note: * indicates 90% level of significance
Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

These coefficients will therefore serve as standard inputs for appraising the indirect benefit component of all upcoming ERM irrigation projects.

6.5 LINKING CURRENT AND PROPOSED BENEFIT-COST RATIO COMPUTATION METHODOLOGIES

6.5.1 Introduction

At present, the Central Water Commission (CWC) evaluates irrigation projects using the benefit-cost ratio (BCR) approach, wherein the present value of total direct benefits derived from the project is compared with the present value of all associated cost components. This ratio serves as a key indicator of the project's economic viability and efficiency.

$$Current\ BCR = \frac{Present\ Value\ of\ Direct\ Benefits}{Present\ Value\ of\ all\ Cost\ Componenets} \quad [6.6]$$

The methodology adopted for the estimation of benefits and costs used in evaluating an irrigation project is detailed below.

6.5.2 Estimation of Cost

The total cost associated with the development of an irrigation project, used for benefit–cost ratio (BCR) calculations, is systematically categorised into various major cost heads, each further subdivided into relevant cost sub-heads.

Table 6.5 provides a breakdown of these major cost heads and their corresponding sub-heads used for the BCR calculations.

Table 6.5: Current cost components for direct benefit calculations

S. No.	Cost Heads	Description
1	Maintenance expenditure	1% of total project cost
2	Operation and maintenance (O&M) charges	Rs. 1,800 per hectare of CCA
3	Interest on capital	10% of total project cost
4	Depreciation	2% of total project cost

Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025

6.5.3 Current Benefit Estimation Methodology

At present, CWC obtains data on both current and projected agricultural incomes from the respective state governments in which the irrigation projects are situated. The difference between these two estimates forms the basis for computing the direct benefits associated with the projects.

Total Direct Benefits = Agricultural Income before the project– Agriculture Income after the project **[6.7]**

While the analysis considers actual agricultural income observed within the CCA before the irrigation intervention, it relies on an estimated figure to capture future benefits anticipated from the project.

The existing methodology captures only the direct benefits resulting from irrigation intervention, while remaining devoid of the wider indirect benefits associated with it.

6.5.4 Proposed Benefit Estimation Methodology

The methodology developed by NCAER enables the quantification of the diverse and wide-ranging indirect benefits arising from irrigation projects. Once these indirect benefits are estimated, they can be incorporated alongside the direct benefits, allowing for the computation of a revised BCR that reflects total benefits more comprehensively.

Adding the indirect benefits to the direct benefits provides a more comprehensive and realistic estimate of the total economic gains from irrigation projects. This combined measure captures not only the immediate agricultural income enhancements due to the irrigation intervention, but also the wider future spillover effects

Total Benefits = Agricultural Income Before and After Irrigation Project + Quantified Value of Indirect Benefits **[6.8]**

6.5.5 Revised Benefit-Cost Ratio

The **revised benefit-cost ratio (BCR)** is computed by taking the ratio of the **composite present value of total benefits,** which now includes both direct and indirect benefits, to the **original cost estimates** used in the initial appraisal**.**

$$\textit{Revised BCR} = \frac{\text{Present Value of Total Benefits (Direct and Indirect)}}{\text{Present Value of all Cost Componenets}} \quad [6.9]$$

6.6 CONCLUSION AND CLOSING REMARKS

This chapter operationalised the empirical framework developed in the preceding analysis by translating the econometric relationships into a practical methodology that the Central Water Commission (CWC) can apply for project appraisal. The introduction of the alpha (α) coefficient, in conjunction with the beta (β) value, provides a statistically significant approach to estimating the indirect and welfare enhancing benefits of irrigation projects using readily available information, by linking measurable changes in per hectare agricultural income to multidimensional welfare improvements through α, and monetising these effects with β.

The adoption of national specific α and β coefficients ensures analytical rigour, while maintaining operational simplicity and cross-project comparability.

In conclusion, the framework developed in this study expands irrigation appraisal beyond conventional productivity metrics and provides a structured mechanism to recognise the full spectrum of indirect and intangible benefits generated by irrigation investments. By translating multidimensional socio-economic improvements into monetisable income equivalents, the approach enables more comprehensive and evidence-based decision-making. The resulting national-level coefficient, supplemented by tourism and gender-related co-benefits where applicable, offers a practical tool for both ex ante appraisal and ex post evaluation. Institutionalising this framework within irrigation planning processes can enhance the economic justification of projects, improve prioritisation across competing investments, and align irrigation development more closely with broader objectives of rural resilience, inclusive growth, and long-term sustainability.

CHAPTER 7

Regional Perspectives on Indirect Benefits: FGD Insights

7.1 INTRODUCTION AND CONTEXT

Focus group discussions (FGDs) conducted across India in 20 states and 57 irrigation projects, provide rich evidence of the multidimensional and region-specific nature of irrigation-induced socio-economic transformation. These villages, representing diverse agro-climatic zones, landholding patterns, and institutional arrangements, illustrate how water infrastructure serves as a catalyst for both agricultural and non-agricultural development.

While the direct benefits of irrigation, such as increased crop yields, multi-cropping potential, and improved reliability of farm outputs, are readily observable and often form the immediate rationale for investment, the FGDs highlight that the indirect benefits are equally consequential. These include significant improvements in women's economic participation and empowerment, enhanced health and hygiene outcomes due to better water availability, higher school enrolment and educational attainment, a reduction in seasonal



FGD in the Integrated Kollang Project in Moriagaon District of Assam

migration, and the emergence of diversified livelihood opportunities both within and beyond agriculture.

Crucially, these indirect outcomes are shaped by the local context. Factors such as regional agro-climatic conditions, institutional capacity (including the functioning of Water User Associations and Panchayati Raj structures), social norms, landholding distribution, and market access mediate the way irrigation translates into tangible socio-economic improvements. In other words, while irrigation provides the infrastructure backbone, the degree and sustainability of its wider developmental impacts are heavily influenced by region-specific ecological, social, and institutional conditions.

Building on cross-village evidence, it becomes apparent that the nature and magnitude of irrigation's socio-economic impacts vary considerably across regions. Each region presents a distinct combination of agro-climatic conditions, institutional arrangements, and social structures that influence how water infrastructure translates into both agricultural and non-agricultural outcomes. For instance, in southern states such as Tamil Nadu and Kerala, irrigation primarily stabilises cropping patterns and supports human development outcomes, including women's empowerment and improved education, whereas in the Deccan regions of Telangana and Maharashtra, it fosters commercialisation, market-oriented agriculture, and integration with agro-industrial value chains. In western India, particularly Gujarat, the emphasis is on community-led water management and groundwater recharge, which reinforces both productivity and social cohesion. In contrast, in the Gangetic plains of Uttar Pradesh, irrigation infrastructure is generating first-generation socio-economic gains, with emerging benefits in household incomes, women's participation, and education, albeit in a context where institutional capacity is still developing.

The following sub-sections provide a detailed, region-wise synthesis for some of the FGDs, illustrating how irrigation impacts manifest across multiple domains—agriculture, livelihoods, gender, education, health, and local governance. This regional perspective highlights both the commonalities and divergences in outcomes, enabling a nuanced understanding of the conditions under which irrigation can deliver broad-based, sustainable development benefits. A detailed project-level comparison for the rest of the FGDs is given in Annexure Table A5.3.

7.1.1 Tamil Nadu – Lower Bhavani Irrigation Project: Water Security, Crop Diversification, and Women's Economic Empowerment

In Kulabilaku village, the Lower Bhavani Irrigation Project (LBP) has catalysed a substantial socio-economic shift typical of Tamil Nadu's mature irrigation landscape. The transition from rainfed, single-crop systems to multi-cropping patterns has not only raised productivity but also stabilised rural incomes. This aligns with the state's long-standing tradition of efficient water management through canal and tank systems, and the presence of active Water Users' Associations (WUAs).

Assured irrigation has facilitated the cultivation of paddy, sugarcane, bananas, and high-value horticultural crops, complemented by the growth



Interview with Line Departments at EE Office, Erode, TamilNadu

of allied sectors such as dairy and poultry. Women's participation in income-generating activities has risen markedly—from about 5 per cent to nearly 20 per cent—largely through self-help groups (SHGs), kitchen gardens, and food processing units supported by state programmes like Mahalir Thittam.

Social gains are equally pronounced. Reliable domestic water supply has improved hygiene, reduced disease incidence, and lowered women's drudgery. School attendance, particularly among girls, has increased due to reduced involvement in other household activities and improved household affordability. Although input costs have risen moderately, these are outweighed by higher yields and market access through improved rural connectivity and local collection centres.

Overall, the Lower Bhavani example exemplifies Tamil Nadu's integrated irrigation-human development nexus, where water infrastructure contributes simultaneously to productivity, gender equity, and social advancement.

7.1.2 Kerala – Kallada Irrigation Project: Smallholders, Collective Institutions, and Human Development

In Erathu village under the Kallada Irrigation Project, the benefits of irrigation have accrued within the distinct socio-economic fabric of Kerala—characterised by small, fragmented holdings, high literacy, and strong local institutions. Before the project, cultivation was largely rainfed and restricted to crops like bananas, coconuts, and arecanuts. The introduction of canal irrigation has stabilised cropping patterns, enhanced yields, and moderately increased household incomes, though large-scale diversification remains limited due to land and soil constraints.



FGD in the Kallada Project Area of Kollam, Kareepra Village, Kerala

A key outcome is the rise in women's participation—from 5 per cent to nearly 20 per cent—driven primarily by the Kudumbashree SHGs. These groups have enabled small-scale entrepreneurship and home-based production, even as women remain excluded from formal irrigation decision-making. The irrigation project has also reduced seasonal migration, improved household diets through kitchen gardens, and facilitated better school attendance among children.

However, challenges persist. Tail-end water inequity, incipient waterlogging, and soil degradation have emerged, while the adoption of micro-irrigation and organic practices remains limited. Nevertheless, Erathu demonstrates how, within Kerala's social context, irrigation contributes more to stability and social welfare than to radical agrarian transformation.

7.1.3 Telangana – Sri Ram Sagar Project: From Subsistence to Commercial Agriculture

The Sri Ram Sagar Project (SRSP) in Ponkal village, Nirmal district, represents the transformative impact of canal irrigation in the semi-arid Deccan region. Before the project, agriculture was rainfall-dependent with low-yield paddy cultivation and widespread seasonal migration. Post-project, the reliable water supply has enabled multi-cropping and the cultivation of commercial and high-value crops such as turmeric, cotton, maize, and vegetables.

This diversification, coupled with improved access to local markets and cooperatives, has significantly raised incomes and reduced vulnerability. Farmers have begun reinvesting in mechanisation and fertilisers, with SHGs providing microcredit and supporting small enterprises. The Rythu Bandhu support scheme and state-level investment in market linkages have further reinforced this momentum.

Indirect benefits are equally visible: reduced migration, improved groundwater levels, and better school attendance—especially for girls, as domestic water collection duties have declined. While women's representation in irrigation management remains limited, their economic contribution has grown. Environmental challenges such as waterlogging, excessive chemical use, and unequal tail-end distribution persist, but community-level coordination has mitigated major conflicts.

Overall, the SRSP typifies Telangana's irrigation-led rural commercialisation, where water infrastructure

serves as a platform for income diversification, social upliftment, and gradual modernisation.

7.1.4 Maharashtra – Krishna Irrigation Project: Irrigation-Industry Linkages and Rural Modernisation

In Koregaon village, Satara district, the Krishna Irrigation Project illustrates the Maharashtra model of irrigation-driven agro-industrial growth. Canal irrigation has transformed local agriculture from low-yield cereals (sorghum, millet) to high-value sugarcane, wheat, and vegetables. The presence of a nearby sugar factory and the APMC market has provided direct market access, improved price realisation, and generated off-farm employment in transport, input supply, and small trading.

The socio-economic effects extend beyond agriculture. School enrolment now stands at nearly 100 per cent, with several youths employed in formal sectors, including the armed forces—a testament to long-term improvements in human capital. Reliable irrigation has also improved sanitation, reduced waterborne diseases, and alleviated women's household drudgery.

The adoption of drip irrigation for sugarcane reflects the region's innovative approach to managing water scarcity, though issues such as canal breaches and maintenance deficits remain. Overall, the Krishna project demonstrates how irrigation can anchor a multi-sectoral rural transformation, blending agricultural growth with industrial linkages, educational advancement, and social mobility.



Field Visit, Ramapur South Goa, (Salauli Dam)

7.1.5 Gujarat – Hathmati Irrigation Project: Community Ownership and Water Governance

The Hathmati Irrigation Scheme in Sonasan village, Sabarkantha district, exemplifies Gujarat's distinctive community-based irrigation governance model. The assured canal supply, combined with improved groundwater recharge, now supports 3-4 crop cycles annually, including cash crops like potatoes and sugarcane.

The most striking feature is the villagers' active participation in maintaining canals and ponds, reflecting a strong sense of ownership and collective responsibility consistent with Gujarat's participatory irrigation management ethos. Reliable irrigation has strengthened local agri-businesses and enabled year-round employment, thereby reducing seasonal migration.

The FGDs reveals 100 per cent school enrolment, improved health outcomes, and enhanced women's engagement in cultivation, though formal SHG activity is limited. Environmental outcomes are largely positive—stable groundwater levels, selective adoption of drip systems, and better sanitation conditions.

Sonasan's experience demonstrates how irrigation, when combined with local initiative, can drive

sustainable and socially cohesive development, balancing productivity gains with environmental stewardship.

7.1.6 Uttar Pradesh – Deokali Irrigation Project: Emerging Gains in the Gangetic Plains

In Khajuhan village, under the Deokali Pump Canal Project in eastern Uttar Pradesh, irrigation has begun to deliver both economic and social dividends in a region traditionally lagging in infrastructure and institutional capacity. Consistent water availability now allows up to three cropping cycles annually, supported by mechanised farming practices.

The resulting rise in incomes has spurred small-scale entrepreneurship, particularly among women engaged in tailoring, dairy, and retail activities. The project has enhanced school attendance, while equitable water distribution has strengthened community cooperation.

Environmental conditions have improved, with stabilised groundwater tables and increasing use of micro-irrigation and organic practices. The Deokali case signifies the onset of first-generation, irrigation-led transformation in the Gangetic belt—where water infrastructure is beginning to generate inclusive growth and gender-sensitive livelihood diversification.



FGD at Penna Reservoir, Varigonda Village of Nellore District, Andhra Pradesh



Field Visit to the IGNP Project in the Bikaner District of Rajasthan

7.1.7 Bihar – Western Sone High-Level Canal: Latent Potential, Uneven Realisation, and Infrastructure First Irrigation Limits

In Kanerkala village under the Western Sone High-Level Command, the irrigation canal has created potential rather than fully realised gains, largely because water delivery is irregular, infrastructure has deteriorated, and maintenance is absent. Although nearly 90 per cent of the cultivable land is nominally covered by the canal system, the seasonal and unpredictable release of water means that farmers cannot reliably plan agricultural operations. As a result, cropping patterns remain dominated by traditional staples, such as paddy and wheat, with very limited diversification despite fertile soil and farmer willingness to experiment. Input intensity has increased (through the greater use of fertilisers and rabi mechanisation), yet productivity improvements remain inconsistent and income gains are modest and unstable.

The most notable indirect benefit has been labour absorption and livelihood security rather than agricultural transformation. Reliable water supply, even if partial, has expanded opportunities for landless workers in sowing, weeding, and harvesting, while women's participation in informal economic activities has risen, though they remain excluded from irrigation governance. Drinking water availability has improved for some households, but only 40-50 per cent enjoy year-round access, and groundwater stress during summer requires costly deep boring, underscoring ecological fragility.

Education indicators show rising enrolment, but learning quality remains poor due to infrastructural gaps and recurrent flood-like conditions around school premises when canals overflow or remain unrepaired. Migration continues at moderate levels, with around 10 per cent of young adults engaging in seasonal work outside the state, reflecting limited local economic diversification. Market linkages are weak, and farmers rely on itinerant traders who purchase at discounted rates, as the nearest mandi lies 10 km away and village-level aggregation is absent.

Kanerkala' s experience highlights a central lesson that, infrastructure without governance delivers partial and uneven benefits. Poor canal linings, breaches, the absence of water-control structures, and lack of panchayat-level maintenance limit both direct agricultural outcomes and wider socio-economic spillovers. Yet villagers consistently note that with timely water release, better canal upkeep, and small-scale lift/boring facilities for tail-end and unconnected plots, the region could achieve substantial productivity gains, and stronger nonfarm linkages. At present, the canal serves as a stabilising asset, but not yet as an engine of rural transformation, which reflects the importance of operations and maintenance.

7.1.8 Manipur - Loktak Lift Irrigation Project: Year-round Vegetable Economy and Women's Time-Use Gains

Khoijuman Khullen under the Loktak Lift Irrigation Project presents a markedly different irrigation story from the rest of India. Here, the



Command Village in Loktak Lift Irrigation Area of Bishnupur Block in Imphal District Manipur



FGD in Loktak Lift Irrigation Area in Bishnupur Block of Imphal District, Manipur Manupuof Rajasthan

reactivation of the lift system after more than a decade of non-functionality has supported an already evolving agrarian shift which is the rise of a year-round vegetable-based economy, anchored less in water abundance and more in the community's adaptive farming practices. Historically dependent on the Thongjaorok River and monsoon flows, the village now uses the revitalised low canal as a supplementary and demand-based source, enabling farmers to expand cultivation of high value crops such as cauliflowers, beans, tomatoes, cucumbers, and traditional vegetables that fetch reliable market prices. Unlike many command areas where diversification is modest, Khoijuman has moved from single- cropping to intensive multi-cropping, with farmers adjusting sowing calendars and using improved varieties to stabilise production. These changes have yielded more frequent crop sales and noticeably steadier household incomes.

The most significant indirect benefit is the dramatic reduction in women's drudgery and the resultant improvement in household wellbeing. With piped connections, public standposts, and Public Health Engineering Department's water supply complementing the irrigation canal, women no longer spend long hours fetching water, time that is now redirected towards childcare, household activities, and in some cases, light agricultural work. Waterborne diseases have reportedly declined, and sanitation has improved, although the poorest households still depend on tanker purchases.

Educational outcomes, too, have benefitted indirectly from higher and more stable incomes, as parents increasingly invest in schooling, and children's involvement in other activities has reduced. While out-migration is low in Manipur generally, villagers noted a further decline in seasonal mobility as vegetable cultivation now provides reliable earnings.

Unlike other irrigation command regions, Khoijuman exhibits strong collective labour traditions and relatively inclusive water governance, with no reported caste or class disparities. However, the absence of local processing units, limit nonfarm enterprises, and the long distances to major mandis (Imphal, Bishnupur, Moirang) constrain value addition. Environmental risks remain tied to natural calamities rather than irrigation, though flash floods occasionally disrupt farming.

Extension services from the Agriculture Department and NGOs are active, strengthening the uptake of improved seeds and integrated pest management. Yet the adoption of advanced irrigation technologies such as drip or sprinklers remains limited. Overall, Khoijuman Khullen demonstrates how revived irrigation when combined with community cooperation and a strong market-oriented vegetable economy can enhance incomes, improve women's wellbeing, and reduce livelihood vulnerability, even without large-scale infrastructural expansion.

7.2 CROSS-REGIONAL SYNTHESIS

Across the six regions, irrigation emerges not merely as a driver of agricultural productivity but as a platform for inclusive socio-economic development (Table 7.1.). The nature and depth of indirect benefits, however, differ across regional contexts:

Table 7.1: Regional variation in outcomes – evidence from FGDs

Region	Representative Project	Dominant Outcomes	Key Challenges
Southern (Tamil Nadu, Kerala)	Lower Bhavani, Kallada	Multi-cropping, improved human development, women's empowerment	Environmental stress, smallholder constraints
*Deccan (Telangana, Maharashtra)	SRSP, Krishna	Commercial agriculture, agri-industrial linkages, rural modernisation	Overuse of inputs, canal maintenance, inequitable water access
Western (Gujarat)	Hathmati	Community-led water management, groundwater recharge, agri-business growth	Limited SHG institutionalisation
Northern (Uttar Pradesh)	Deokali	Mechanised multi-cropping, women's enterprises, equitable access	Need for sustained governance and technical capacity
Eastern (Bihar)	Western Sone High-Level Command (Kanerkala)	Near-universal irrigation coverage (90% of command); increased use of modern machinery; strong labour absorption benefits for landless; high social cohesion and absence of caste conflicts	Highly seasonal canal flows; severe maintenance deficits; poor market access and price realisation; declining soil quality
North-Eastern (Manipur)	Loktak Lift Irrigation Project (Khoijuman Khullen)	Year-round vegetable-based economy; high diversification; strong education uptake; reduced women's drudgery due to PHED and canal water; community-led labour cooperation	Inadequate irrigation functionality; limited non-farm diversification; climate vulnerability; low adoption of modern technology

Note: The Deccan region is treated as mixed (western–southern) due to its transitional agro-climatic and institutional features.
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

7.3 CONCLUSION

The FGDs underscore that while the most immediate and visible impacts of irrigation are reflected in enhanced agricultural productivity and cropping intensity, and the adoption of multi-cropping practices, the more enduring and transformative outcomes extend far beyond the farm. Over time, reliable irrigation fosters a chain of secondary effects that manifest in the spheres of social welfare, women's empowerment, education, health, and livelihood diversification. In several project villages, access to assured water supply has enabled households to shift from subsistence farming to market-oriented cultivation, expand kitchen gardens, and invest in livestock or micro-enterprises, thereby improving food security and household incomes.

Women, in particular, emerge as key beneficiaries of this transformation. With reduced drudgery in fetching water and increased participation in agricultural and allied activities, their role in decision-making—both within the household and



FGD in the Command Village Area of Ajoy Barrage, Jamtara, Jharkhand

in community-level institutions—has strengthened noticeably. Improvements in irrigation have also contributed to higher school attendance among children, as the household income stability improves, resulting in affordable education for children. Likewise, better nutrition and hygiene outcomes are observed due to improved cropping diversity and water availability for domestic use.

These multidimensional impacts, however, are not uniform across regions. They are mediated by agro-climatic conditions, institutional capacities (such as functioning Water User Associations and Panchayat coordination), and underlying social structures including caste, land ownership, and gender norms. In regions with strong institutional linkages and inclusive governance, irrigation catalyses a virtuous cycle of economic and social progress. Conversely, in areas with weaker institutional presence or skewed land distribution, the benefits tend to be more concentrated and less sustainable. On the other hand, tourism-related observations emerging from FGDs are observed to be localised and project-specific.

In sum, the comparative village narratives highlight that irrigation's indirect benefits are profoundly context dependent but universally transformative. The evidence reinforces the centrality of water infrastructure not merely as a driver of agricultural growth, but as a foundational pillar of rural human development serving simultaneously as an economic catalyst and a social equaliser in India's diverse rural landscape.

CHAPTER 8

Quantifying the Indirect Health Benefits of Irrigation Projects in India: A DALY-Based Analysis

8.1 INTRODUCTION

As part of assessing the indirect and intangible benefits of irrigation projects, the reduction particularly in water-borne diseases is quantified using the Disability-Adjusted Life Years (DALY) metric. This approach estimates the health benefits resulting from improved water availability, sanitation, and hygiene conditions in the command areas (CMD) of irrigation projects, compared to the non-command areas (NCMD). Irrigation infrastructure is critical not only for enhancing agricultural productivity and water security but also for generating significant indirect benefits, particularly in the domain of public health. Among these, the reduction in waterborne diseases, such as diarrhoea, represents a vital but often overlooked dimension of the development impact. This study applies the Disability-Adjusted Life Years methodology to quantify the health co-benefits associated with major irrigation projects in India, using perception-based disease incidence data collected by the National Council of Applied Economic Research (NCAER).

8.2 METHODOLOGICAL FRAMEWORK

To quantify the health benefits, this study adopts a DALY-based approach focusing on diarrhoeal/water-borne disease as a representative water-borne illness. DALY is a standardised metric used by the World Health Organization (WHO) and Global Burden of Disease (GBD) studies to quantify the burden of disease, combining both, years of life lost (YLL) and years lived with disability (YLD).[37] Since water-borne disease rarely leads to mortality in the studied context, this analysis focuses on the YLD component.

The perceived incidence of diarrhoeal and water-borne diseases was assessed in both the command areas — regions benefiting from irrigation — and the non-command areas — regions without such interventions. The analysis is based on perception-based survey data collected from local residents, who were asked whether they observed a high or increasing occurrence of diarrhoeal diseases in their community. This approach helps capture the community's perspective on the potential health impacts of irrigation projects.

[37]Murray, C.J.L. & Lopez, A.D., eds. 1996. The Global Burden of Disease: A Comprehensive Assessment of Mortality and Morbidity from Diseases, Injuries, and Risk Factors in 1990 and projected to 2020. Boston: Harvard University Press.
World Health Organization. 2000. The World Health Report 2000 — Health Systems: Improving Performance. Geneva: WHO. (This includes discussions of the burden of disease metrics, including DALYs.)
Vos, T., Lim, S.S., Abbafati, C., et al. 2020. 'Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019.' The Lancet, 396(10258):1204–1222. doi:10.1016/S0140-6736(20)30925-9

The calculation of Disability-Adjusted Life Years involves two main components:

1. Years of Life Lost (YLL) due to premature death, and
2. Years Lived with Disability (YLD) caused by illness or poor health.[38]

Since deaths from diarrhoea are relatively low in the Indian context, this study considers only the YLD component. In other words, the analysis focuses on the burden of illness — the time people spend living with diarrhoea-related health problems — rather than on premature deaths.

YLD = Number of Cases (episodes) * Disability Weight (DW) * Duration (in years) **[8.1]**

This formula is used to estimate the total health burden caused by a disease when mortality is negligible.

Here is what each term means:

- Number of Cases: The total number of people affected by the disease (in this case, diarrhoea and each affected person has one episode of the disease);
- Disability Weight (DW): A factor that reflects the severity of the disease on a scale from 0 to 1, where 0 means perfect health and 1 means death. It indicates how much the disease reduces quality of life; and
- Duration (in years): The average period for which the disease lasts in an individual case (i.e., in one episode).

By multiplying these three components, we get the Years Lived with Disability (YLD) — that is, the total number of healthy years lost due to the disease in the population. Since diarrhoea rarely causes death in the study area, YLD is taken as equal to a loss of health life years, i.e., DALY lost, representing the full disease burden.

Table 8.1 shows how diarrhoea affects children under five years of age, grouped by the severity of the illness — mild, moderate, or severe. Mild cases make up the majority (about 65% of all cases). These children have relatively minor symptoms and remain sick for around four days on average. Moderate cases account for about 35 per cent of the total cases, lasting for a similar duration (about four days) but causing greater discomfort and with a greater health impact. Severe cases are very few (only 0.5%), but are much more serious, lasting around eight days and having the highest health burden.[39] The Disability Weight (DW) increases with severity — from 0.074 for mild to 0.247 for severe — showing that more serious cases lead to a greater loss of healthy life.

Table 8.1: Severity distribution, disability weights, and duration of diarrhoeal episodes among children under five

Severity	Disability Weight (DW)	Proportion of Cases (Under 5) (%)	Average Sick Days
Mild	0.074	64.80	4.3
Moderate	0.188	34.70	4.3
Severe	0.247	0.50	8.4

Source: Lamberti, L. M., Fischer Walker, C. L., & Black, R. E. (2012). 'Systematic Review of Diarrhea Duration and Severity in Children and Adults in Low- And Middle-Income Countries.' *BMC Public Health*, 12, 276. https://doi.org/10.1186/1471-2458-12-276

Building on the information in Table 8.1, which shows different severity levels of diarrhoea among children under five, the same approach was applied to the overall population (including all age groups):

Average days lose due to disability (DLD) = (0.648*0.074*4.3) + (0.347*0.188*4.3) +(0.005*0.247*8.4) = 0.4971 **[8.2]**

An affected person on average loses half a day per episode of illness due to disability.

[38]World Health Organization (WHO). 2020. Metrics: Disability-Adjusted Life Year (DALY).https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158

Murray, C. J. L., & Lopez, A.D. 1996. The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and projected to 2020. Harvard School of Public Health. GBD. 2019. Diseases and Injuries Collaborators. (2020). 'Global Burden of 369 Diseases and Injuries in 204 Countries and Territories, 1990–2019.' The Lancet, 396(10258), 1204–1222. https://doi.org/10.1016/S0140-6736(20)30925-9

8.3 DALY SAVED COMPUTATION STEPS

The methodological framework for computing DALYs saved provides a systematic approach to quantify the health benefits resulting from improved water management in irrigation command areas. It aims to measure the reduction in the burden of water-borne diseases—particularly diarrhoea—by comparing their prevalence between command and non-command regions. The method involves calculating the difference in disease incidence across these areas and translating this into DALYs to capture overall health gains attributable to irrigation interventions. Through this approach, the analysis links improved access to irrigation with reduced disease occurrence, healthier households, and enhanced well-being. The following sections describe each computation step in detail, from estimating changes in disease incidence to deriving the total DALYs saved (Table 8.2).

Table 8.2: Systematic approach to quantify health benefits resulting from improved water management

Steps	Methodology
Step 1	Increase in water-borne disease in command areas (CMDs) (proportion)
Step 2	Increase in water-borne disease non-command areas (NCMDs) (proportion)
Step 3	Difference in proportions (NCMD - CMD)
Step 4	Saved HH = Total HH in CCA * Diff in proportion
Step 5	DALY Saved = Saved HH *DLD/365 (assuming one person in the family is affected)

8.3.1. Step 1: Proportion Difference

In Step 1, the analysis measures the difference in the proportion of households reporting diarrhoeal illness between the command (CMD) and non-command (NCMD) areas for each irrigation project. This difference, represented as $\Delta P = P_NCMD - P_CMD$, helps identify whether access to irrigation has any influence on reducing diarrhoeal cases. Here, P_CMD refers to the share of households affected by diarrhoea in the command area, while P_NCMD represents the same for the non-command area. A positive value of ΔP indicates that diarrhoeal illness is more prevalent in non-command areas, suggesting that irrigation and related water management in command areas may contribute to improved health and sanitation outcomes.

$$\Delta P = P_NCMD - P_CMD \quad [8.3]$$

Table 8.3: Comparison of perceived diarrhoeal illness in CMD and NCMD regions

Irrigation Project	Region	Command Proportion (%)	Non-Command Proportion (%)	Proportional Difference (%)
Adwa Canal Irrigation Project	North	10.0	45.0	35.0
Chambal Irrigation Project	North	25.0	35.0	10.0
Deokali Irrigation Project	North	6.0	30.0	24.0
Haripur Reservoir Irrigation Project	North	26.9	30.0	3.1
Hindon Krishi Irrigation Project	North	17.0	29.3	12.3
IGNP Irrigation Projects	North	8.1	15.0	6.9
Makhu Irrigation Project	North	37.4	52.5	15.1
Matatila Irrigation Project	North	34.4	45.0	10.6
Sharda Sahayak Irrigation Project	North	16.9	37.5	20.6
Jayakwadi (Recovered)	West	18.9	20.0	1.1
Ukai	West	70.0	79.5	9.5
Kuttiyadi	South	26.5	40.0	13.5
Mayurakshi Jharkhand	East	9.0	12.8	3.8
Sakri lower Valley	East	0.0	2.5	2.5
Loktak Lift (MR)	North East	3.0	22.5	19.5

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

The analysis of perceived diarrhoeal illness across irrigation projects reveals a consistent pattern of lower reported cases in command (CMD) areas compared to non-command (NCMD) areas, suggesting that irrigation development has contributed to improved public health outcomes. Across almost all projects, households in command areas report a lower prevalence of diarrhoeal illness, indicating better access to cleaner and safer water, improved sanitation practices, and possibly reduced dependence on contaminated surface sources.

The Adwa Canal Irrigation Project shows the largest difference (35.0 percentage points), implying substantial health benefits in the irrigated zone. Other projects such as Deokali (24.0%), Sharda Sahayak (20.6%), and Loktak Lift (19.5%) also record notable positive differentials, reinforcing the association between irrigation infrastructure and reduced water-borne disease risks. Even in cases where the proportionate difference is modest—such as Haripur Reservoir (3.1%), Jayakwadi (1.1%), and Mayurakshi (3.8%)—the direction of change remains consistent, with command areas reporting fewer incidences of diarrhoeal illness.

Collectively, these findings underline the broader health co-benefits of irrigation interventions, where enhanced water management and improved household water security in command regions contribute to lowering the incidence of diarrhoeal and related water-borne illnesses.

8.3.2 Step 2: Estimation of Affected Population

In Step 2, the calculation estimates how many households benefitted from reduced diarrhoeal illness due to irrigation. This is done using the formula:

$$\text{Saved HH} = \text{Total Households} * \Delta P \qquad [8.4]$$

Here, Saved HH represents the number of households that avoided diarrhoeal illness in the command area compared to the non-command area. In simple terms, by multiplying the total number of households by the difference in diarrhoea rates (ΔP), we can estimate how many families were protected from the disease because of improved conditions in irrigated areas.

Table 8.4: Saved households: Estimated number of households avoiding diarrhoeal illness in command areas compared to non-command areas

Irrigation Project	Region	Proportion Diff	Total Households	Saved HH
Adwa Canal Irrigation Project	North	35.0	10,523	3,683
Chambal Irrigation Project	North	10.0	1,40,787	14,079
Deokali Irrigation Project	North	24.0	50,002	12,000
Haripur Reservoir Irrigation Project	North	3.1	5,375	168
Hindon Krishi Irrigation Project	North	12.3	152,799	18,746
IGNP Irrigation Projects	North	6.9	47,721	3,281
Makhu Irrigation Project	North	15.1	10,447	1,580
Matatila Irrigation Project	North	10.6	89,187	9,476
Sharda Sahayak Irrigation Project	North	20.6	2,315,614	4,77,595
Jayakwadi (Recovered)	West	1.1	79,010	894
Ukai	West	9.5	6,79,345	64,451
Kuttiyadi	South	13.5	65,828	8,867
Mayurakshi Jharkhand	East	3.8	97,403	3,721
Sakri lower Valley	East	2.5	26,506	663
Loktak Lift (MR)	North East	19.5	1,10,916	21,595

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

Table 8.4 quantifies the health benefits of irrigation interventions by estimating the number of households in command areas that potentially avoided diarrhoeal illness compared to those in non-command areas. The estimates combine the difference in reported illness prevalence (Proportion

Diff) with the total number of households in each project area to calculate the Saved Households (Saved HH) — representing households that likely benefitted from improved water access, sanitation, and hygiene associated with irrigation development.

The results indicate substantial variation across projects, depending on both the scale of the project and the size of the covered population. The Sharda Sahayak Irrigation Project in northern India shows the largest health impact, with a 20.6 percentage point difference, translating to approximately 4,77,595 households reporting lower diarrhoeal incidence in command areas. Similarly, Ukai (64,451 households), Hindon Krishi (18,746 households), and Loktak Lift (21,595 households) also show large positive impacts.

Smaller projects such as Haripur Reservoir (168 households) and Sakri Lower Valley (663 households) record modest absolute numbers of beneficiaries, primarily due to their limited population coverage despite observable positive differentials.

Overall, these findings highlight that irrigation projects not only enhance agricultural productivity and livelihoods but also yield significant public health co-benefits, reducing the burden of water-borne diseases and improving well-being in rural communities.

8.3.3 Step 3: DALY Saved

In Step 3, the calculation estimates the health benefits of irrigation in terms of Disability-Adjusted Life Years saved. The formula used is:

DALY = Saved HH * DLD/365 (assuming one affected person per family) **[8.5]**

Here:

Saved HH = number of households protected from diarrhoeal illness (from Step 2)

DLD = average number of disable days per episode per affected person

By applying this formula, we convert the reduction in diarrhoeal cases into total years of healthy life gained for the population. Essentially, it shows how many healthy life years were preserved because households in irrigated areas experienced fewer or less severe cases of diarrhoea.

Table 8.5: Disability-adjusted life years (DALYs) saved due to irrigation

Irrigation Project	Region	Saved Years
Adwa Canal Irrigation Project	North	5.0
Chambal Irrigation Project	North	19.2
Deokali Irrigation Project	North	16.3
Haripur Reservoir Irrigation Project	North	0.2
Hindon Krishi Irrigation Project	North	25.5
IGNP Irrigation Projects	North	4.5
Makhu Irrigation Project	North	2.2
Matatila Irrigation Project	North	12.9
Sharda Sahayak Irrigation Project	North	650.4
Jayakwadi (Recovered)	West	1.2
Ukai	West	87.8
Kuttiyadi	South	12.1
Mayurakshi Jharkhand	East	5.1
Sakri lower Valley	East	0.9
Loktak Lift (MR)	North East	29.4

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

Table 8.5 illustrates the estimated Disability-Adjusted Life Years saved across irrigation projects, capturing the health gains associated with a reduced incidence of diarrhoeal and related water-borne diseases in command areas. DALYs saved represent the cumulative improvement in healthy life years resulting from enhanced water quality, sanitation, and reduced disease exposure due to irrigation infrastructure.

The results reveal significant variation across projects in both magnitude and regional distribution. The Sharda Sahayak Irrigation Project demonstrates the largest health benefit, with 650.4 healthy life years saved, reflecting the extensive coverage and strong health co-benefits of large-scale irrigation systems. Other notable projects include Ukai (87.8 years), Hindon Krishi (25.5 years), and Loktak Lift (29.4 years), all showing substantial reductions in disease burden.

Medium-sized projects such as Deokali (16.3 years), Matatila (12.9 years), and Adwa Canal (5.0 years) also indicate meaningful improvements in population health within their respective command areas. In contrast, smaller schemes like Haripur Reservoir (0.2 years) and Sakri Lower Valley (0.9 years) show relatively modest impacts, consistent with their limited scale and beneficiary reach.

Overall, the findings show that irrigation interventions generate not only economic and agricultural benefits but also significant public health dividends, contributing to improved quality of life and reduced disease-related productivity losses in rural communities.

8.4 LIMITATIONS AND ASSUMPTIONS

The methodology used for estimating DALYs saved involves several assumptions and inherent limitations that may influence the accuracy and interpretation of results (Table 8.6).

Table 8.6: Limitations and assumptions used in DALY calculation

S. No.	Limitations and Assumptions
1	Overestimation of command and non-command proportions, as increased diseases and expenses could be from another ailment.
2	Assumption that from each HH, only one member got sick in a particular year
3	Assumption that only one person got sick only once in the entire year; thus, instances of reoccurrence of the disease not accounted for
4	Assumption that the non-command village selection is correct; if it is wrong, the comparison fails.

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects,* 2025

First, there is a potential overestimation of disease prevalence in both command and non-command areas, as reported cases of increased illness and healthcare expenses may include ailments unrelated to water-borne diseases such as diarrhoea. Second, the analysis assumes that only one household member falls ill in a given year, which may underestimate the true disease burden in households where multiple members experience similar illnesses. Third, the reoccurrence of diseases has not been considered—each individual is assumed to have contracted the illness only once during the year—potentially ignoring repeated or chronic episodes that could significantly increase the total health burden. Lastly, the validity of the comparison between command and non-command areas heavily depends on the correct selection of non-command villages. Any mismatch or bias in the selection process could distort the observed differences and lead to misleading conclusions about the health benefits of irrigation interventions.

8.5 CONCLUDING REFLECTIONS

The estimation of households protected from diarrhoeal illness and the corresponding Disability-Adjusted Life Years (DALYs) saved provides a quantitative perspective on the broader social dividends of irrigation infrastructure. Beyond its direct economic impacts on crop productivity and income, irrigation plays a vital role in improving rural health outcomes by enhancing access to cleaner water, facilitating better sanitation practices, and reducing exposure to contaminated water sources.

The findings across 15 irrigation projects demonstrate substantial regional variation in health benefits, driven largely by differences in project scale, household coverage, and contextual sanitation conditions. Large, multi-district systems such as the Sharda Sahayak Irrigation Project exhibit much higher health gains, suggesting that the magnitude of infrastructural reach and integration with local

water management systems amplifies positive outcomes. Mid-sized projects like Hindon Krishi, Loktak Lift, and Ukai also reveal measurable reductions in disease burden, highlighting the role of medium-scale irrigation schemes in fostering localised health resilience. Even smaller projects, though showing modest numerical gains, signify tangible improvements in household well-being within their limited operational areas.

By translating reductions in diarrhoeal prevalence into DALYs saved, the analysis underscores irrigation's indirect contribution to human capital formation. Each healthy life-year preserved reflects not only reduced morbidity but also enhanced productivity, fewer workdays lost, and improved educational attendance—particularly in rural settings where illness often disrupts livelihoods and learning.

Nevertheless, these estimates must be viewed within the framework of the methodological assumptions and limitations acknowledged in this analysis. Simplifying assumptions—such as one illness episode per household, or the exclusion of recurrent cases—may lead to conservative or, in some contexts, overstated outcomes. Similarly, the robustness of comparisons between command and non-command areas hinges critically on the accuracy of village selection and the reliability of self-reported health data. Recognising these caveats helps ensure that the results are interpreted as indicative rather than absolute measures of health improvement.

In essence, the evidence reinforces an important policy insight: irrigation investments yield multidimensional benefits—not only augmenting agricultural output but also delivering measurable public health and social welfare gains. Incorporating such health externalities into project appraisal frameworks could strengthen the economic rationale for integrated water resource management, encourage convergence with rural health and sanitation programmes, and advance the broader goal of sustainable rural development.

CHAPTER 9

Regional and National Workshops

9.1. INTRODUCTION

A series of Regional and National Workshops were organised as part of the study to assess the indirect and intangible benefits of irrigation projects in India. These workshops were conducted in collaboration with key stakeholders at the central and state levels, including policymakers, technical experts, and field practitioners.

The consultations provided a platform for deliberation on expanding traditional cost-benefit frameworks to incorporate wider socio-economic, environmental, and regional development impacts.

9.2. OBJECTIVES OF THE WORKSHOPS

- Present the NCAER study framework and methodology
- Obtain feedback from stakeholders across regions
- Identify region-specific irrigation challenges
- Refine the approach for inclusion of indirect and intangible benefits

9.3. SUMMARY OF WORKSHOPS

Region	Date	Location	States Covered
Northern	2 Feb 2026	New Delhi	Uttar Pradesh, Uttarakhand, Punjab, Haryana, Rajasthan, J&K
Western	9 Feb 2026	Pune	Maharashtra, Gujarat, Goa, Madhya Pradesh
Eastern & NE	13 Feb 2026	Guwahati	Assam, Bihar, Jharkhand, Odisha, Manipur
Southern	20 Feb 2026	Bengaluru	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Telangana
National	17 Mar 2026	New Delhi	20 States & UTs

9.4. REGIONAL CONSULTATIONS: KEY DISCUSSION POINTS

i. **Northern Region:** Focus on agricultural productivity, irrigation efficiency, and socio-economic indicators.

ii. **Western Region:** Emphasis on water-use efficiency, drought resilience, and diversification of livelihoods.

iii. **Eastern & North-Eastern Region:** Focus on flood management, irrigation linkages, and livelihood security.

iv. **Southern Region:** Discussions on water resource management, crop diversification, and sustainability.

9.5. NATIONAL WORKSHOP: KEY OUTCOMES

The National Workshop consolidated regional insights and facilitated discussion among policymakers, experts, and stakeholders from across the country.

There was broad agreement on the need to expand irrigation project appraisal frameworks to include indirect and intangible benefits such as employment generation, livelihood enhancement, environmental sustainability, and regional development.

The deliberations during the National Workshop played an important role in refining several key methodological aspects of the study. In particular, detailed discussions were held on the appropriate treatment of tourism-related effects, the interpretation and classification of groundwater recharge, and the need to clearly distinguish between different components of indirect benefits to avoid overlap. These exchanges provided valuable insights into how the analytical framework could be strengthened and made more consistent. The suggestions emerging from these discussions have been carefully incorporated into the final report, improving both conceptual clarity and the overall robustness of the methodology.

9.6. KEY FINDINGS AND POLICY IMPLICATIONS

The consultations across regional and national workshops highlighted several important considerations for advancing irrigation appraisal frameworks:

i. The need to move beyond conventional cost–benefit approaches and incorporate indirect and intangible benefits in a structured manner.

ii. The importance of recognising regional diversity in irrigation outcomes, reflecting variations in agro-climatic, institutional, and socio-economic conditions.

iii. The necessity of clearly distinguishing between different categories of benefits to avoid overlap and ensure methodological consistency.

iv. The role of improved data systems and field-based evidence in strengthening the reliability of such assessments.

These insights have informed the refinement of the analytical framework presented in this report. The detailed integration of these workshop insights into the analytical framework and conclusions of the study is presented in Chapter 9

9.7. ILLUSTRATIVE PHOTOGRAPHS FROM REGIONAL AND NATIONAL WORKSHOPS

The photographs below provide visual documentation of stakeholder participation and deliberations held during the regional and national workshops conducted as part of the study. These consultations brought together representatives from central and state governments, technical experts, and local stakeholders, and played an important role in refining the analytical framework along with validating the study findings.

Workshop 1 | a: Northern Regional Workshop (New Delhi, CWC Head Office, 2 February 2026): Stakeholder consultations on irrigation efficiency, agricultural productivity, and socio-economic outcomes



b: Northern Regional Workshop (New Delhi, CWC Head Office, 2 February 2026): Contd...



Workshop 2 | a: Western Regional Workshop (Pune, National Water Academy, 9 February 2026): Discussions on water-use efficiency, drought resilience, and livelihood diversification



b: Western Regional Workshop (Pune, National Water Academy, 9 February 2026): Contd...



Workshop 3 | a: Eastern & North-Eastern Workshop (Guwahati, Bramhaputra Board, 13 February 2026): Focus on flood management, irrigation linkages, and livelihood security



b: Eastern & North-Eastern Workshop (Guwahati, Bramhaputra Board, 13 February 2026): Contd...



Workshop 4 | a: Southern Regional Workshop (Bengaluru, Vikasa Soudha, 20 February 2026): Deliberations on water resource management and sustainability



4b: Southern Regional Workshop (Bengaluru, Vikasa Soudha, 20 February 2026): Contd...



Workshop 5 | a: National Workshop (New Delhi, NCAER, 17 March 2026): Consolidation of regional insights and methodological discussions on indirect benefit assessment



5b: National Workshop (New Delhi, NCAER, 17 March 2026): Contd...



CHAPTER 10

Groundwater Sustainability: A Cross-Regional Assessment

10.1: INTRODUCTION

Groundwater sustainability emerged as an important policy issue during the consultative process undertaken as part of this study. During both the Northern Regional Workshop and the National Workshop, representatives—particularly from Punjab—highlighted the growing dependence on groundwater extraction in non-command areas and emphasised the need to examine the broader implications of canal irrigation on groundwater resources. Subsequently, during the 9th and 10th Consultative Management Committee (CMC) meetings, it was suggested that the groundwater-related findings obtained from the primary household survey be further corroborated using secondary evidence published by the Central Ground Water Board (CGWB).

In response to these recommendations, the NCAER study undertook a comparative assessment of groundwater conditions across selected irrigation projects representing the Northern, Western, Southern, and Eastern regions of India. The analysis was designed to examine whether the groundwater-related patterns observed in the primary household survey were broadly consistent with independently observed groundwater trends under diverse agro-climatic and hydrogeological settings.

The assessment follows a common analytical framework across all selected irrigation projects. First, representative command and non-command villages were identified using Geographic Information System (GIS)-based mapping of the project command areas and the CGWB groundwater monitoring network. Second, household-level information collected through the NCAER primary survey was used to assess respondents' perceptions regarding changes in groundwater conditions. Finally, these findings were compared with groundwater-level observations obtained from the CGWB for the corresponding command and non-command locations.

It is important to note that the primary survey and the CGWB database differ in terms of village coverage, reference periods, and data collection methodologies. Consequently, the objective of the analysis is not to establish a one-to-one correspondence between the two datasets or to infer a direct causal relationship between canal irrigation and groundwater outcomes. Rather, the exercise seeks to examine whether the broad patterns emerging from the primary survey are consistent with independently observed groundwater trends and to assess the extent to which groundwater sustainability may be considered an important indirect environmental outcome associated with major irrigation projects.

The following sections present the groundwater analysis for the selected irrigation projects on a region-wise basis, followed by a cross-regional synthesis highlighting the key policy insights emerging from the comparative assessment.

10.2: REGIONAL ANALYSIS

10.2.1 Northern Region

To examine whether the groundwater level patterns observed in the primary survey for the northern region are broadly consistent with the trends reflected in the secondary data from CGWB, two irrigation projects in Punjab—Makhu Canal and Sirhind Canal—were selected for detailed analysis.

The analytical methodology commenced with the identification of appropriate command and non-command villages for each irrigation project. As the villages covered in the primary survey were not available in the CGWB secondary dataset, three command and three non-command villages were selected for each project using GIS to ensure a comparable spatial analysis. Subsequently, the groundwater trends of each selected village derived from the secondary data were examined to assess their consistency with the patterns identified in the primary survey.

10.2.1.1 Makhu Canal Irrigation Project – Punjab

The Makhu Canal is an important irrigation canal located in the state of Punjab. It serves agricultural blocks in and around the Ferozepur district, particularly including Ferozepur, Ghall Khurd, and Makhu, and plays a vital role in supporting irrigation and agricultural activities in the region.

NCAER conducted a primary survey of households in command and non-command areas in 2025. In this survey, Question 54 for the command areas and Question 52 for the non-command areas specifically asked households about the impact of irrigation on groundwater levels in command regions and the effect that the lack of irrigation facilities has had on the groundwater table in non-command regions, respectively. The table below presents the responses and findings pertaining to these questions for the five command villages and four non-command villages surveyed.

Table 10.1: Primary Survey findings - Makhu

Command Villages		
Block	**Village name**	**Decline %**
Ferozpur	Bhagwanpura	45%
	Hamidwala	45%
	Katora	15%
Ghall Khurd	Hastiwala	50%
	Changali Qadim	55%
Non-Command Villages		
Block	**Village name**	**Decline %**
Makhu	Bhedanwala	80%
	Maujgarh	30%
Sultanpur Lodhi	Bishanpur	50%
	Pattiwaras	30%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

Based on the responses from both command and non-command households, it can be inferred that, on average, 42% of respondents in the command villages reported a deterioration in the groundwater table, compared to approximately 50% of the respondents in the non-command villages, suggesting a relatively higher incidence of perceived groundwater deterioration in non-command areas.

To assess whether these findings are broadly consistent with the long-term groundwater trends observed over the years, groundwater table data published by the Central Ground Water Board for the period 1991 to 2020 was analysed, subject to data availability. Table 10.2 below presents the command and non-command villages, along with their corresponding blocks, that were considered for this analytical exercise.

Table 10. 2: GIS- based list of command and non-command villages - Makhu

Command Region		
S.N.	**Block**	**Village**
1	Ferozepur	Dhulchi Ke
		Rukne Wala
		Wagewala
Non-Command Region		
S.N.	**Block**	**Village**
2	Dhilwan	Chakoki
		Hamira
		Minai Bolan

Source: *Central Ground Water Board database*

To study and analyse the trend in groundwater levels across these villages, a trend analysis was conducted by plotting groundwater level values over time for each village and subsequently examining the slope and steepness of their respective trendlines.

Figure 10.1, Figure 10.2, and Figure 10.3 illustrate the trend in groundwater levels for the command villages of Dhulchi Ke, Rukne Wala, and Wagewala, respectively. The trendlines for these villages, although positively sloped, are not particularly steep, indicating that groundwater levels have remained relatively stable over the period under consideration. On the other hand, Figure 10.4, Figure 10.5, and Figure 10.6 illustrate the trend in groundwater levels for the non-command villages of Chakoki, Hamira, and Minai Bolan, respectively. A simple visual comparison of the trendlines of these non-command villages with those of the command villages reveals that, although both exhibit a positive slope, the trendlines for the non-command villages are considerably steeper, indicating a relatively faster decline in groundwater levels.

These findings broadly corroborate the patterns observed in the primary survey, wherein a larger proportion of respondents in the non-command areas reported groundwater depletion attributable to inadequate irrigation facilities, as compared to respondents in the command areas, while also serving as a connecting link between the groundwater data for the period 1991–2020 and the ground realities observed during the primary survey conducted in 2025. In essence, these findings suggest a relatively higher incidence of groundwater stress in non-command areas compared to command areas.

Groundwater level analysis – Makhu Canal Irrigation Project

Command Region	Non-Command Region

Figure 10.1: Groundwater Level - Dhulchi Ke

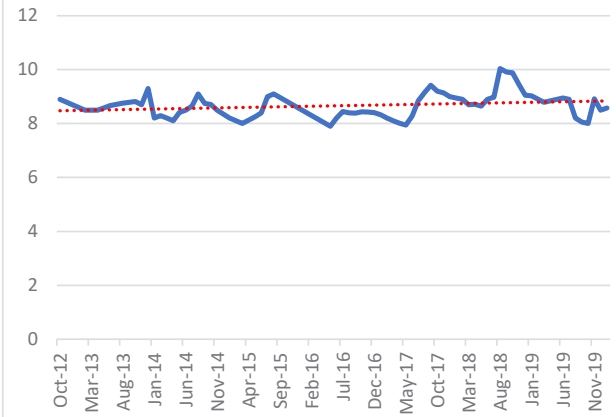


Figure 10.4: Groundwater Level - Chakoki

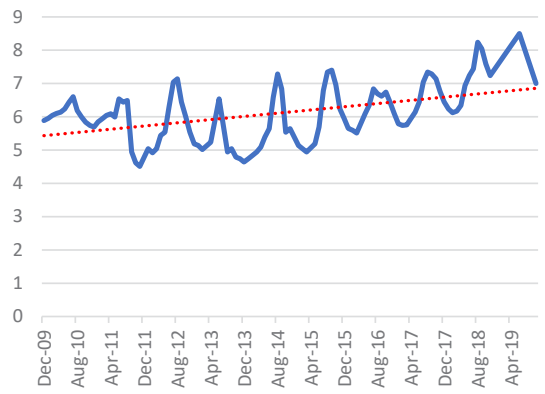


Figure 10.2: Groundwater Level - Rukne Wala

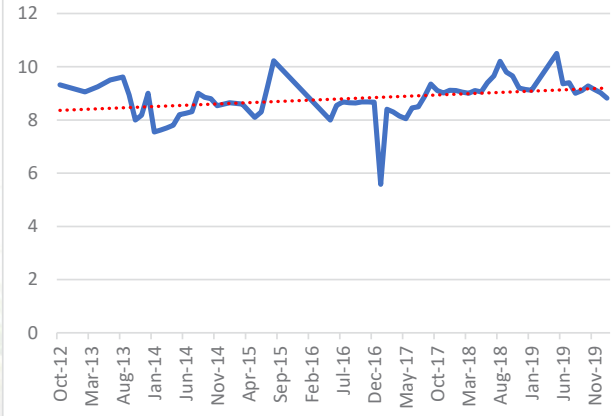
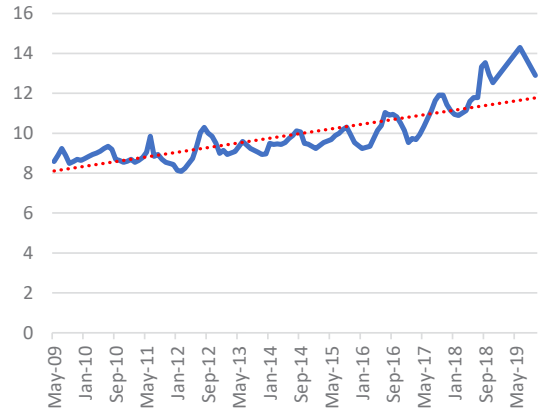
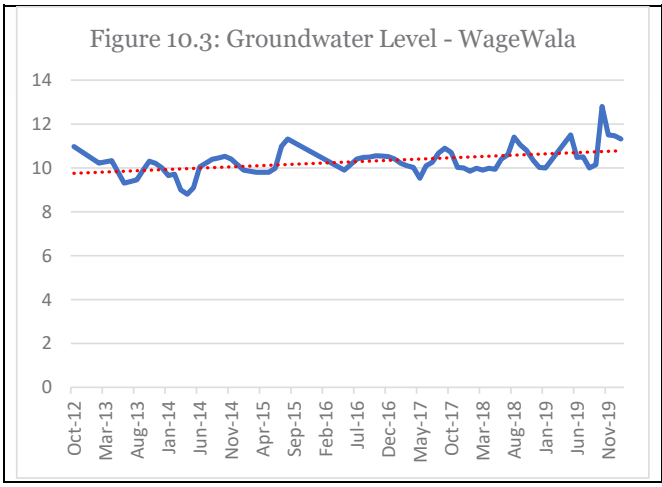
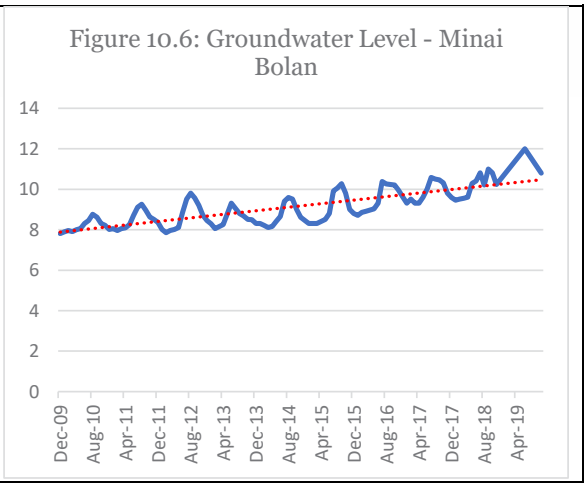


Figure 10.5: Groundwater Level - Hamira







10.2.1.2 Sirhind Canal Irrigation Project – Punjab

Sirhind Canal is one of the oldest and largest irrigation canal systems in India, drawing water from the Sutlej River. It irrigates a vast agricultural region of Punjab, particularly the districts of Ludhiana, Patiala, Sangrur, Fatehgarh Sahib, Mansa, and Bathinda.

A similar assessment of the primary responses obtained from household respondents, as undertaken for the Makhu Canal system, is presented in Table 10.3 below. The analysis, as before, seeks to compare perceptions and experiences of households residing in the command and non-command areas of the Sirhind Canal system.

Table 10.3: Primary Survey findings - Sirhind

Command Villages		
Block	**Village name**	**Decline %**
Chamkaur Sahib	Bhalian	30%
	Garhi	0%
Rampura	Dhade	40%
Kot bhai	Rokhala	75%
Rupnagar	Shampura	50%
Phul	Dhingar	50%
	Ghandawna	65%
Lambi	Bidowali	35%
Non-Command Villages		
Block	**Village name**	**Decline %**
Rupnagar	Malikpur	80%
	Alampur	70%
	Bahadarpur	80%
	Dakala	80%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

It can be inferred from the table above that, on average, approximately 43% of households in the command area reported a decline in groundwater availability, compared to a significantly higher proportion of around 78% in the non-command area. This substantial disparity points towards considerably greater groundwater stress in non-command villages and underscores the role of canal irrigation in mitigating dependence on groundwater resources.

As in the case of the Makhu Canal system, the command and non-command villages selected for the secondary data analysis of the Sirhind Canal system were identified using GIS-based techniques. The resulting village selection is presented in Table 10.4 given below.

Table 10.4: GIS- based list of command and non-command villages - Sirhind

Command Region		
S.N.	**Block**	**Village**
1	Ludhiana - 1 and 2	Mangat
		Chaunta
		Katanikalan
Non-Command Region		
S.N.	**Block**	**Village**
2	Hoshiarpur - 1	Hoshiarpur
	Nurpur Bedi	Bainsa
		Rajgiri (Neeli)

Source: *Central Ground Water Board database*

For the villages selected above, secondary data obtained from the CGWB was utilised to assess trends in groundwater levels over the period from 1991 to 2020.

Figure 10.7, Figure 10.8, and Figure 10.9 illustrate the trend in groundwater levels for the command villages of Mangat, Chaunta, and Katanikalan, respectively. On the other hand, Figures 10.10, 10.11, and 10.12 illustrate the trends in groundwater levels for the non-command villages of Bainsa, Rajgiri (Neeli), and Hoshiarpur, respectively.

A comparative assessment of the groundwater trend lines for the command and non-command villages reveals that the non-command villages exhibit noticeably steeper trends, indicating a more pronounced deterioration in groundwater levels over the study period. In contrast, the trend lines for the command villages are relatively flatter, suggesting greater stability in the water table and a lower rate of groundwater depletion. Moreover, the average depth to groundwater in the non-command villages is considerably greater than that observed in the command villages. This indicates that, in addition to experiencing a more rapid decline in groundwater levels, the non-command villages already have a substantially lower water table to begin with. Consequently, non-command areas face not only a faster rate of groundwater depletion but also a more severe baseline groundwater situation, further underscoring the extent of water stress in these regions.

Groundwater level analysis – Sirhind Canal Irrigation Project

Command Region	Non-Command Region
Figure 10.7: Groundwater Level - Mangat	Figure 10.10: Groundwater Level - Rajgiri
Figure 10.8: Groundwater Level - Chaunta	Figure 10.11: Groundwater Level - Hoshiarpur

Figure 10.9: Groundwater Level - Katanikalan

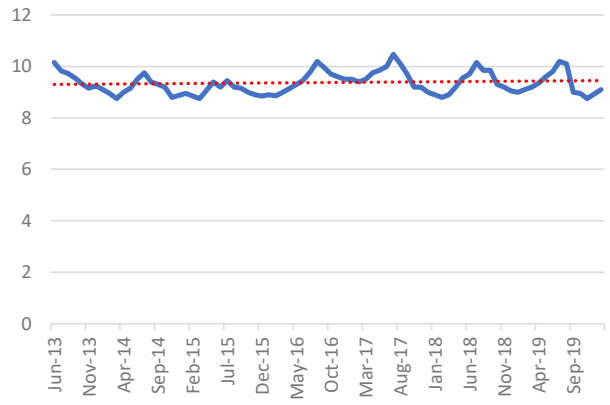
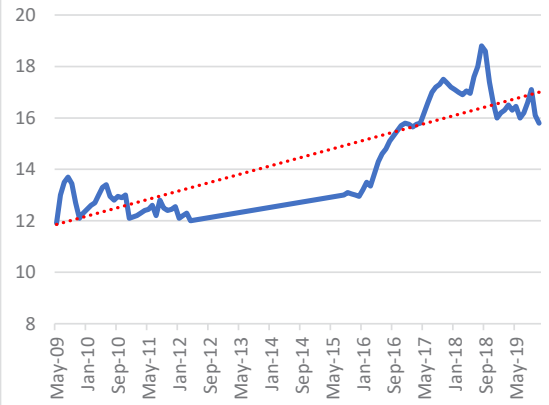


Figure 10.12: Groundwater Level - Bainsa



10.2.2 Western Region

To examine whether the groundwater-related observations emerging from the Northern Region are also evident under different agro-climatic and hydrogeological conditions, the analysis was extended to selected irrigation projects in the Western Region. Following the same methodological framework adopted for the Northern Region, representative command and non-command villages were identified using GIS, household-level perceptions on groundwater conditions were obtained from the primary survey, and these observations were subsequently compared with groundwater-level data published by the CGWB. This exercise provides an additional cross-verification of the groundwater-related findings across different irrigation systems.

10.2.2.1 Karjan Irrigation Project – Gujarat

The Karjan Irrigation Project, located on the Karjan River in Gujarat, is a major multipurpose irrigation project serving the districts of Vadodara, Bharuch and Narmada. As in the Northern Region, the analysis commenced with the identification of representative command and non-command villages using GIS, followed by an examination of the corresponding household responses obtained through the primary survey.

Table 10.5 presents the GIS-identified command and non-command villages associated with the Karjan Irrigation Project, while Table 10.6 summarises the corresponding findings from the household survey.

Table 10.5: GIS- based list of command and non-command villages - Karjan

Command Region		
S.N.	**Block**	**Village**
1	Jhagadia	Simodra
	Nandod	Garudeshwar
		Kewadia
Non-Command Region		
S.N.	**Block**	**Village**
2	Jhagadia	Jesajpur
	Nandod	Rasela
		Sunderpura

Source: *Central Ground Water Board database*

Table 10.6: Primary Survey findings - Karjan

Command Region		
Block Name	**Village name**	**Decline %**
Nandod	Rajuvadia	0%
	Tankari	0%
	Rajpipla	10%
Jagadia	Sanjali	0%
	Ratapore	0%
Non-Command Region		
Block Name	**Village name**	**Decline %**
Nandod	Boridra	60%
	Nani Chikli	80%
Jagadia	Ambakhadi	80%
	Choki	60%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

As shown in Table 10.6, only about 2 per cent of respondents in the command villages reported a decline in groundwater levels, compared with nearly 70 per cent of respondents in the non-command

villages. The household survey therefore suggests substantially greater groundwater stress in the non-command areas relative to the command areas.

To examine whether these perceptions are broadly consistent with independently observed groundwater conditions, groundwater-level data obtained from the CGWB were analysed for the GIS-identified command and non-command villages.

The CGWB data indicate that groundwater levels in the command villages remained relatively stable over the study period, with only modest seasonal fluctuations. In contrast, the non-command villages exhibited comparatively greater fluctuations and, in several locations, a gradual decline in groundwater levels. The overall pattern observed from the secondary data is therefore broadly consistent with the findings of the primary survey, indicating relatively better groundwater conditions within the command area than in the adjoining non-command area.

Taken together, the evidence from both the household survey and the CGWB groundwater records suggests that the command area of the Karjan Irrigation Project exhibits comparatively more stable groundwater conditions (Figures 10.13-10.15) than the neighbouring non-command area (Figures 10.16-10.18). While groundwater behaviour is influenced by several factors—including rainfall, hydrogeological characteristics, cropping patterns and groundwater abstraction—the consistency observed between the primary and secondary evidence suggests that canal irrigation may contribute to moderating groundwater stress and promoting groundwater sustainability in the command area.

Groundwater level analysis - Karjan Irrigation Project

Command Region	Non-Command Region

Figure 10.13: Groundwater Level - Simodra

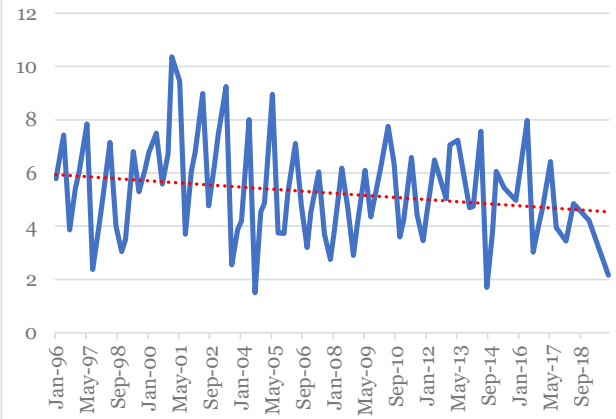


Figure 10.16: Groundwater Level - Jesajpur

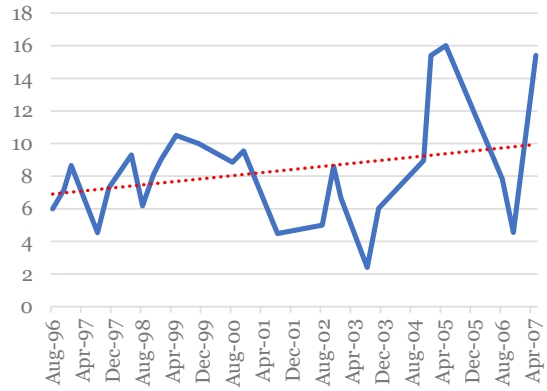


Figure 10.14: Groundwater Level - Garudeshwar

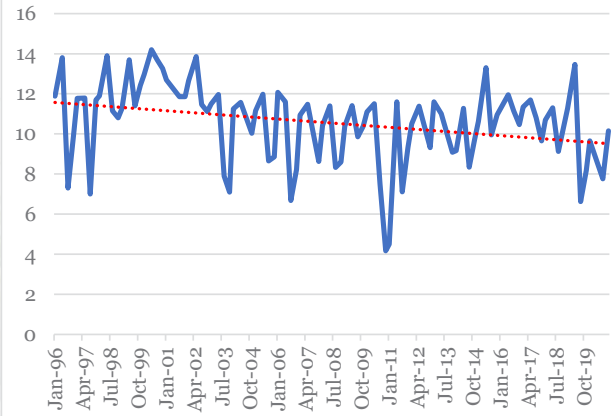


Figure 10.17: Groundwater Level - Rasela

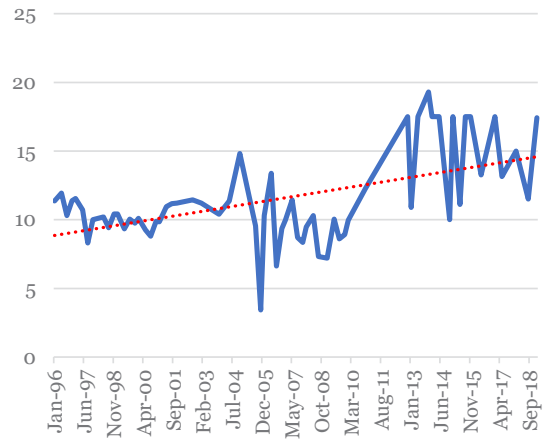


Figure 10.15: Groundwater Level - Kewadia

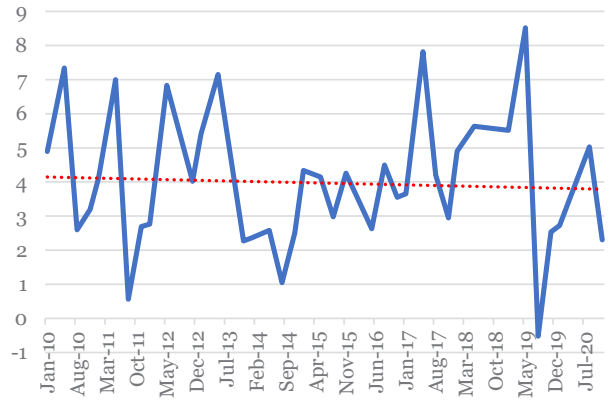
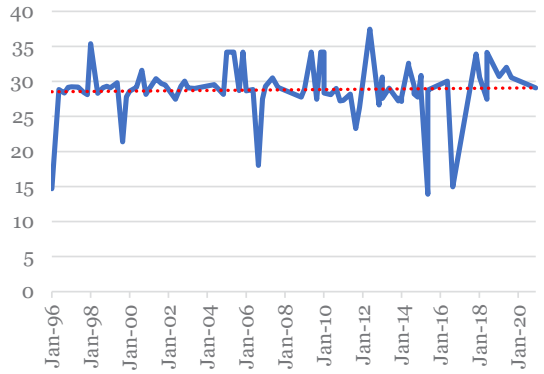


Figure 10.18: Groundwater Level - Sunderpura



10.2.2.2 Girna Irrigation Project – Maharashtra

The Girna Irrigation Project, located in Maharashtra, is a major multipurpose irrigation project constructed on the Girna River, a tributary of the Tapi River. The project primarily serves the Nashik and Jalgaon districts, providing irrigation, water supply, and support for agricultural development in the region. Following the methodology adopted for the Karjan Irrigation Project, representative command and non-command villages were first identified using GIS, following which household-level information on groundwater conditions was obtained through the primary survey.

Table 10.7: GIS- based list of command and non-command villages - Girna

Command Region		
S.N.	**Block**	**Village**
1	Erandol	Dharangaon
		Kasoda
		Pimpalkotha
Non-Command Region		
S.N.	**Block**	**Village**
2	Pachora	Varkhedi
	Parola	Sadavan Bk.
	Bhadgaon	Bhadgaon

Source: *Central Ground Water Board database*

Table 10.7 presents the GIS-identified command and non-command villages associated with the Girna Irrigation Project, while Table 10.8 summarises the corresponding findings from the household survey.

Table 10.8: Primary Survey findings - Girna

Command Region		
Block	**Village name**	**Decline %**
Dharangaon	Salva	5%
Erandol	Galapur	20%
	Talai	20%
Bhadgaon	Wak	15%
Chalisgaon	Jamada	5%
Non-Command Region		
Block	**Village name**	**Decline %**
Parola	Hirapur	80%
	Tambole	40%
Bhadgaon	Pendgaon	0%
Chalisgaon	Kunza	0%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

As shown in Table 10.8, an average of 13 per cent of respondents from the command villages reported a decline in groundwater levels, compared with 30 per cent of respondents from the non-command villages. The primary survey therefore indicates a relatively higher incidence of perceived groundwater stress in the non-command areas than in the command areas.

To examine whether these observations are broadly consistent with independently observed groundwater conditions, groundwater-level data obtained from the CGWB were analysed for the GIS-identified command and non-command villages. The CGWB data indicate that groundwater levels in the command villages remained relatively stable over the study period (Figures 10.19-10.21), exhibiting only modest seasonal fluctuations. In contrast, the non-command villages experienced

comparatively greater variability in groundwater levels and, in several locations, displayed a gradual declining trend (Figures 10.22-10.24). Overall, the secondary data are broadly consistent with the findings of the primary survey and suggest relatively more stable groundwater conditions within the command area than in the adjoining non-command area.

Overall, the evidence from both the household survey and the CGWB groundwater records suggests that the command area of the Girna Irrigation Project exhibits comparatively better groundwater conditions than the neighbouring non-command area. While groundwater behaviour is influenced by several factors—including rainfall variability, hydrogeological characteristics, cropping patterns, and groundwater abstraction practices—the consistency observed between the primary and secondary evidence suggests that canal irrigation may contribute to moderating groundwater stress and promoting groundwater sustainability within the command area.

Groundwater analysis - Girna Irrigation Project

Command Region	Non-Command Region
Figure 19: Groundwater Level - Dharangaon	Figure 22: Groundwater Level - Varkhedi
Figure 20: Groundwater Level - Kasoda	Figure 23: Groundwater Level - Sadavan Bk.
Figure 21: Groundwater Level - Pimpalkotha	Figure 24: Groundwater Level - Bhadgaon

10.2.3 Eastern Region

To examine whether the groundwater-related observations emerging from the Northern and Western Regions are also evident in the Eastern Region, the analysis was extended to two major irrigation projects in Bihar, namely the Sakri Lower Valley Project and the Uderusthan Irrigation Project. Following the same methodological framework adopted for the other regions, representative command and non-command villages were identified using GIS, household-level perceptions on groundwater conditions were obtained through the primary survey, and these observations were subsequently compared with groundwater-level data published by the CGWB.

10.2.3.1 Sakri Lower Valley Project – Bihar

The Sakri Lower Valley Project, located in Bihar, is a major irrigation project on the Sakri River serving the districts of Gaya and Nalanda. The project aims to provide irrigation support and mitigate drought-related agricultural risks in the region.

As in the previous case studies, representative command and non-command villages were identified using GIS, following which the groundwater conditions observed through the household survey were compared with independently observed groundwater trends obtained from the CGWB. Owing to differences in village coverage, reference periods, and the nature of the primary and secondary datasets, the comparison is intended to assess the broad consistency of groundwater conditions rather than establish a one-to-one correspondence between individual villages.

Table 10.9. GIS- based list of command and non-command villages - Sakri Lower Valley Project

Command Region		
S. No	**Block**	**Village**
1	Warisaliganj	Warish aliganj
2	Nawada	Gonama
		Nawada
Non-Command Region		
S. No.	**Block**	**Village**
3	Bihar	Ranabigha
4	Kawakole	Kawakol ashram
		Rupau

Source: *Central Ground Water Board database*

Table 10.9 above presents the GIS-identified command and non-command villages associated with the Sakri Lower Valley Project, while Table 10.10 below summarises the corresponding findings from the household survey.

Table 10.10: Primary Survey findings - Sakri Lower Valley Project

Command Region		
Block	**Village name**	**Decline %**
Warisaliganj	Saur	65%
Nawada	Samai	90%
	Kena	75%
Sheikpura sarai	Onama	95%
	Ambari	90%
Barbhiga	Samas Kurd	70%
Asthwan	Jethiar	65%
	Uganwan	70%
Non-Command Region		
Block	**Village name**	**Decline %**
Nawada	Lohra	80%
	Anandpura	70%
Nardiganj	Parman	90%
Khashi chak	Pojh	80%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

The household survey indicates a high incidence of perceived groundwater decline across both the command and non-command areas. Reported groundwater decline ranged from 65 per cent to 95 per cent in the command villages and from 70 per cent to 90 per cent in the non-command villages. These findings suggest that groundwater stress is widespread across the project area and is not confined to the non-command region.

Groundwater-level information obtained from the CGWB exhibits a broadly similar pattern, indicating persistent groundwater stress in both command and non-command villages. The consistency between the household survey responses and the independently observed groundwater trends suggests that the primary survey accurately reflects the prevailing groundwater conditions in the project area.

Unlike the irrigation projects examined in the Northern and Western Regions, the Sakri Lower Valley Project does not exhibit a pronounced contrast between command (Figures 10.25-10.27) and non-command areas (Figures 10.28-10.30) with respect to groundwater conditions. This suggests that

groundwater behaviour in the region is influenced by a broader set of factors—including hydrogeological conditions, rainfall variability, cropping practices, and groundwater abstraction—in addition to canal irrigation. The findings therefore highlight that while canal irrigation can contribute to groundwater sustainability, its influence is likely to be context-specific and should be interpreted alongside other regional determinants of groundwater availability.

Groundwater analysis – Sakri Lower Valley Project

Command Region	Non-Command Region

Figure 10.25: Groundwater Level - Warish Aliganj

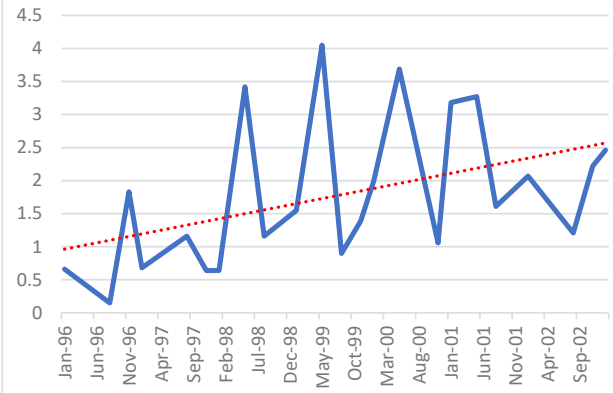


Figure 10.26: Groundwater Level - Gonama

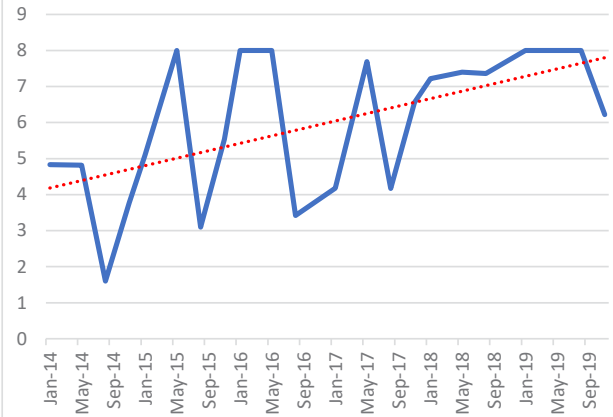


Figure 10.27: Groundwater Level - Nawada

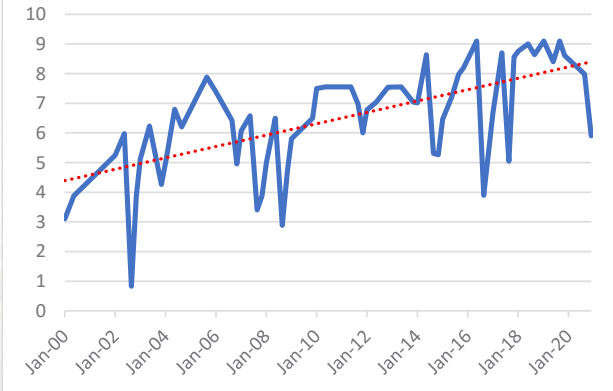


Figure 10.28 Groundwater Level - Ranabigha

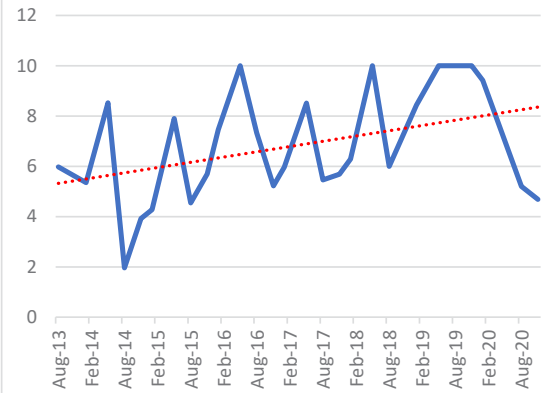


Figure 10.29: Groundwater Level - Kawakol Ashram

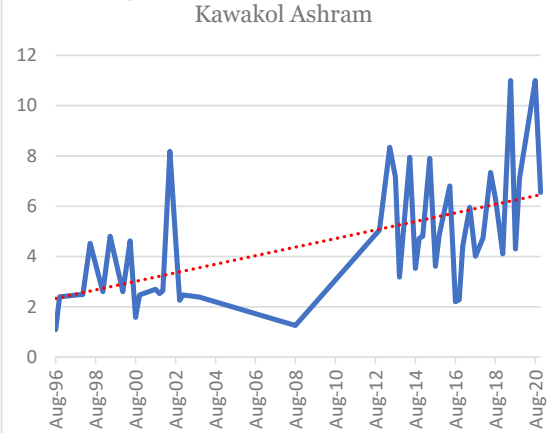
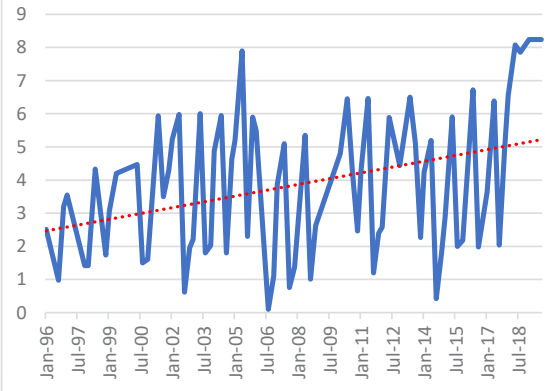


Figure 10.30: Groundwater Level - Rupau



10.2.3.2 Uderusthan Irrigation Project – Bihar

The Uderusthan Irrigation Project, located in Bihar, is a major multipurpose irrigation project on the Falgu River. The project primarily provides irrigation to agricultural lands across the Jehanabad, Gaya, and Nalanda districts. Following the analytical framework adopted for the preceding case studies, representative command and non-command villages were identified using GIS, following which

the household-level perceptions on groundwater conditions were compared with independently observed groundwater-level data obtained from the CGWB.

Given the differences in village coverage, reference periods, and methodological approaches between the primary survey and the CGWB database, the comparison is intended to examine the broad consistency of groundwater conditions across the two sources rather than establish a one-to-one correspondence between individual villages.

Table 10.11: GIS- based List of command and non-command villages - Uderusthan

Command Region		
S. No	**Block**	**Village**
1	Ghoshi	Ghoshi
		Kako
2	Ekangarsarai	Nischalganj
Non-Command Region		
S. No	**Block**	**Village**
3	Masaurhi	Maner
4	Jehanabad	Jahanabad hosp.
5	Hilsa	Hilsa

Source: *Central Ground Water Board database*

Table 10.11 presents the GIS-identified command and non-command villages associated with the Uderusthan Irrigation Project, while Table 10.12 below summarises the corresponding findings from the household survey.

Table 10. 12: Primary Survey findings - Uderusthan

Command Region		
Blocks	**Village name**	**Decline %**
Ghoshi	Lakhawar	10%
	Kure	15%
Modanganj	Gandhar	25%
Khisarsarai	Jamuawan	20%
	Dhansingra	40%
	Simrauka	70%
Ekangarsarai	Narainpur	30%
	Aungari	45%
Non-Command Region		
Block	**Village name**	**Decline %**
Kako	Dharampur	40%
	Murasa	50%
Makhdhumpur	Kharauna	50%
Khisrisarai	Sonas	70%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

The household survey indicates noticeable spatial variation in groundwater conditions across the project area. Reported groundwater decline ranged from 10 per cent to 70 per cent in the command villages, whereas the corresponding values in the non-command villages ranged from 40 per cent to 70 per cent. Overall, the findings suggest relatively lower groundwater stress within the command area, although considerable variation exists across individual villages.

Groundwater-level information obtained from the CGWB exhibits a broadly similar pattern. The CGWB observations indicate relatively more stable groundwater conditions in the command villages, while the non-command villages generally exhibit comparatively greater groundwater stress. Although the magnitude of the differences varies across locations, the overall pattern observed from the secondary data is broadly consistent with the findings of the household survey.

Taken together, the evidence from the primary survey and the CGWB groundwater records suggests that the command area of the Uderusthan Irrigation Project generally exhibits comparatively more favourable groundwater conditions (Figures 10.31-10.33) than the adjoining non-command area (figures 10.34-10.36). At the same time, the observed variation across villages indicates that groundwater behaviour is influenced not only by canal irrigation but also by regional hydrogeological conditions, rainfall variability, cropping patterns, and groundwater abstraction practices. The findings therefore reinforce the need to interpret groundwater sustainability within a broader context of integrated water resource management.

Command Region	Non-Command Region

Figure 10.31: Groundwater Level - Ghoshi

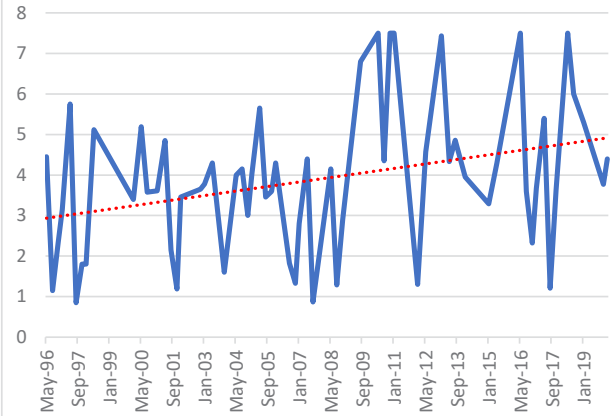


Figure 10.32 Groundwater Level - Kako

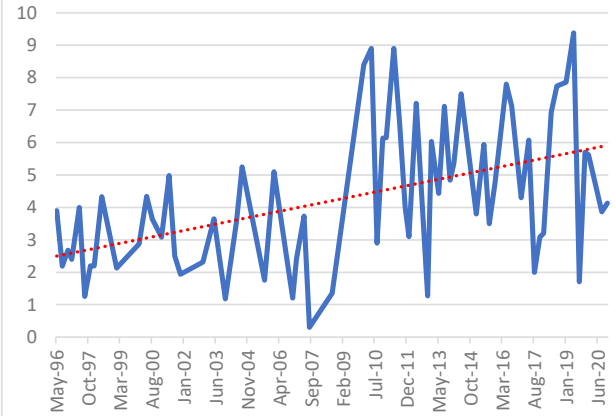


Figure 10.33 Groundwater Level - Nischalganj

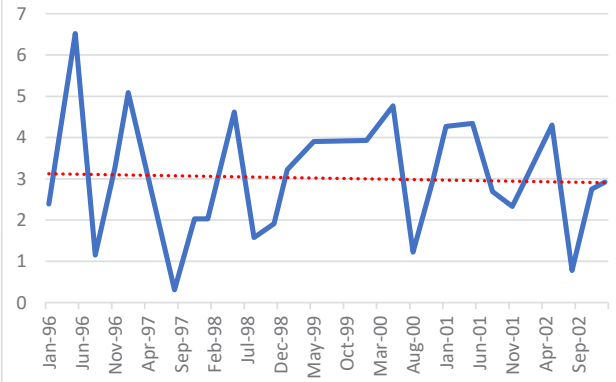


Figure 10.34 Groundwater Level - Maner

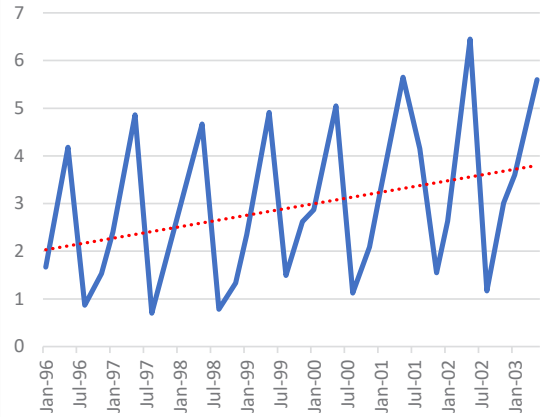


Figure 10.35 Groundwater Level - Hilsa

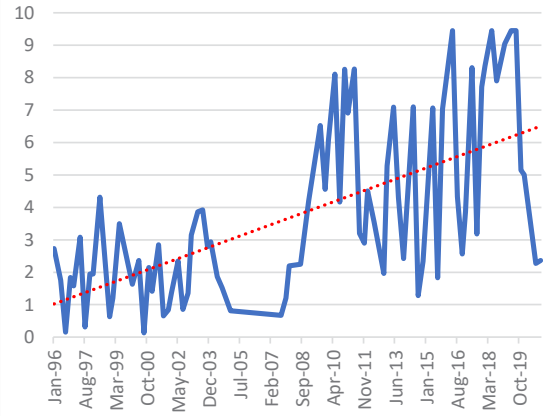
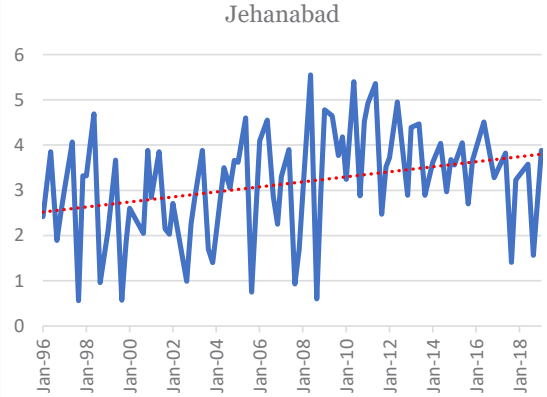


Figure 10.36 Groundwater Level - Jehanabad



10.2.4 Southern Region

For the Southern region, two irrigation projects were shortlisted, namely Kallada Irrigation Project (Kerala) and Tungabhadra Irrigation Project (Karnataka and Andhra Pradesh). The groundwater analysis for these projects is presented below.

10.2.4.1 Kallada Irrigation Project – Kerala

The Kallada Irrigation Project is a multipurpose irrigation project in southern Kerala that primarily supports agricultural irrigation across parts of Kollam and adjoining districts. Following the analytical framework adopted for the preceding case studies, representative command and non-command villages were identified using GIS, following which household-level perceptions of groundwater conditions were compared with independently observed groundwater-level data obtained from the CGWB.

Table 10. 13: GIS- based List of command and non-command villages – Kallada

Command Region		
S.N.	**Block**	**Village**
1	Vettikkavala	Pavitreswaram
	Chittumala	Kumbalam
	Parakkode	Enathu
Non-Command Region		
S.N.	**Block**	**Village**
2	Varkala	Edava
	Kilimanoor	Madavur
	Anchal	Tadicaud

Source: *Central Ground Water Board database*

Table 10.13 presents the GIS-identified command and non-command villages associated with the Kallada Irrigation Project, while Table 10.14 below summarises the corresponding findings from the household survey.

Table 10.14: Primary Survey findings - Kallada

Command Region		
Block	**Village name**	**Decline %**
Pathanapuram	Thalavoor	5%
Vettikkavala	Puthur	10%
	Melila	0%
Parakode	Adoor	5%
	Erathu	5%
Pandlamn	Pandalam	0%
Bharanicavu	Chunakkara	0%
	Vallikunnam	15%
Non-Command Region		
Block	**Village name**	**Decline %**
Anchal	Alayamon	10%
	Eroor	0%
Chadayamangalam	Ittiva	10%
	Kadakkal	0%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

As shown in Table 10.14, only about 5 per cent of respondents from both the command and the non-command villages reported a decline in groundwater levels. The primary survey therefore suggests that groundwater conditions are broadly similar across the two areas, with relatively low levels of perceived groundwater stress throughout the project region.

To examine whether these observations are consistent with independently observed groundwater conditions, groundwater-level data obtained from the CGWB were analysed for the GIS-identified command and non-command villages.

The CGWB data indicate relatively stable groundwater conditions in both the command and non-command villages over the study period, with improvements observed in several locations. Unlike the irrigation projects examined in the Northern and Western Regions, no pronounced difference in groundwater conditions is evident between the command and non-command areas. The secondary evidence therefore broadly corroborates the findings emerging from the household survey.

The evidence from the primary survey and the CGWB groundwater records suggests (Figures 10.37-10.39) that groundwater conditions in the Kallada project area are generally favourable in both the command and non-command regions (Figures 10.40-10.42). This pattern indicates that groundwater sustainability in the region is likely to be influenced by a combination of factors, including favourable hydrogeological conditions, relatively high rainfall, and the presence of canal irrigation. The findings therefore suggest that, in regions characterised by naturally favourable recharge conditions, the incremental differences between command and non-command areas may be less pronounced than those observed in relatively water-stressed regions.

Command Region

Figure 10.37: Groundwater Level - Pavitreswaram

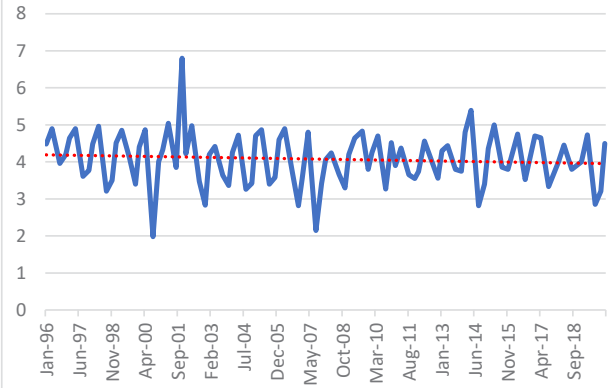


Figure 10.38: Groundwater Level - Enarthu

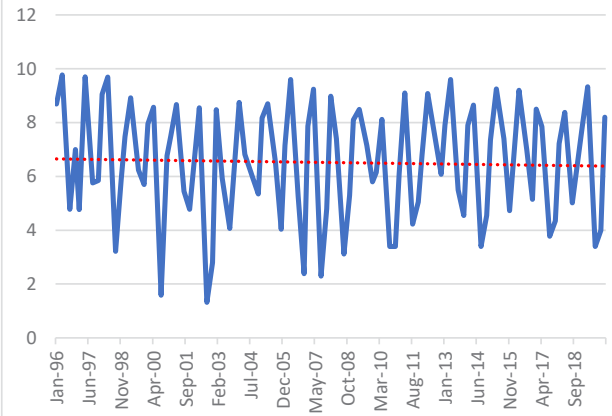
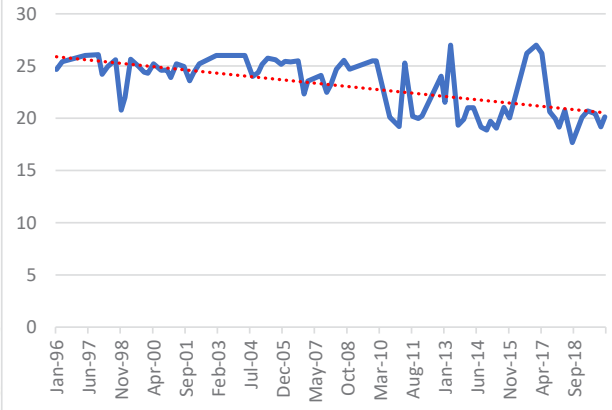


Figure 10.39: Groundwater Level - Kumbalam



Non-Command Region

Figure 10.40: Groundwater Level - Edava

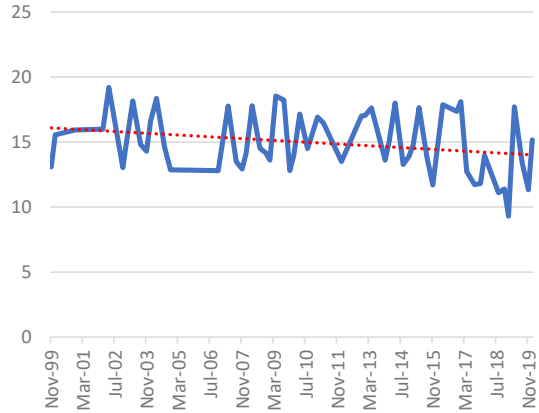


Figure 10.41: Groundwater Level - Madavur

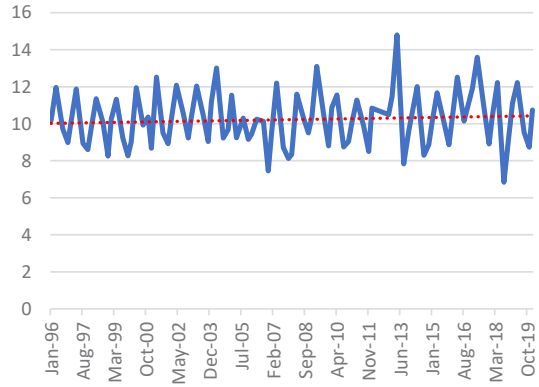
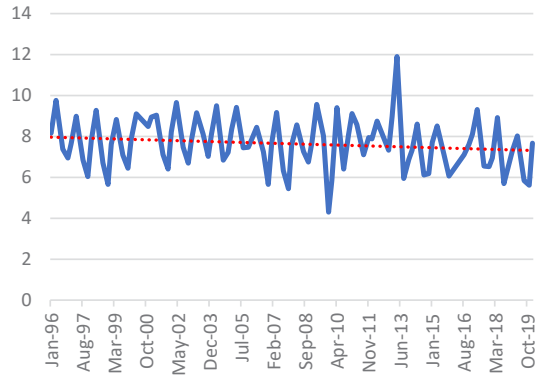


Figure 10.42: Groundwater Level - Tadicaud



10.2.4.2 Tungabhadra Irrigation Project – Karnataka and Andhra Pradesh

The Tungabhadra Project is a multipurpose river valley project on the Tungabhadra River that provides irrigation, hydropower generation, and water supply to parts of Karnataka and Andhra Pradesh. Following the analytical framework adopted for the preceding case studies, representative command and non-command villages were identified using GIS, following which household-level perceptions of groundwater conditions were compared with independently observed groundwater-level data obtained from the CGWB.

Table 10. 15: GIS- based List of command and non-command villages - Tungabhadra

Command Region		
S.N.	**Block**	**Village**
1	Sindhnur	Jawalgera
	Bellary	Allipuram
		Bisalahalli
Non-Command Region		
S.N.	**Block**	**Village**
2	Kushtagi	Mudenoor
		Kushtagi
		Hanamsagar

Source: *Central Ground Water Board database*

Table 10.15 presents the GIS-identified command and non-command villages associated with the Tungabhadra Irrigation Project, while Table 10.16 below summarises the corresponding findings from the household survey.

Table 10.16: Primary Survey findings - Tungabhadra

Command Region		
Block	**Village name**	**Decline %**
Siruguppa	Nadivi	5%
	Muddatanur	0%
Kosigi	Duddi	10%
Mantralayam	Budur	10%
Ballari	Emmiganur	5%
Non-Command Region		
Block	**Village name**	**Decline %**
Ballary	Haraginadone	100%
	Janikunte	0%
Adoni	Bychigeri	70%
	Kapati	90%

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025*

As shown in Table 10. 16, only about 6 per cent of respondents in the command villages reported a decline in groundwater levels, compared with an average of 65 per cent of respondents in the non-command villages. The primary survey therefore indicates a marked contrast in perceived groundwater conditions, suggesting substantially lower groundwater stress within the command area. The responses from the non-command villages also exhibit considerable spatial variation, reflecting differences in local groundwater conditions across villages.

To examine whether these observations are broadly consistent with independently observed groundwater conditions, groundwater-level data obtained from the CGWB were analysed for the GIS-identified command and non-command villages.

The CGWB data indicate relatively stable groundwater conditions, and in several locations an improvement in groundwater levels, within the command villages over the study period. In contrast, the non-command villages generally exhibit greater fluctuations and a more pronounced declining trend in groundwater levels. The overall pattern observed from the secondary data is therefore broadly consistent with the findings of the household survey, indicating comparatively more favourable groundwater conditions within the command area.

In essence, the evidence from the household survey and the CGWB groundwater records suggests that the command area of the Tungabhadra Irrigation Project exhibits relatively better groundwater conditions (Figures 10.43-10.45) than the adjoining non-command area (Figures 10.46-10.48). While groundwater behaviour is influenced by a range of factors—including rainfall variability, hydrogeological characteristics, cropping patterns, and groundwater abstraction practices—the consistency observed between the primary and secondary evidence suggests that canal irrigation may contribute to moderating groundwater stress and promoting groundwater sustainability within the command area.

Command Region	Non-Command Region

Figure 10.43 Groundwater Level - Allipuram

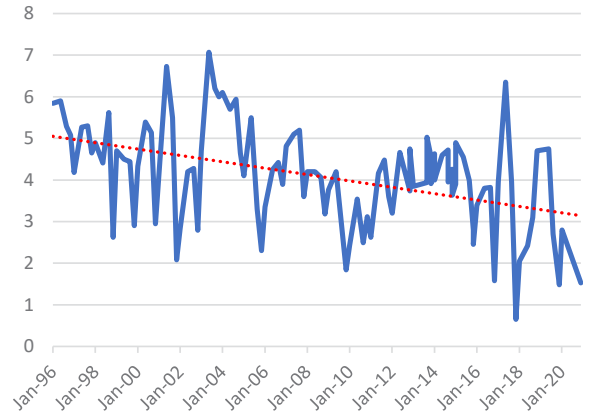


Figure 10.44: Groundwater Level - Jawalgera

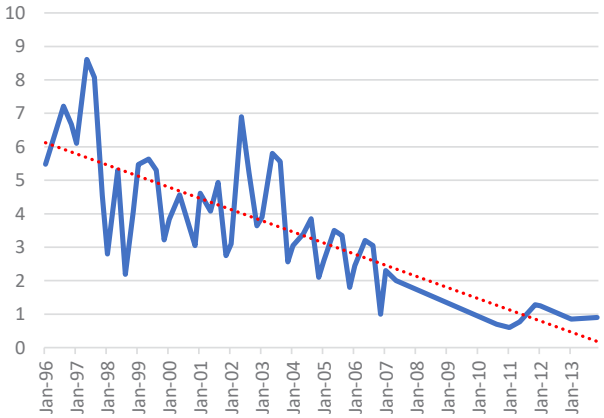


Figure 10.45: Groundwater Level - Bisalahalli

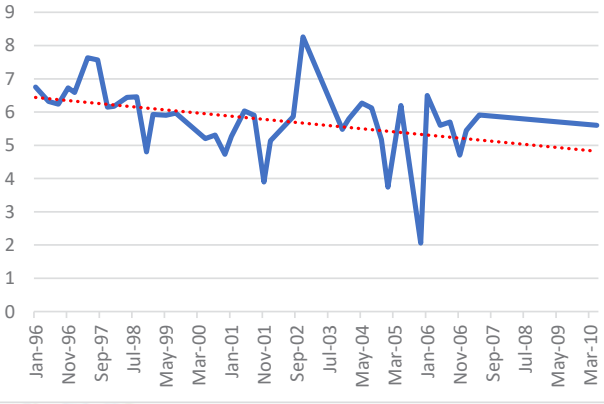


Figure 10.46 Groundwater Level - Mudenoor

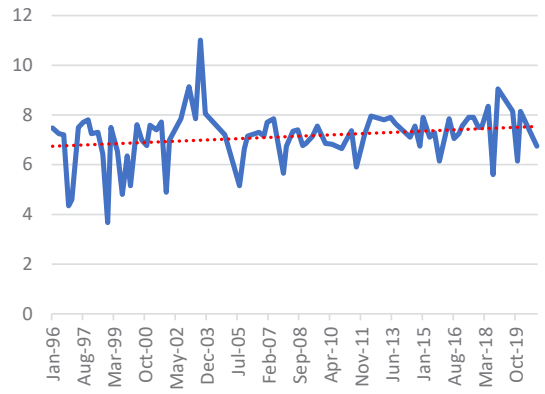


Figure 10.47: Groundwater Level - Kushtagi

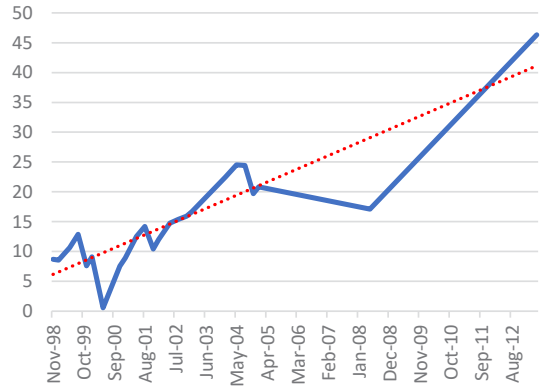
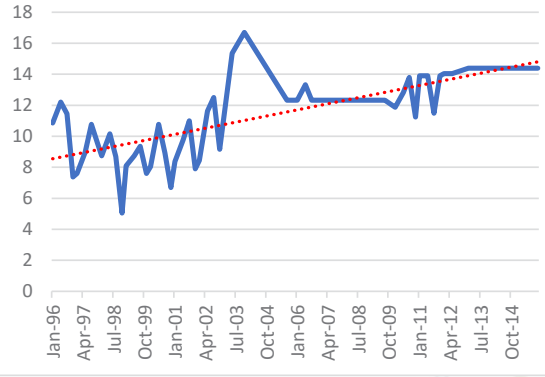


Figure 10.48: Groundwater Level - Hanamsagar



10.3 COMPARATIVE ASSESSMENT ACROSS SELECTED IRRIGATION PROJECTS

Table 10.17 provides a comparative summary of the groundwater assessment undertaken across the selected irrigation projects. The comparison draws upon both household-level perceptions obtained through the primary survey and groundwater-level observations published by the CGWB. Rather than examining each project in isolation, the table enables a cross-regional comparison of groundwater conditions under diverse agro-climatic and hydrogeological settings.

Table 10.17: Comparative Assessment of Groundwater Conditions Across Selected Irrigation Projects Using Primary Survey and CGWB Data

Region	Irrigation Project	Primary Survey Findings	CGWB Observations	Overall Interpretation
Northern Region	Sirhind Canal	Lower incidence of groundwater decline in command area than in non-command area	Groundwater levels relatively more stable in command villages	Strong consistency between primary and secondary evidence; command areas exhibit comparatively better groundwater conditions.
	Makhu Canal	Lower perceived groundwater decline in command area	Groundwater trends broadly more favourable in command villages	Strong evidence of comparatively better groundwater sustainability in command areas.
Western Region	Karjan	2% (command) vs. 70% (non-command) reported groundwater decline	Command villages exhibit relatively stable groundwater levels; non-command villages show greater variability	Primary and secondary evidence are broadly consistent, suggesting comparatively lower groundwater stress within command areas.
	Girna	13% (command) vs. 30% (non-command) reported groundwater decline	Groundwater conditions relatively more stable in command villages	Moderate command-area advantage; findings broadly corroborated by CGWB data.
Southern Region	Kallada	Nearly identical perception of groundwater decline (≈5%) in both command and non-command areas	Stable groundwater conditions observed in both areas	Groundwater conditions are favourable across the project area; little distinction between command and non-command regions, reflecting favourable regional hydrogeological conditions.
	Tungabhadra	6% (command) vs. 65% (non-command) reported groundwater decline	Command villages exhibit relatively stable groundwater levels; non-command villages show greater decline	Strong consistency between the two data sources; comparatively favourable groundwater conditions in command areas.
Eastern Region	Sakri Lower Valley	High groundwater stress reported in both command (65–95%) and non-command (70–90%) areas	CGWB also indicates widespread groundwater stress across the project area	Groundwater stress is pervasive throughout the region; findings suggest strong influence of regional hydrogeological and climatic factors beyond canal irrigation.
	Uderusthan	Lower groundwater decline in command area (10–70%) than non-command area (40–70%)	Relatively more stable groundwater conditions in command villages	Moderate command-area advantage with considerable spatial variation; primary and secondary evidence broadly consistent.

Note: *The comparison presented above is intended to examine the broad consistency between household-level perceptions obtained through the primary survey and independently observed groundwater trends reported by the CGWB. Given differences in village coverage, reference periods, and data collection methodologies, the analysis should be interpreted as a comparative assessment rather than a one-to-one validation exercise.*

Three broad patterns emerge from the comparative assessment. First, projects such as Sirhind, Makhu, Karjan, Girna and Tungabhadra exhibit relatively better groundwater conditions within command areas than in adjoining non-command areas. Second, the Kallada project demonstrates favourable groundwater conditions in both command and non-command areas, suggesting that regional hydrogeological and climatic conditions play an important role alongside canal irrigation. Third, the Sakri Lower Valley Project indicates widespread groundwater stress across both command and non-command areas, while the Uderusthan Project represents an intermediate case where command areas perform relatively better despite persistent spatial variation.

10.4 KEY FINDINGS AND POLICY IMPLICATIONS

Table 10.17 presents a comparative assessment of groundwater conditions across the selected irrigation projects based on evidence from both the NCAER primary household survey and groundwater-level observations published by the CGWB. Using a common analytical framework across diverse agro-climatic and hydrogeological settings, the analysis provides an opportunity to examine the extent to which the groundwater-related patterns emerging from the household survey are broadly consistent with independently observed groundwater trends.

The comparative assessment reveals that groundwater outcomes associated with canal irrigation are not uniform across regions. In projects such as the Sirhind Canal, Makhu Canal, Karjan, Girna, and Tungabhadra Irrigation Projects, both the household survey and the CGWB data indicate relatively more favourable groundwater conditions within the command areas than in the adjoining non-command areas. These findings are broadly consistent with the proposition that access to canal irrigation may reduce dependence on groundwater extraction and thereby contribute to improved groundwater sustainability.

In contrast, the Kallada Irrigation Project in Kerala exhibits relatively favourable groundwater conditions in both the command and non-command areas. The absence of a pronounced distinction between the two regions suggests that groundwater behaviour in this area is influenced not only by canal irrigation but also by favourable hydrogeological conditions, relatively high rainfall, and natural groundwater recharge.

The Sakri Lower Valley Project presents a different pattern, with both the household survey and the CGWB data indicating widespread groundwater stress across the command and non-command areas. This finding highlights that groundwater sustainability is influenced by a broader set of regional factors, including hydrogeological conditions, rainfall variability, cropping patterns, and groundwater abstraction practices. The Uderusthan Irrigation Project represents an intermediate case, where the command area exhibits relatively better groundwater conditions than the non-command area, although considerable spatial variation persists across villages.

In sum, these findings indicate that groundwater sustainability is a context-specific outcome that cannot be attributed solely to the presence or absence of canal irrigation. Rather, canal irrigation constitutes one of several interacting factors influencing groundwater conditions. The extent of its contribution depends upon local hydrogeological characteristics, climatic conditions, cropping practices, groundwater abstraction, and the operational performance of the irrigation system.

From a methodological perspective, the comparative assessment demonstrates that the household-level perceptions obtained through the primary survey are broadly corroborated by independently observed groundwater trends reported by the Central Ground Water Board. Although the two datasets differ in terms of spatial coverage, reference periods, and data collection methodologies, the broad consistency observed across the selected irrigation projects enhances confidence in the reliability of the primary survey findings. This, in turn, strengthens the rationale for including groundwater sustainability as one of the ten indicators comprising the Composite Index developed under this study.

From a policy perspective, the analysis suggests that the benefits of major irrigation projects extend beyond improvements in agricultural production alone. In several regions, canal irrigation appears to contribute to improved groundwater

sustainability by moderating dependence on groundwater extraction, while in other regions the findings underscore the need for complementary interventions such as groundwater regulation, conjunctive use of surface and groundwater resources, efficient irrigation practices, and region-specific water management strategies. The evidence presented in this chapter therefore reinforces the view that groundwater sustainability constitutes an important indirect environmental benefit that deserves explicit consideration in the broader appraisal and evaluation of major irrigation projects.

CHAPTER 11

Conclusion and Way Forward

11.1 OVERVIEW

The present study—Assessment of Indirect and Intangible Benefits of Irrigation Projects in India—undertaken by the National Council of Applied Economic Research (NCAER) for the Central Water Commission (CWC), represents an important step toward broadening how irrigation investments are understood, measured, and valued in India. Traditionally, irrigation projects have been appraised primarily in terms of increases in irrigated area, crop yields, agricultural output, and direct economic returns. While these indicators remain important, they capture only a limited portion of the wider developmental impacts generated by large- and medium-scale irrigation systems. By moving beyond these conventional metrics, the present study introduces an evidence-based framework that captures the broader social, economic, environmental, institutional, and health-related benefits associated with irrigation.

This expanded perspective is supported by an extensive empirical exercise. The study draws on a large-scale primary survey of nearly 10,000 households across 57 major and medium irrigation projects located in 20 states, representing a wide range of India's agro-climatic and socio-economic contexts. GIS-based sampling ensured spatial representativeness, while qualitative fieldwork—including focus group discussions with farmers, women's groups, and Water User Associations—provided important contextual insights into local experiences of irrigation. These field observations were complemented by an analytical framework that quantifies indirect and intangible benefits through the construction of a Composite Index and the estimation of valuation coefficients, enabling improvements in socio-economic conditions to be expressed in measurable economic terms.

Taken together, the evidence from the study points toward a broader understanding of irrigation as a driver of rural transformation rather than merely an input to agricultural production. Reliable irrigation contributes to livelihood stability, encourages diversification of rural economic activities, reduces distress migration, improves education and health outcomes, strengthens community institutions, and enhances women's participation in economic and social life. In several project areas, irrigation has also been associated with environmental improvements such as better vegetation cover, enhanced groundwater recharge, and improved water management practices. These outcomes highlight the multi-dimensional role of irrigation in supporting rural prosperity, social cohesion, and environmental sustainability.

This concluding chapter synthesises the key insights emerging from the study and reflects on their

broader implications for policy, planning, and future research. It outlines how the methodological innovations and empirical evidence presented in the report can bring in more comprehensive irrigation appraisal frameworks and guide the next generation of water resource governance and evaluation in India.

11.2 KEY INSIGHTS

The findings of the study indicate that irrigation plays a far broader developmental role than merely supporting agricultural production. Using a with-and-without analytical framework that compares command and non-command areas, the analysis shows that irrigation is associated with significant improvements in agricultural productivity, income stability, and livelihood diversification. These economic gains are accompanied by important social improvements, including reductions in distress migration, higher school attendance, increased participation of women in economic activities, and overall improvements in household wellbeing. In several regions, irrigation has also contributed to the strengthening of community-based institutions such as Water User Associations, self-help groups, and local panchayats, thereby reinforcing more equitable water distribution and collective management practices.

A key contribution of the study lies in the development of a nationally applicable analytical framework to quantify indirect and intangible benefits arising from irrigation systems. The Composite Index developed in the study—covering ten socio-economic and environmental dimensions—captures the multidimensional nature of irrigation's impacts. By linking differences in the Composite Index between command and non-command areas with observed income differentials, and estimating regression-based valuation coefficients, the framework provides a mechanism for translating improvements in socio-economic conditions into measurable annual income equivalents. This represents one of the first systematic efforts to monetise such indirect benefits at a national scale and integrate them into a structured evaluation framework. The model is scalable, statistically validated, and capable of informing future benefit–cost analyses of irrigation investments.

Qualitative evidence from the field further reinforces the survey findings. In focus group discussions conducted across multiple states, community members consistently emphasised the importance of reliable water availability for both economic security and social stability. Irrigation was associated not only with higher agricultural output but also with reduced production uncertainty, improved household stability, and expanded opportunities for youth and women. Participants also highlighted environmental improvements such as better vegetation cover, improved soil moisture, rising groundwater levels in certain areas, and the adoption of more climate-resilient agricultural practices. Importantly, projects where institutional mechanisms were strong—where water delivery was predictable and complementary rural infrastructure was available—tended to demonstrate more pronounced benefits. These observations suggest that the developmental outcomes of irrigation depend not only on engineering infrastructure but also on effective governance and active community participation.

11.3 IMPLICATIONS FOR POLICY AND PRACTICE

The findings of this study carry important implications for policy formulation and implementation, pointing towards a more holistic and evidence-based approach to irrigation planning in India. First, the analysis highlights the need to explicitly incorporate indirect and intangible benefits into irrigation project appraisal frameworks. Conventional benefit–cost analyses tend to underestimate the full developmental value of irrigation investments because they primarily focus on direct agricultural outputs and incremental crop income. Such approaches often overlook broader gains such as improvements in health outcomes, reductions in drudgery, ecosystem services, women's empowerment, livelihood diversification, and the reduction of distress migration. By integrating the Composite Index developed in this study—along with the associated valuation coefficients—policymakers can obtain a more comprehensive assessment of project returns. This would enable more informed investment prioritisation, better targeting of modernisation and ERM (Extension, Renovation and Modernisation) interventions, and improved estimation of long-term economic, environmental, and social benefits.

Second, the study highlights the central role of institutional capacity, governance quality, and community participation in shaping irrigation

outcomes. The effectiveness of irrigation systems depends not only on engineering design but also on how efficiently they are managed. Strengthening Water User Associations, improving coordination between State irrigation departments and Panchayati Raj Institutions, and establishing clear accountability mechanisms can enhance reliability, equity, and efficiency in water distribution. Adequate financial provision for operation and maintenance—often overlooked in public investment planning—is equally critical for sustaining system performance and preventing infrastructure deterioration. In this context, the adoption of digital technologies such as telemetry systems, SCADA-based monitoring, GIS-enabled command area mapping, and real-time water management platforms can significantly improve transparency, predictability of water releases, and data-driven decision-making. Institutional reforms that combine participatory governance with technological modernisation will therefore be essential for building resilient irrigation management systems.

Third, the study underlines the strong and often under-recognised linkages between irrigation and broader aspects of rural development. Reliable irrigation facilitates diversifies into horticulture, livestock, fisheries, and high-value cropping systems, while supporting rural entrepreneurship and agri-service markets. By stabilising agricultural production and incomes, irrigation reduces vulnerability for small and marginal farmers and strengthens local economic linkages. In several project regions, reservoirs and canal systems have created opportunities for fisheries, tourism, and recreational activities, generating additional sources of local employment. However, it may be noted that certain outcomes, such as tourism-related activities, are context-specific and have not been included in the core quantitative framework.

Realising the full potential of these linkages requires stronger alignment between irrigation infrastructure and complementary development programmes such as PMKSY, PMFME, NRLM, MSME initiatives, and state-level livelihood missions. Strengthening value chains—through improved storage, processing, transport, and cold-chain infrastructure—can further amplify the developmental spillovers of irrigation investments. In this way, irrigation can serve not merely as a sectoral intervention but as a platform for broader rural economic transformation.

Finally, the environmental and climate-related dimensions highlighted in the study underlines the importance of ecological stewardship in irrigation planning and management. Improvements in vegetation cover, soil moisture retention, and groundwater recharge observed in several command areas suggest that well-managed irrigation systems can generate significant ecological benefits. At the same time, climate variability, rising evapotranspiration, and increasing pressure on groundwater resources present growing challenges. Conjunctive use strategies that balance surface water and groundwater, expansion of micro-irrigation to reduce conveyance and field losses, and watershed development initiatives to strengthen catchment health will therefore be essential for sustaining irrigation benefits. Systematic monitoring of environmental indicators—including water quality, land degradation, groundwater dynamics, and health-related outcomes—should form an integral part of long-term irrigation planning. Embedding climate resilience and environmental safeguards into irrigation design and management will be critical to ensuring that water resources are managed responsibly in an era of increasing climatic uncertainty.

11.4 KEY CHALLENGES AND STUDY LIMITATIONS

11.4.1 Key Challenges

Several concerns and issues were raised by State officials during the regional workshops. These concerns, along with the clarifications provided during the discussions, are summarised below.

1. Over-exploitation of groundwater in non-command areas:

Participants raised concerns regarding severe groundwater depletion in some non-command areas due to over-extraction. It was clarified that groundwater status was captured through the primary household survey and secondary data in both command and non-command areas and has therefore been incorporated in the assessment of indirect benefits (Refer to Chapter 10). Groundwater conditions constitute one of the ten parameters included in the Composite Index used for estimating indirect benefits.

2. Rehabilitation, modernisation, and O&M of ageing irrigation infrastructure:

Participants emphasised that ageing irrigation

infrastructure—particularly storage tanks and associated distribution systems—along with inadequate operation and maintenance (O&M), poses a major challenge in many regions. Siltation in tanks and reservoirs was also pointed out as a factor affecting effective storage capacity. While the responsibility for infrastructure rehabilitation primarily rests with the respective State Governments, these systemic constraints have been acknowledged as important contextual factors influencing irrigation outcomes.

3, Regional heterogeneity and comparability:

Concerns were raised regarding variations in land topography and agro-climatic conditions across states within the same region. It was clarified that the analytical framework explicitly accounts for income differentials between command and non-command areas on a project-specific basis. Regional delineation and stratified sampling were designed to ensure comparability while recognising geographical diversity.

4. Livelihood losses due to land acquisition:

Participants sought clarification on how livelihood losses arising from land acquisition for irrigation projects were addressed. It was clarified that costs related to land acquisition and Rehabilitation and Resettlement (R&R) of project affected families/ persons are incorporated within the standard Benefit–Cost (B–C) ratio framework used in project appraisal. In addition, land value appreciation and livelihood improvements are captured under the "Employment and Livelihood Improvement" component of the command-area questionnaire.

5. Parameters beyond the scope of indirect benefits:

Certain factors—such as seasonal variations in crop benefits or energy transition issues—relate to direct agricultural benefits and therefore fall outside the scope of the present analysis. Similarly, indicators related to infrastructure efficiency and operational performance are primarily associated with O&M functions under the jurisdiction of State Water Resources Departments and were not included in the indirect benefit framework.

6. Water-use efficiency and climate change considerations:

Issues relating to water-use efficiency and climate change impacts, including groundwater recharge and soil degradation, were considered during the selection of parameters for the Composite Index. These aspects are reflected indirectly through environmental and resource-management indicators included in the study.

7. Carbon credit mechanisms:

Participants suggested exploring the potential role of carbon credit mechanisms associated with irrigation-related environmental improvements. However, as carbon markets and associated regulatory frameworks are still evolving in India, these benefits could not be incorporated within the current analytical framework.

8. Impact of extreme flood and drought conditions:

Extreme climatic events in certain states, including flood and drought conditions, were noted as important contextual factors. Since the analysis is based on primary field-level data reflecting actual household incomes and conditions, such climatic variability is implicitly reflected in the dataset and captured within the comparative framework used in the study.

9. Spatial variation in land values:

Land values may vary across head, middle, and tail reaches of command areas as well as between command and non-command areas. To minimise the influence of such variations, average values across the three command-area zones were used for comparison with non-command areas.

10. Groundwater recharge and statistical significance:

Groundwater recharge did not emerge as statistically significant in the Z-test comparison between command and non-command areas at the national level. However, this finding reflects aggregated pan-India results. In specific regions, field observations indicate stronger *hydrological* spillovers. The absence of statistical significance at the national level therefore does not negate the existence of localised recharge effects but indicates that such impacts are not uniformly observable across all sampled projects.

11. Institutional innovations and community models:

Participants highlighted alternative community-based management systems such as the "Laskar system", where farmer collectively and voluntarily

contribute to irrigation management, generating employment and strengthening social capital. While such institutional innovations demonstrate the dynamic potential of irrigation systems, their replication and scaling fall within the policy domain of State Governments. The analytical framework used in the study remains capable of capturing such socio-economic dimensions where empirical evidence is available.

12. Operation and Maintenance (O&M) and sustainability of benefits:

The long-term sustainability of both direct and indirect irrigation benefits depends critically on effective O&M practices. While the present study identifies and quantifies indirect benefits, their durability and amplification over time are contingent upon sustained system maintenance and efficient canal management by the responsible State authorities.

13. Infrastructure linkages and attribution:

Questions were raised regarding the attribution of benefits arising from complementary infrastructure, such as road development in project areas. Since such infrastructure may exist in both command and non-command areas, the study uses comparative analysis between the two zones to isolate irrigation-related differentials and minimise attribution bias.

14. Environmental costs and ecological considerations:

Participants also noted that ecological impacts, including soil degradation or environmental costs, may warrant further analysis. The present study focuses exclusively on estimating indirect and intangible benefits. Environmental costs fall outside the current scope and would require a separate environmental–economic evaluation framework.

15. Treatment of Market Linkages

Participants sought clarification on the rationale for including improvement in market linkages as a parameter within the composite index. It was explained that enhanced irrigation availability enables farmers to increase cropping intensity and diversify production, thereby stimulating demand for agricultural inputs and encouraging the development of local supply networks and output markets. Improved market access was also associated with better price realisation, reduced transaction and transportation costs, and more frequent participation in market transactions. These changes were considered to reflect a broader process of economic integration and efficiency gains facilitated by irrigation development. Participants broadly agreed that such dynamics constitute an important indirect channel of income enhancement and should be captured within the analytical framework.

16. Treatment of Tourism-Related Benefits

Considerable discussion took place regarding the inclusion of tourism-related benefits in the estimation of indirect impacts. It was observed that tourism effects associated with irrigation infrastructure are spatially uneven and typically concentrated in areas surrounding reservoirs or dam sites. While empirical analysis indicated a statistically significant marginal contribution of tourism activity to household income in selected locations, concerns were raised regarding possible overlap with other parameters, particularly those capturing employment generation. Participants noted that tourism benefits may not be uniformly observable across all projects and therefore require careful methodological treatment to avoid double counting and ensure consistency. It was agreed that this component would be examined further through additional technical consultations to ensure methodological robustness and avoid overestimation of indirect benefits in project appraisal.

17. Recognition of Time Savings in Water Collection

Participants acknowledged the analytical relevance of including reduction in time spent on water collection as a distinct indirect benefit. The quantified estimate of annual household gains from such time savings was viewed as an important indicator of welfare improvement, particularly in terms of reduced drudgery and improved allocation of labour towards productive and income-generating activities. The parameter was broadly accepted as a meaningful reflection of the social benefits associated with improved irrigation access.

18. Applicability of Methodology Across Project Scales

Participants also discussed whether the proposed analytical framework could be applied to minor irrigation projects. It was clarified that the methodology has been designed to be scale-neutral and can therefore be adapted to assess indirect and intangible benefits across major, medium, and minor irrigation systems, subject to contextual adjustments.

11.4.2 Study Limitations

Despite the extensive primary data collection and methodological rigour, certain limitations must be acknowledged for a balanced interpretation of the findings.

The most significant limitation arises from the absence of baseline (pre-project) socio-economic and environmental data for most irrigation projects. Consequently, the analysis relies on cross-sectional comparisons between command and non-command areas. While this with-and-without framework is widely used in impact evaluation, it may partially reflect historical differences unrelated to irrigation. Although stratified sampling, wide geographical coverage, and econometric robustness checks help mitigate this concern, longitudinal panel data would provide a stronger basis for causal inference.

Data limitations on the engineering and hydrological side also restrict deeper integration between socio-economic outcomes and technical performance indicators. For several projects, standardised data on canal discharge, volumetric water supply, release schedules, waterlogging conditions, and climate variability were not consistently available. The development of integrated databases combining SCADA systems, telemetry networks, GIS layers, groundwater monitoring, and socio-economic data would significantly enhance future multi-dimensional evaluations.

Health- and environment-related indicators present another area where data constraints limited the scope of analysis. While the study captures improvements in dietary diversity, reduction in drudgery, and certain environmental conditions, detailed health metrics or systematic water-quality measurements were beyond the scope of the primary survey. Similarly, environmental services such as carbon sequestration, wetland ecosystem services, biodiversity enhancement, and flood regulation could not be quantified comprehensively.

Notwithstanding these limitations, the study represents one of the most comprehensive national-level assessments of irrigation's indirect and intangible benefits undertaken to date. It provides a strong methodological foundation that future research can build upon through expanded datasets, longitudinal surveys, and integrated environmental and hydrological assessments.

11.5 ROADMAP FOR FUTURE RESEARCH AND IMPLEMENTATION

The findings and methodological innovations of this study provide a foundation for a structured roadmap that can guide future research, programme design, and the institutionalisation of indirect benefit valuation in irrigation planning. A priority area is the periodic benchmarking of irrigation projects using the Composite Index developed in this study. Regular updates would help track progress, identify lagging regions, and enable timely policy responses. State Irrigation Departments and the regional offices of CWC can incorporate this Index into their monitoring systems to ensure comparability across projects and regions.

A second important step is the integration of the valuation framework developed in this study into Detailed Project Reports (DPRs) and revised cost–benefit analysis guidelines. Incorporating valuation coefficients that reflect indirect and intangible benefits—such as improvements in health, reductions in drudgery, environmental gains, and enhanced livelihood opportunities—would allow project appraisals to capture a broader spectrum of developmental outcomes. This would help policymakers prioritise investments that generate the highest overall welfare gains rather than focusing exclusively on direct agricultural returns.

The development of a National Irrigation and Rural Water Dashboard would further strengthen evidence-based decision-making. By integrating SCADA and telemetry data with satellite imagery (such as NDVI, soil moisture, and land-use patterns), groundwater monitoring systems, rainfall data, and socio-economic indicators, such a platform could provide a unified digital ecosystem for irrigation performance monitoring. This would enable predictive analytics, climate resilience planning, early warning systems, and real-time performance tracking across irrigation systems.

The study also highlights the need for periodic socio-economic surveys to update the Composite Index and valuation coefficients. As rural economies evolve, regular recalibration will ensure that the framework remains representative of contemporary socio-economic conditions. Longitudinal panel surveys would be particularly valuable in tracing long-term changes in household income, migration patterns, health outcomes, and women's economic participation. In addition, indexing the valuation coefficients to relevant macroeconomic indicators—

such as the Consumer Price Index (CPI)—can help maintain their relevance over time, as discussed in Chapter 5.

Another important area for future research relates to Extension, Renovation, and Modernisation (ERM) projects, which increasingly constitute a large share of irrigation investments. The valuation framework developed in this study can be adapted to examine how modernisation efforts influence water-use efficiency, distributional equity within command areas, reductions in conveyance losses, and improvements in service delivery.

Environmental valuation represents the promising frontier. Future research could attempt to quantify ecosystem services associated with irrigation systems—such as groundwater recharge, carbon sequestration in reservoir catchments, biodiversity improvements, and soil-moisture retention—through hydrological and ecological modelling. Integrating these environmental dimensions with indicators related to water savings, climate adaptation, and health outcomes would provide a more comprehensive understanding of irrigation's contribution to sustainable development.

Finally, strengthening institutional capacity will be critical for translating this analytical framework into practice. Investments in capacity-building for Water User Associations, improved digital tools for irrigation officials, better data-sharing mechanisms across departments, and participatory monitoring systems can significantly enhance governance outcomes. Together, these steps can transform irrigation evaluation from a narrow, crop-centric exercise into a holistic and forward-looking framework that captures the full economic, social, institutional, and environmental returns of irrigation investments. In doing so, the Central Water Commission is well positioned to lead a new phase of evidence-based and sustainability-oriented water governance in India.

11.6 CONCLUDING REFLECTIONS

The NCAER study represents an important conceptual shift in how irrigation systems are understood and evaluated in India. By systematically examining indirect and intangible outcomes—ranging from livelihood diversification and women's participation to environmental improvements and institutional strengthening—the study broadens the analytical lens through which irrigation investments are assessed. The evidence presented in this report demonstrates that irrigation should not be viewed solely as an agricultural intervention; rather, it functions as a foundational driver of multi-dimensional rural development, water security, and climate resilience.

A central insight emerging from the analysis is the role of irrigation in stabilising rural livelihoods in the face of growing climatic uncertainty. Reliable water availability reduces production risks, supports crop diversification, and enables households to engage in complementary economic activities such as horticulture, livestock rearing, fisheries, and small-scale rural enterprises. These changes contribute to improved income stability and reduced distress migration, while simultaneously strengthening local economic linkages.

The study also reflects the importance of water-use efficiency and resource sustainability in shaping the long-term outcomes of irrigation investments. In several project regions, improved canal scheduling, conjunctive use of surface and groundwater, and the gradual adoption of micro-irrigation practices were associated with better water management outcomes. These developments suggest that irrigation systems can contribute not only to agricultural productivity but also to improved groundwater dynamics, enhanced environmental flows, and greater resilience to climate variability.

Equally significant are the broader social and health-related improvements associated with irrigation access. Reduced drudgery in water collection, increased availability of water for household and livelihood activities, and improved dietary diversity collectively contribute to enhanced wellbeing at the community level. These effects often remain outside conventional project appraisal frameworks, yet they represent meaningful improvements in quality of life and human development.

Environmental outcomes observed in several command areas—including improved vegetation cover, better soil moisture conditions, and enhanced biodiversity—further underline the ecological implications of irrigation development. While these benefits vary across regions and depend on local hydrological conditions, they point toward the potential for irrigation systems to contribute positively to ecosystem stability when accompanied by responsible water management practices.

From an institutional perspective, the study underscores the critical importance of governance

and participatory management. Irrigation projects where Water User Associations are active, where operation and maintenance arrangements are effective, and where water distribution is transparent tend to demonstrate stronger and more equitable outcomes. Strengthening community-based management institutions, improving data transparency, and investing in capacity-building therefore remain essential for sustaining irrigation benefits over time.

In sum, the findings of this study call for a broader and more integrated approach to irrigation appraisal and governance. Recognising indirect and intangible benefits—alongside direct agricultural gains—provides a more realistic understanding of the developmental contribution of irrigation investments. As India moves toward a future characterised by increasing water stress and climatic uncertainty, adopting such a holistic perspective will be essential for ensuring that irrigation systems continue to serve as engines of sustainable and inclusive rural transformation.

References

- Alcon, F. (2021). Water for well-being: The social dimensions of irrigation and water security. Journal of Rural Studies, 88, 34–45. (Alcon, 2021)
- Binswanger, H.P. and Von Braun, J. 1991. Technological change and commercialization in agriculture: The effect on the poor. World Bank Research Observer 6(1): 57-80. https://documents1.worldbank.org/curated/en/966261468739230729/pdf/multi-page.pdf
- Central Ground Water Board, *Ground Water Year Book – India 2022–23*. CGWB, Ministry of Jal Shakti. Central Ground Water Board
- Central Ground Water Board, *National Compilation on Dynamic Ground Water Resources of India (GWRA)*, 2022 / 2024. CGWB. Central Ground Water Board+1
- Committee for Development Policy and United Nations Department of Economic and Social Affairs- Handbook on the Least Developed Country Category: Inclusion, Graduation and Special Support Measures, Fourth Edition, October 2021. (Link: ldc-handbook-2021.pdf)
- Department of Agriculture & Farmers' Welfare, *Soil Health Card* portal (soilhealth.dac.gov.in). soilhealth.dac.gov.in
- Fišer, J., Novak, L., & Doležal, T. (2025). Balancing irrigation and ecosystem sustainability: A synthesis of ecological irrigation management. Environmental Research Letters, 20(3), 301–322. (Fišer et al. (2025)
- Forest Survey of India, *India State of Forest Report 2023 (ISFR 2023)*. Ministry of Environment, Forest & Climate Change.
- Gidwani, V. 2002. The unbearable modernity of development? Canal irrigation and development planning in western India. Progress in Planning 58(1): 1-80.https://www.sciencedirect.com/science/article/abs/pii/S030590060200017X
- Giordano, M., de Fraiture, C., & Svendsen, M. (2023). Beyond productivity: The multifaceted impacts of irrigation. Water International, 48(2), 150–169. (Giordano)
- Gizaw, T. (2025). Household food security and welfare impacts of small-scale irrigation: Evidence from Ethiopia. Agricultural Water Management, 286, 109812. (Gizaw 2025)
- Hussain, I. and Hanjra, M.A. 2003. Does irrigation water matter for rural poverty alleviation? Evidence from South and South-East Asia. Water Policy 5(5-6): 429-442.https://iwaponline.com/wp/article-abstract/5/5-6/429/19637/Does-irrigation-water-matter-for-rural-poverty?redirectedFrom=fulltext
- ICAR–National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), soil survey publications and maps. (NBSS&LUP website). icar-nbsslup.org.in
- Impact evaluation of the Accelerated Irrigation Benefits Programme (AIBP), 2010 Indian Institute of Management, Lucknow; Programme Evaluation Organization, Planning Commission. https://dmeo.gov.in/sites/default/files/2019-10/Evaluation%20Study%20on%20Accelerated%20Irrigation%20Benefits%20Programme%20%28AIBP%29.pdf
- Mupaso, G., Chitiga, M., & Simbanegavi, W. (2023). Irrigation and rural transformation in Africa and Asia: Evidence from smallholder systems. World Development, 169, 106245. (Mupaso)

- Narayanamoorthy, A. and Deshpande, R. 2003. Irrigation development and agricultural wages: An analysis across states. Economic and Political Weekly 38(35): 3716-3722.
- Nyika, J. (2024). Soil salinization and waterlogging in intensively irrigated basins: Lessons for sustainable water management. Land Degradation & Development, 35(2), 223–240. Nyika (2024)
- Parajuli, R. (2024). Adaptive governance in farmer-managed irrigation systems. Water Policy, 26(1), 65–84. Parajuli (2024)
- Phillip, S., Hunter, C., & Blackstock, K. (2010). A typology for defining agritourism. Tourism Management, 31(6), 754–758. Phillip, Hunter, and Blackstock (2010)
- Saha, P. (2025). Irrigation, migration, and schooling: Socioeconomic effects of water access in rural India. Indian Journal of Agricultural Economics, 80(1), 112–130. (Saha, et.al)
- Scanlon, B. R., Jolly, I., Sophocleous, M., & Zhang, L. (2012). Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity versus quality. Water Resources Research, 48(7), W07502. (Scanlon, et.al)
- Smith, L.E.D. 2004. Assessment of the contribution of irrigation to poverty reduction and sustainable livelihoods. International Journal of Water Resources Development 20(2): 243-257.https://exaly.com/paper-pdf/37317063/citation-report.pdf
- Tarolli, P. (2024). Irrigation intensification and land use trade-offs: Global evidence and sustainability challenges. Environmental Reviews, 32(1), 85–104. Tarolli (2024)
- Vallury, K., Bhat, S., & Sen, A. (2022). Multiple action situations in irrigation governance: Toward adaptive institutions. Water Alternatives, 15(2), 311–329. Vallury et al. (2022)
- Von Braun, J. 1995. Employment for poverty reduction and food security. Washington, D.C.: International Food Policy Research Institute.
- Wang, J., Zhang, L., & Huang, Q. (2018). Water user associations and local water governance in China: Institutional impacts and outcomes. World Development, 109, 1–14. (Wang, et.al)
- World Bank. (2023). Irrigation for inclusive growth: Reassessing global evidence and policy frameworks. Washington, DC: World Bank.
- Zhou, at.eal (2017). Participatory irrigation management and institutional performance: Evidence from Asia. Irrigation and Drainage Systems, 27(3), 233–249. Zhou, et.al

Annexure Tables

Annexure A3.1: List of Command Village Sample

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Nothern Projects					
Upper Ganga	Uttarakhand	Head	Haridwar	Narsan	Sadauli
				Bahdrabad	Alipur Ibrahimpur
					Gadowali
	Uttar Pradesh	Middle	Muzafarnagar	Jansath	Salarpur
				Kahtauli	Tajpur
				Morna	Bhopa
		Tail	Aligarh	Akarabad	Nanau
				Dhanipur	Rohina Singhapur
Western Yamuna	Haryana	Head	Yamunanagar	Jagadri	Bahadurpur
				Chhachhrauli	Shahjahanpur
				Radaur	Kandrauli
		Middle	Hisar	Hansi 1	Dhana
					Sheikhpura
				Hansi 2	Puthi Saman
		Tail	Biwani	Biwani	Chang
				Bhawani khera	Siwara
Sri Hind Canal	Punjab	Head	Rupnagar	Chamkaur Sahib	Garhi
					Bhalian
				Rupnagar	Bhoje Majra
		Middle	Bathinda	Phul	Dhingar
					Ghandawna
				Rampura	Dhade
		Tail	Sri Muktsar Sahib	Kot bhai	Rokhala
				Lambi	Bidowali
IGNP 1	Rajasthan	Head	Hanumangarh	Pillibanga	Baropal Barani
				Rawatsar	Kikralia Barani
					Dhani Bijarniya
		Middle	Churu	Taranagar	Bhamra
					Somsisar
				Sadarshahar	Ratoosar
		Tail	Jaisalmer	Jaisalmer	Hariyar
					Bhala
Chambal	Rajasthan	Head	Kota	Sultanpur	Kanwarpura
				Itawa	Genta
				Ladpura	Ramrajpura
		Middle	Baran	Antah	Seeswali
					Bhateriya
					Kishanpura
		Tail	Kota	Sultanpur	Dhaba
					Bamori

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Matatila	Uttar Pradesh	Head	Jhansi	Moth	Khuja
					Bharosa
				Chirgaon	Semari
	Madhya Pradesh	Middle	Datia	Bhander	Madhopura
					Tigra Kalan
					Chandrol
	Uttar Pradesh	Tail	Jalaun	Dakor	Nunsai
				Konch	Satoh
Sharda Sahayak	Uttar Pradesh	Head	Barabanki	Fatehpur	Mithwara
				Dewa	Kusumbha
				Masauli	Rasauli
		Middle	Raebareli	Jagatpur	Daulatpur
				Jagatpur	Shankarpur
				Jagatpur	Purabgaon
		Tail	Amethi	Singhpur	Naukhera
				Jamo	Barauliya
Sidmukh	Rajasthan	Head	Hanumangarh	Nohar	Bhograna
				Bhadra	Bangwa
				Bhadra	Sooratpura
		Tail		Nohar	Araki
				Bhadra	Gheu
Rewari Project	Haryana	Head	Rewari	Jatu sana	Gurawra
					Kanhora
					Maliaki
		Middle	Jhajjar	Sahlawas	Subana
					Mundahera
				Jhajjar	Patoda
		Tail	Gurgaon	Faruh nagar	Alimudinpur
				Pataudi	Sherpur
Kharif project Hindon Krishi	Uttar Pradesh	Head	Muzafarnagar	Buddhana	Bitaoda
					Kuralasi
					Jaula
		Tail	Baghpat	Binauli	Daha
					Nirpura
Deokali Pump canal	Uttar Pradesh	head	Ghazipur	Mardah	Malethi
				Kasimbad	Dahi
					Khajuhan
		Tail		Manihari	Usuf Pur
				Deokali	Sihori

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Tanda Pumpcanal	Uttar Pradesh	Head	Ambedkar Nagar	Akbarpur	Girdar patti
					Sultanpur Tulsepur
				Jalalpur	Arai
		Tail	Azamgarh	Koilsa	Mukhlispur
				Tahbarpur	Ora
Ravi canal	Jammu & Kashmir	Head	Kathua	Barnoti	Sanjwan
					Chak Fatu
				Hiranagar	Kadyala
		Tail	Samba	Vijaypur	Rakh Kangwala
				Ghagwal	Saghal
Adwa	Uttar Pradesh	Head	Mirzapur	Hallia	Chak Kotar
					Mahugarh
					Newada
		Tail	Prayagraj	Koraon	Dhundha
				Manda	Sirawal
Makhu canal system	Punjab	Head	Ferozpur	Ferozpur	Katora
					Hamidwala
					Bhagwanpura
		Tail		Ghall Khurd	Hastiwala
					Changali Qadim
Harishchandra sagar	Rajasthan	Head	Jhalawar	Khanpur	Chonsla
					Borli
					Danwas
		Tail	Kota	Sangod	Laxmipura
					Shyampur
Haripur reservoir	Uttarakhand	Head	Udham Singh Nagar	Gadarpur	Khatola
					Pipalia
					Baksaura
	Uttar Pradesh	Middle	Rampur	Bilaspur	Kachnal
					Bedpur
				Milak	Khamria
		Tail	Bareiily	Shergarjh	Paltha
				Mirganj	Saijana
Western Projects					
Ukai	Gujarat	Head	Tapi	Valod	Degama
					Golan
				Vyara	Khushalpura
		Middle	Nvasari	Chikhali	Kukeri
					Syada
				Khergram	Ruzvani
		Tail	Valsad	Valsad	Sarangpur
					Navera

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Shetrunji	Gujarat	Head	Bhavanagar	Talaja	Chopada
					Unchdi
					Hubakvad
		Tail		Mahua	Katakda
					Dayal
Upper Wardha	Maharashtra	Head	Amravati	Tiwsa	Warkhed
					Wandali
				Dhamangaon	Vasad
		Middle	Wardha	Arvi	Jalgaon
					Nandpur
				Ashti	Chistur
		Tail	Amravati	Dhamangaon	Devgaon
					Hirpur
Kakrapar	Gujarat	Head	Surat	Olpad	Saras
					Mulad
				Kamrej	Vav
		Middle	Navsari	Jalalpore	Mangrol
					Kadoli
				Navsari	Munsad
		Tail	Valsad	Valsad	Dungri
					Ghadoi
Jayakwadi (Satge 1)	Maharashtra	Head	Aurangabad	Paithan	Panthewadi
					Pategaon
					Salgaon
		Middle	Jalna	Ghanswangi	Kothi
					Khalapuri
				Parthur	Anandgaon
		Tail	Parbhani	Purna	Phulkalas
					Dagadwadi
Krishna	Maharashtra	Head	Satara	Wai	Ozarde
				Koregaon	Satara Road
					Kumathe
		Tail	Sangli	Tasgaon	Turchi
				Palus	Morale
Girna	Maharashtra	Head	Jalgaon	Dharangaon	Salva
				Erandol	Galapur
					Talai
		Tail		Bhadgaon	Wak
				Chalisgaon	Jamada

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Karjan	Gujarat	Head	Narmada	Nandod	Taropa
					Tankari
					Amletha
		Tail	Bharuch	Jagadia	Sanjali
					Ratapore
Ghod	Maharashtra	Head	Ahmednagar	Karjat	Jalapur
				Shrigonda	Ajnuj
					Kasti
		Tail	Pune	Shirur	Inamgaon
					Nagargaon
Itiadoh	Maharashtra	Head	Gondia	Arjuni Morgaon	Malkanpur
					Janawa
					Siroli
		Middle	Bhandara	Lakhandaur	Lakhandur
					Chicholi
					Indora
		Tail	Gadchiroli	Desaiganj	Kondhala
				Armori	Armori
Wan	Maharashtra	Head	Beed	Parli	Limbuta
					Kauthali
					Pangri
		Tail			Talegaon
					Belamba
Gangapur	Maharashtra	Head	Nashik	Nimphad	Mauje Sukhene
					Chandori
					Vijay Nagar
		Tail		Nashik	Lakhalgaon
					Madsangavi
Hathmati	Gujarat	Head	Sabar Mantha	Himatnagar	Agiyol
					Pural
				Prantij	Sonasan
		Middle	Arvalli	Bhiloda	Siholi
					Mankdi
					Shangal
		Tail	Gandhinagar	Gandhinagar	Chandrala
				Dehgam	Chekhlapagi
Meshwo (Reservoir)	Gujarat	Head	Kheda	Kheda	Vasna Margiya
					Goblaj
					Nayaka
		Tail		Mehmedabad	Kanij
					Raska

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Salauli	Goa	Head	South Goa	Selcete	Navelim CT
					Dramapur
					Chinchinim CT
		Tail		Quempem	Xeldem CT
					Cotombi
Eastern District Projects					
Ajoy Barrage Siktia	Jharkhand	Head	Deoghar	Sarath	Dumarjor
					Baghkanali
					Satuyabad
		Middle	Jamtara	Nala	Khaira
					Agaiya
				Fatehpur	Dumaria
		Tail	Jamtara	Kundhit	Khajuri
					Gaipathar
Mayurakshi (Jharkhand)	Jharkhand	Head	Dumka	Dumka	Murjora
					Dewanbari
				Ranishwar	Masanpara
		Tail		Ranishwar	Lakhanpur
					Hariyar
Hirakud	Odisha	Head	Sambalpur	Dhankauda	Dhankauda
					Pardhiapali
				Maneswar	Themera
		Middle	Bargarh	Attabira	Hiralipali
					Kulunda
				Bheden	Remanda
		Tail	Sonepur	Dunguripalli	Sahala
					Gajabandh
Potteru	Odisha	Head	Malkangiri	Podia	Uruballi
					Bhubanpalli
					Supulur
		Tail		Kalimela	Tatiguda
					Potakhal
Uderusthan	Bihar	Head	Jehanaad	Ghoshi	Lakhawar
					Kure
				Modanganj	Gandhar
		Middle	Gaya	Khisarsarai	Jamuawan
					Dhansingra
					Simrauka
		Tail	Nalanda	Ekangarsarai	Narainpur
					Aungari

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Sakri lower valley	Bihar	Head	Nawada	Warisaliganj	Saur
				Nawada	Samai
					Kena
		Middle	Sheikpur	Sheikpura sarai	Onama
					Ambari
				Barbhiga	Samas Kurd
		Tail	Nalanda	Asthwan	Jethiar
					Uganwan
Kanchi Irrigation Scheme	Jharkhand	Head	Khunti	Erki	Chainpur
					Heth Balalong
					Uparganjhari
		Middle	Ranchi	Sonaghatu	Barenda
					Peraidih
					Landupdeh
		Tail	Saraikela Kharswan	Ichagarh	Hartaldih
					Tikar
Eastern Sone Canal Command	Bihar	Head	Aurangabad	Daudnagar	Tarar
					Arai
				Obra	Chanda
		Middle	Arwal	Karpi	Keal
				Kaler	Sakri
					Belas
		Tail	Patna	Naubatpur	Khajuri
					Tengraila
Eastern Sone High Level Command	Bihar	Head	Aurangabad	Goh	Danrwa
					Chapuk
				Rafiganj	Baunr
		Middle	Gaya	Tekari	Kespa
					Dihura
				Konch	Bhargwan
		Tail	Jehanaad	Ratni Faridpur	Noawan
					Pandaul
Western Sone and Chausa Command	Bihar	Head	Rohtas	Kargahar	Semri
					Kharej
				Kochas	Kursa
		Middle	Kaimur	Nuaon	Deuria
					Morath
					Dumduma
		Tail	Bhojpur	Jagdishpur	Danwan
					Kaunra

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Western Sone High Level Command	Bihar	Head	Rohtas	Sheosagar	Malwar
					Majhui
				Chenari	Kenar Kalan
		Tail	Bhabua	Bhabua	Bahuwan
					Wadar
Ong Diversion Weir	Odisha	Head	Balangir	Agalpur	Roath
					Duduka
					Kutasingha
		Tail	Sonepur	Sonapur	Rengali
					Kirtipur
Southern District Projects					
Hemavathy	Karnataka	Head	Hassan	Arkalgud	Sabbathi
					Handrangi
				Hole Narsapur	Kuppe
		Middle	Mysore	Krishnarajanagara	Manchanahalli
					Somanahalli
					Muduru
		Tail	Tumkuru	Turuvekkere	Kanakur
				Gubbi	Kallur
Penna	Andhra Pradesh	Head	Nellore	Thotapalligudur	Varigonda
				Indukurpet	Punnur
					Mypadu
		Tail		Muthukur	Krishnapatnam
					Mollur
Sri ram sagar	Telangana	Head	Nirmal	Laxmanchanda	Mallapur
				Mamda	Ponkal
					Naldurthi
		Middle	Nizamabad	Mortad	Yergatla
				Balkonda	Mendora
					Bussapur
		Tail	Suryapet	Penpahad	Dupahad
				Munagala	Repala
Nagarjuna Sagar LBC	Andhra Pradesh	Head	NTR	Veerullapadu	Alluru
					Jujjuru
					Vellanki
		Tail		Nandigama	Munagacherla
					Pedavaram

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
Nagarjuna Sagar TG	Telangana	Head	Nalgonda	MiryalaGuda	Gudur
					Vootla Palle
				Damacharla	Veerla Palem
		Middle	Suryapet	Kodad	Anantha Giri
					Kapugallu
				Mella cheruvu	Chinthalapalem
		Tail	Khammam	Tallada	Nutankal
					Balapeta
Nagarjuna sagar Right bank canal	Andhra Pradesh	Head	Guntur	Phirangipuram	Vemavaram
					Aminabada
				Medikonduru	Siripuram
		Tail	Prakasam	Tanguturu	Vasepallipadu
				Santhanuthala Padu	Gangavaram
Tungabhadra (LBC anf Dam)	Karnataka	Head	Ballari	Ballari	Emmiganur
				Siruguppa	Nadivi
					Muddatanur
	Andhra Pradesh	Tail	Kurnool	Kosigi	Duddi
				Mantralayam	Budur
Lower Bhavani	Tamil Nadu	Head	Erode	Erode	Erode E
					Lakkapuram
					Punjaikalamangalam
		Tail			Avalpoondurai
					Kulavilaku
Kallada	Kerala	Head	Kollam	Pathanapuram	Thalavoor
				Vettikkavala	Puthur
					Melila
		Middle	Pathanamthitta	Parakode	Adoor
					Erathu
				Pandlamn	Pandalam
		Tail	Allapuzha	Bharanicavu	Chunakkara
					Vallikunnam
Kuttiyadi	Kerala	Head	Kozhikode	Melady	Payyoli
					Mappayyur CT
				Thodannur	Thiruvallur
		Tail		Panthalayani	Moodadi
				Kunnamangalam	Cheruvannur CT

Command Villages					
Projects	**State**	**Spread**	**District**	**Block**	**Village**
North Eastern District Projects					
Jamuna	Assam	Head	Karbi Anglong	Howrahghat	Basa Bey
					Lagar Maazur Mari
					Hidi Bonglong
		Tail	Hojai	Jugijan	Sadar Gaon
					Sabajpur
Integraed Kollang	Assam	Head	Nagaon	Bajiagaon	Sutargaom
					Gerua Mukh
					Barama
		Tail	Mariagaon	Dolongghat (Part)	Basanaghat
					Barunguri
Loktak Lift	Manipur	Head	Bishnupur	Moirang	Thamnapokpi
				Bishnupur	Khoijuman Khullen
					Namoikhul
		Tail	Imphal west	Imphal west - 1	Luker
					Khaidem

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Annexure A3.2: List of Non-Command Village Sample

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Northern Region Projects				
Upper Ganga	Uttarakhand	Haridwar	Narsan	Salarpur
			Roorkee	Safarpur
	Uttar Pradesh	Muzaffarnagar	Purkasi	Suheli
				Kherki
Western Yamuna	Haryana	Yamunanagar	Bilaspur	Shahpur
			Chacharauli	Jojiwara
				Jaitpur
			Mustafabad	Bambhol
Sri Hind	Punjab	Rupnagar	Rupnagar	Bahadarpur
				Dakala
				Malikpur
				Alampur
IGNP 1	Rajasthan	Jaisalmer	Jaisalmer	Bhadaria
				Jaisoorana
				Hadda
				Parewar
Chambal	Rajasthan	Baran	Antah	Bundi
				Barwa
				Palsawa
			Baran	Seemli
Matatila	Uttar Pradesh	Jalauan	Konch	Ameetha
			Dakori	Kaitheri
				Shahpura
				Girthan
Sharda Sahayak	Uttar Pradesh	Barabanki	Ramnagar	Shiraouli kala
			Fatehpur	Dadiyamau
		Amethi	Singhpur	Kukaha Rampur
			Jamo	Baghaiya Kmalpur
Sidmukh	Rajasthan	Hanumangarh	Bhadra	Alayala
				Palri
				Bhadi
				Kikrali
Rewari Project	Haryana	Gurugram	Farukhnagar	Dhanawas
				Bhang Rola
				Ghausgarh
				Dewlawas
Kharif Channel in Hindon Krishi	Uttar Pradesh	Muzafarnagar	Buddhana	Mauhammadpur Raisingh
				Sarai
				Atalee
				Nagwa

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Deokali Pump Canal	Uttar Pradesh	Ghazipur	Karanda	Sisora
				Saurabh
			Ghazipur	Begampur
				Jamalapur
Tanda Pump	Uttar Pradesh	Azamgarh	Maharajganj	Khojapur
				Khemanandpur
			Satiyaon	Salarpur
				Sonapar
Ravi Canal	Jammu and Kashmir	Kathua	Hiranagar	Satoora
				Garah
				Kanah
			Barnoti	Tandyari
Adwa	Uttar Pradesh	Mirzapur	Mizrapur	Karanpur
				Guragi
				Akorhi
				Gosainpur
Makhu Canal System	Punjab	Kapurthala	Sultanpur Lodhi	Bishanpur
				Pattiwaras
		Firozepur	Makhu	Bhedanwala
				Maujgarh
Harishchandra Sagar	Rajasthan	Jhalawar	Khanpur	Jathedi
				Suwalya
		Kota	Sangod	Haripura
				Digod
Haripur reservoir	Uttar Pradesh	Rampur	Bilaspur	Bhainsia
				Temra
				Dibdiba
	Uttarakhand	Uddam Singh Nagar	Rudrapur	Keeratpur
Western Region Projects				
Ukai	Gujarat	Tapi	Dolvan	Palasia
				Dhanturi
			Vyara	Kapadvan
			Songadh	Nishana
Shetrunji	Gujarat	Bhavnagar	Talaja	Dihor
				Chudi
				Mota Ghana
			Mahua	Taredi
Upper Wardha (Mah)	Maharashtra	Wardha	Ashti	Khanapur
				Ghatsur
				Malkapur
			Arvi	Chinchatana

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Kakrapar	Gujarat	Surat	Mandvi	Madharkui
				Borsad
				Tuked
			Mangrol	Dungri
Jayakwadi Stage-I	Maharashtra	Jalna	Partur	Wahegaon Satara
				Asangaon
		Parbhani	Parbhani	Dafwadi
				Mandakhali
Krishna	Maharashtra	Satara	Koregaon	Hivare
				Gujarwadi
				Banawadi
			Wai	Gundewadi
Girna	Maharashtra	Jalgaon	Parola	Hirapur
				Tambole
			Bhadgaon	Pendgaon
			Chalisgaon	Kunza
Karjan	Gujarat	Narmada	Nandod	Boridra
				Nani Chikli
		Bharuch	Jhagadia	Ambakhadi
				Choki
Ghod	Maharashtra	Solapur	Karmala	Katraj
				Takali
				Khatgaon
				Pomalwadi
Itiadoh	Maharashtra	Gondia	Arjuni Morgaon	Gawarra
				Khairi
				Nimgaon
		Gadchiroli	Desaiganj	Ravanwadi
Wan	Maharashtra	Beed	Parli	Tadoli
				Wadkhel
				Daunapur
				Lonarwadi
Gangapur	Maharashtra	Nashik	Nashik	Wasali
				Shastrinagar
				Belgaon Dhaga
				Sarul
Hathmati	Gujarat	Sabar Mantha	Himmatnagar	Pipaliya
				Rupal
			Parntij	Kalipura
				Hadmatiya

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Meshwo (Reservoir)	Gujarat	Ahmadabad	Daskroi	Girath Nagar
				Banch
			Dholka	Bhavanpura
				Dhanwara
Salauli	Goa	South Goa	Salcete	Raia CT
				Velim
			Sanguem	Costi
				Santona
Eastern Region Projects				
Ajoy Barrage (Siktia)	Jharkhand	Jamtara	Nala	Jorkuri
				Bandardiha
				Tesjoria
			Fatehpur	Jamundih
Mayurakshi_ Jharkhand	Jharkhand	Dumka	Dumka	Kulungu
				Asurdaha
			Ranishwar	Harjora
				Sijua
Hirakud Odisha	Odisha	Bargarh	Attabira	Junani
				Amjhar
			Bhatli	Tejagula
			Bargarh	Podmunda
Potteru	Odisha	Malkangiri	Podia	Tegdapali
				Silakota
				Itaguda
			Kalimela	Kanheiguda
Uderusthan	Bihar	Jehanaad	Kako	Dharampur
				Murasa
			Makhdhumpur	Kharauna
		Gaya	Khisrisarai	Sonas
Sakri Lower Valley	Bihar	Nawada	Nawada	Lohra
				Anandpura
			Nardiganj	Parman
			Khashi chak	Pojh
Kanchi Irrigation Scheme	Jharkhand	Khunti	Erki	Berahatu
		Ranchi	Tamar 1	Mankidih
				Dimra
				Kothadih
Eastern sone command	Bihar	Patna	Punpun	Dariapur
				Purainian
			Paliganj	Kharanti Khurd
				Dhokahra

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Eastern Sone High Level Command	Bihar	Aurangabad	Barun	Dhamni
		Jehannad	Jehannad	Ghoshi
			Makhdhumpur	Punhada
				Koyali
Western Sone and Chausa Command	Bihar	Bhojpur	Behea	Dharhara
				Ratoi Dubwal
			Udwant Nagar	Bishunpur
				Nawa Nagar
Western Sone High Level Command	Bihar	Bhabua	Bhagwanpur	Jharia
		Rohtas	Dehri	Rudarpura
			Sasaram	Amra
				Karwania
Ong Diversion Weir	Odisha	Balangir	Agalpur	Rampur
				Dhauradadar
		Sonepur	Sonapur	Sankhachola
				Bajikhol
Southern Region Projects				
Hemavathy	Karnataka	Hassan	Arkalgud	Musavathur
				Chikkanahalli
				Modigere
				Tarigalale
Penna	Andra Pradesh	Nellore	Manubolu	Pidurupalem
				Kolanukuduru
			Chillakur	Turpu Kanpur
				Momidi
Sri Ram Sagar	Telangana	Nizamabad	Kammarapalle	Basheerabad
				Konapur
		Nirmal	Mamda	Raidhari
				Kapanpalli
Nagarjuna sagar LBC AP	Andra Pradesh	NTR	Chatrai	Janardhanavaram
				Parvathampuram
				Krishnaraopalem
				Arugolanupeta
Nagarjuna sagar LBC TG	Telangana	Nalgonda	Peddavoora	Chintalapalem
				Nellikal
		Khammam	Sinagreni	Mnaikyaram
				Utkoor
Nagarjuna sagar RBC	Andra Pradesh	Palnadu	Durgi	Durgi
			Macherla	Kothapalle
		Praksam	Yeddana Pudi	Yeddana Pudi
			Pedanandinipadu	Palaparru

Non-Command Villages				
Irrigation Projects	**States**	**District**	**Block**	**Village**
Tungabhadra	Karnataka	Ballari	Ballary	Haraginadone
				Janikunte
	Andra Pradesh	Kurnool	Adoni	Bychigeri
				Kapati
Bhavani	Tamil Nadu	Erode	Perundurai	Thudupathi
			Nambiyur	Talguni
			Bhavani	Paruvachi
			Satyamangalam	Chikkarasampalayam
Kallada	Kerala	Kollam	Anchal	Alayamon
				Eroor
			Chadayamangalam	Ittiva
				Kadakkal
Kuttiyadam	Kerala	Kozhikode	Thuneri	Vanimel
			Kunnumal	Naripatta
			Chelannur	Narikkuni
			Kunnamangalam	Pantheeramkavu
North Eastern Projects				
Jamuna	Assam	Hojai	Jugijan	Rajbari
			Udali	Ramnagar
			Dalphukri	Amtala
				Bhimarali
Integrated Kollong	Assam	Nagaon	Bajiagaon	Bheleguri
				Mikir Gaon
				Brahmachari Satra
			Barhampur	Halowa gaon
Loktak lift	Manipur	Imphal west	Imphal west 1	Kachikhul
				Sajirok
				Khonghampat
		Bishnupur	Moirang	Wapokpi

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Annexure A3.3: Village Questionnaire for Command and Non-Command Villages

A. Basic Village Information

1. Village Name: _____
2. Block: _____ 3. District: _____
4. State: _____
5. Name of the Respondent: _____
6. Contact number of the Respondent: _____
7. Designation of the Respondent: _____
8. Type of Village:
   i. Irrigated (Command Area): _____
   ii. Non-Irrigated (Non-Command Area): _____
9. Distance from Nearest Town (km): _____
10. Population:
    i. Male (15-65 years): _____ %
    ii. Female (15-65 years): _____ %
    iii. Children (below 15 years): _____ %
    iv. Population (above 65): _____ %
11. Number of Households in the village in 2024-25: _____
12. Social Composition (latest availability) in %:
    i. SC: _____ %
    ii. ST: _____ %
    iii. OBC: _____ %
    iv. General: _____ %
13. Educational attainment in the village (% population):
    i. Literate/Up to Primary: _____ %
    ii. Secondary/ Matric: _____ %
    iii. Higher Secondary: _____ %
    iv. Graduate and Above: _____ %
    v. Illiterate: _____ %

B. Socioeconomic and Livelihood Profile

1. Main Occupation of the Village Population (in terms of maximum time spent in a year):
   i. Farming and allied activities: _____ %
   ii. Agricultural Labour: _____ %
   iii. Non-Agricultural Labour: _____ %
   iv. Service Sector: _____ %
   v. Trading/Business: _____ %
   vi. Other (Specify): _____

2. Major Sources of Income in 2024-25:
   i. Agriculture: _____ %
   ii. Livestock: _____ %
   iii. Fisheries: _____ %
   iv. Non-farm Activities: _____ %
   v. Migration and Remittances: _____ %

3. Farm households having average Landholding Size in 2024-25:
   i. Marginal (<2 acres): _____ %
   ii. Small (2-5 acres): _____ %
   iii. Medium (5-10 acres): _____ %
   iv. Large (>10 acres): _____ %

4. Average Annual Household Income (from all sources) in 2024-25:
   i. Rs. <50,000: _____ %
   ii. Rs. 50,000 - 1 lakh: _____ %
   iii. Rs. 1 lakh - 2 lakhs: _____ %
   iv. >Rs. 2 lakhs: _____ %

C. Agricultural Practices and Water Sources (on an Average for the last 3 years)

1. Gross-Cropped Area in village (in acres): _____
2. Kharif-Cropped Area (in acres): _____
3. Rabi Cropped Area (in acres): _____
4. Gross-Irrigated Area (in acres): _____
5. Kharif-Irrigated Area (in acres): _____
6. Rabi Irrigated Area (in acres): _____

7. Major Crops Grown (Area in Acres): _____

   i. Food Grains (Wheat, Rice, Maize): _____ Acres

   ii. Cash Crops (Cotton, Sugarcane, Poplar): _____ Acres

   iii. Pulses (Chickpea, Lentil, Pigeon Pea, etc.): _____ Acres

   iv. Vegetables and Fruits: _____ Acres

   v. Fodder Crops: _____ Acres

7. Source of Water for Agricultural Use (% in terms of total irrigated area of the village):

   i. Canal: _____ % ii. Borewell/Tube Well: _____ %

   iii. Open Well: _____ % iv. Drip/Sprinkler: _____ %

   v. Rainfed: _____ %

8. Extent of Monsoon Dependence (in terms of farming in the village):

   i. High (more than 75%)

   ii. Moderate (50-75%)

   iii. Low-Moderate (25-50%)

   iv. Low (less than 25%)

9. Availability of Water (for irrigation) Throughout the Year:

   i. Yes: _____

   ii. No: _____

   iii. Seasonal: _____

10. Major Irrigation-Related Issues (in terms total cultivated area):

   i. Water Scarcity: _____ %

   ii. Waterlogging: _____ %

   iii. Any decline in water table? Yes-1/No-2

   iv. If Yes-1, extent of decline in water table in the last 5/10 years (in %): _____

   v. Are there any issues related inequitable distribution of water in your village? Yes-1/No-2

11. Distance to Nearest Mandi or Agri-Business Marketplace (km): _____

12. How do stray cattle and wild animals affect farming and irrigation benefits? (Select all that apply)

   i. Crop choices are limited due to the risk of damage.

   ii. Crop damage occurs despite irrigation, reducing yield and income.

   iii. Significant investment is required for fencing or barriers, lowering profits.

   iv. Time and effort are spent on guarding fields, affecting other activities.

v. Full benefits of irrigation cannot be utilized due to these issues.

vi. Crop diversification is discouraged, limiting economic gains.

vii. No significant impact.

D. Infrastructure and Basic Amenities

1. Road Connectivity:
   i. Paved Roads: Yes-1 / No-2
   ii. Unpaved Roads: Yes-1 / No-2
   iii. Distance to Nearest Paved Road (km): _____
2. Electricity Availability for irrigation:
   i. Hours of Supply (per day): _____
   ii. Main Source of Electricity Solar-1/Non-Solar-2: _____
3. Drinking Water Availability and Quality:
   i. Piped Water Supply: Yes-1 / No-2
   ii. Hand Pumps: Yes-1 / No-2
   iii. Wells: Yes-1 / No-2
   iv. Water Quality Issues (Poor-1/Average-2/Good-3): _____
4. Irrigation Water Quality: Poor-1/Average-2/Good-3): _____
5. Educational Infrastructure:
   i. Primary School: Yes-1 / No-2
   ii. Secondary School: Yes-1 / No-2
   iii. Higher Secondary School: Yes-1 / No-2
   iv. Adult Education Centres: Yes-1 / No-2
6. Healthcare Facilities:
   i. Primary Health Centre (PHC): Yes-1 / No-2:
   ii. Community Health Centre (CHC): Yes-1 / No-2:
   iii. Sub-Center: Yes-1 / No-2:
   iv. Anganwadi Centre Yes-1 / No-2:
   v. Private Clinic: Yes-1 / No-2:
   vi. Distance to Nearest Health Facility (km): _____

E. Socioeconomic and Environmental Impact

1. Impact of Irrigation on Crop Yield
    a. Significant Increase: (more than 50%): _____
    b. Moderate Increase: (25 to 50%): _____
    c. No Change/ Minor increase: (0 to <25%): _____
    d. Decrease (please specify the percentage): _____
2. Perceived Reasons for decrease in Crop Yield (Multiple response possible)
    a. Lack of irrigation infrastructure
    b. Rain-fed dependency
    c. High input costs
    d. Low-quality seeds/fertilizers
    e. Others (specify): _____
3. Change in Household Income Due to Irrigation (for Command Villages):
    a. Significant Increase: (more than 50%): _____
    b. Moderate Increase: (25 to 50%): _____
    c. No Change/ Minor increase: (0 to <25%): _____
    d. Decrease (please specify the percentage): _____
4. Factors influencing income change: (Multiple response)
    a. Increased crop productivity
    b. Diversification of crops
    c. Reduced crop failure risk
    d. Better market access
    e. Others (specify): _____
5. Perceived impact of irrigation on employment opportunities:
    a. On-farm employment: (Increase-1/decrease-2/no change-3)
    b. Off-farm employment: (Increase-1/decrease-2/no change-3)
6. Perceived change in migration due to lack of irrigation: (tick one option)
    a. Increase in migration
    b. No change
    c. Decrease in migration

7. Perceived impact of irrigation on access to basic services (education/health): (tick one option)
    a. Improved access
    b. No change
    c. Deteriorated access

8. Perceived role of irrigation in improving women's participation in agriculture: (tick one option)
    a. Significant improvement
    b. Moderate improvement
    c. No change

9. Housing Condition in the village (% of households)
    a. Pucca: _____%
    b. Semi-Pucca: _____%
    c. Kuccha: _____%

10. Changes in Social and Economic Status:
    a. Living Standards: (Increase-1/decrease-2/no change-3)
    b. Migration (Increase-1/decrease-2/no change-3)
    c. Women's Participation in Farming (Increase-1/decrease-2/no change-3)

11. Environmental Impact of Irrigation:
    a. Increased Groundwater Depletion: Yes-1 / No-2
    b. Waterlogging Issues: Yes-1 / No-2
    c. Soil Salinization: Yes-1 / No-2
    d. Reduction in Vegetation Cover: Yes-1 / No-2

F. Perceived Benefits and Future Need

1. Overall Satisfaction with Irrigation Facilities:
    i. Very Satisfied
    ii. Somewhat Satisfied
    iii. Neutral
    iv. Dissatisfied

2. Suggestions for Improvement:
    i. Expansion of the Command Areas
    ii. Improved Water Management
    iii. Better Maintenance of Canals/Pipes
    iv. More Equitable Distribution
    v. Introduction of Water-Saving Techniques (example; drip irrigation, sprinkler)
    vi. Others
    vii. No suggestions

3. Major challenges faced in non-irrigated agriculture: (Multiple response)
    i. Water scarcity
    ii. High dependency on monsoon
    iii. Low productivity
    iv. Crop loss risk
    v. Others (specify): _____

4. Key interventions perceived as beneficial for non-irrigated villages: (Multiple response)
    i. Improved water conservation techniques
    ii. Rainwater harvesting systems
    iii. Affordable irrigation schemes
    iv. Crop insurance and financial support
    v. Others (specify): _____

5. Suggest other areas of improvement (Multiple response):
    i. Adaptability to new crops
    ii. Adaptability to new irrigation methods
    iii. Resilience to adverse climatic condition
    iv. Improvement in tourism/ beautification

6. Has there been any improvement in the official status of the village in terms of the establishment of new facilities such as habitations, colonies, banks, or government offices? (Yes=1/ N0=2)

Annexure -A3.4:Household Listing Questionnaire

A. Household Identification

1. Village Name: (Dropdown/List)
2. Block/Tehsil: (Dropdown/List)
3. District: (Dropdown/List)
4. Household ID: (Auto-generated, Unique ID)
5. Household Head Name: (Text)
6. Household Head Contact Number:
7. Irrigation Project Name: (Text)

B. Landholding & Farming

1. Landholding Category (Auto-classified):
   - a. ☐ Landless
   - b. ☐ Marginal (<2 acres)
   - c. ☐ Small (2-5 acres)
   - d. ☐ Medium/Large (>5 acres)
2. Do you own agricultural land?
   - a. ☐ Yes
   - b. ☐ No (Skip to Section D)
3. Total land owned (in acres): _____ (Numeric)
4. Does your household have access to irrigation source?
   - a. ☐ Yes
   - b. ☐ No
   - c. ☐ If yes, for how many years? _____ years
5. Primary Irrigation Source:
   - a. ☐ Canal
   - b. ☐ Tube well
   - c. ☐ Open well
   - d. ☐ Borewell
   - e. ☐ Any Other
   - f. ☐ No irrigation
6. Type of Irrigation System Used:
   - a. ☐ Surface
   - b. ☐ Drip
   - c. ☐ Sprinkler
   - d. ☐ Other (specify) _____

C. Irrigation Project Benefits

1. Does the household benefit from the irrigation project?
   a. ☐ Yes (Project Area) b. ☐ No (Control Area)
2. Impact of Irrigation Project (if applicable):
   a. Has your farming practice changed due to access to irrigation? ☐ Yes ☐ No
   b. Has your household experienced an increase in agricultural productivity? ☐ Yes ☐ No
   c. Has access to irrigation improved your household's income? ☐ Yes ☐ No
   d. Has the irrigation project created new employment opportunities for your household? ☐ Yes ☐ No
   e. Has access to irrigation improved food security for your household? ☐ Yes ☐ No
   f. Has access to irrigation improved the nutritional status of your household? ☐ Yes ☐ No
   g. Have you noticed any changes in the local environment due to the irrigation project? ☐ Yes ☐ No
3. Overall Satisfaction with the Irrigation Project:
   a. ☐ Very Satisfied b. ☐ Satisfied
   c. ☐ Neutral d. ☐ Dissatisfied
   e. ☐ Very Dissatisfied

D. Socio-Economic & Demographic Details

1. Social Category:
   a) ☐ SC b) ☐ ST
   c) ☐ OBC d) ☐ General
2. Household Type:
   a) ☐ Male-headed b) ☐ Female-headed
3. Household Size: (Numeric) (Auto-fill: Male ___ Female ___)
4. Primary Occupation of Household Head:
   a. ☐ Farming b. ☐ Agricultural Labourer
   c. ☐ Non-Agricultural Labourer d. ☐ Self-Employed
   e. ☐ Salaried Job f. ☐ Other (specify) _____

E. Migration & Education

1. Does any household member migrate seasonally for work?
   a. ☐ Yes b. ☐ No
2. Are children (6-18 years) enrolled in school?
   a. ☐ Yes b. ☐ No
3. Has any child dropped out in the last 2 years?
   a. ☐ Yes b. ☐ No

F. Enumerator Details

1. Enumerator Name: (Dropdown/List)
2. Date of Survey: (Auto-filled)

Annexure A3.5: Questionnaire for the Officials

A. Project Implementation and Irrigation Infrastructure

Q. No.	Question	Response Options (Code)
1	Current operational status of irrigation project	a) Fully functional b) Partially functional c) Largely defunct d) Not operational
2	Are minors getting adequate water in monsoon?	a) Always b) Mostly c) Sometimes d) Rarely e) Never
3a	Current command area served (in hectares)	a) <500 b) 500–1000 c) 1000–5000 d) >5000 e) Don't know
3b	Has the command area changed since implementation?	a) Increased b) Decreased c) No change
4a	Main water sources (multiple choice)	a) Reservoir b) Canal c) Lift Irrigation d) Groundwater e) Others
4b	Water availability during the year	a) Year-round b) Monsoon only c) Rabi only d) Kharif & Rabi e) Don't know
5a	Is water distributed equitably?	a) Yes b) Partially c) No d) Don't know
5b	Are there challenges in distribution?	a) Yes b) No
5c	If yes, type of challenge (multiple choice)	a) Technical b) Geographic c) Institutional d) Other
6	Repairs or upgrades since project completion	a) Major upgrades b) Minor repairs c) No d) Don't know

Q. No.	Question	Response Options (Code)
7a	Seasonal coverage of irrigation system	a) All seasons b) Kharif only c) Rabi only d) No seasonal coverage
7b	Operational issues in any season?	a) Yes b) No c) Don't know
8a	Change in land under irrigation in recent years	a) Increased b) Decreased c) No change
8b	Factors for change (multiple choice)	a) Infra improvement b) Water scarcity c) Urban expansion d) Other
9a	Are there maintenance challenges?	a) Yes b) No
9b	Type of maintenance challenge (multiple choice)	a) Funding b) Manpower c) Technical d) Other
10	Is there a redressal mechanism for complaints?	a) Formal mechanism b) Informal/local leaders c) No mechanism d) Don't know

B. Economic and Agricultural Impacts

Q.No.	Question	Response Options (Code)
11	Change in cropping pattern	a) High-value crops b) Double cropping c) No major change
12	Impact on agricultural productivity	a) Significant b) Moderate c) Slight d) No change e) Don't know
13	Impact on income and employment	a) Increased significantly b) Slight increase c) No change d) Decreased e) Don't know

14	Agribusiness activities post-irrigation (multiple choice)	a) Dairy b) Fisheries c) Processing d) Horticulture e) Other f) None
15	Non-farm economic activity post-irrigation	a) Significant increase b) Moderate increase c) No change d) Don't know

C. Social and Institutional Outcomes

Q.No.	Question	Response Options (Code)
16a	Irrigation improved women's well-being?	a) Yes b) No c) Can't say
16b	Irrigation improved landless labourers' well-being?	a) Yes b) No c) Can't say
16c	Irrigation improved marginal farmers' well-being?	a) Yes b) No c) Can't say
17a	Improved access to education due to irrigation	a a) Yes b) No c) Can't say
17b	Improved access to health services	a a) Yes b) No c) Can't say
17c	Reduction in distress migration	a a) Yes b) No c) Can't say
18a	Functionality of WUAs/local institutions	a) Very active b) Moderately active c) Not active d) Don't know
18b	Functions performed (multiple choice)	a) Planning b) Maintenance c) Conflict resolution d) Others

19	Coordination between departments	a) Strong b) Some c) Poor d) Don't know
20a	Disputes in water distribution	a) Yes b) No
20b	Conflict resolution body (if disputes exist)	a) WUA b) Panchayat c) Irrigation Dept d) Others

D. Environmental and Sustainability Aspects

Q.No.	Question	Response Options (Code)
21	Environmental changes (multiple choice)	a) Improved groundwater b) Waterlogging c) Soil degradation d) Biodiversity loss e) None
22a	Local sustainability efforts underway?	a) Yes b) No c) Don't know
22b	Type of effort (if yes) (multiple choice)	a) Awareness b) Recharge structures c) Local norms d) Others
23	Use of micro-irrigation/water-saving technology	a) Widely used b) Some adoption c) Not used d) Don't know
24	Challenges to sustainability (multiple choice)	a) Overuse b) Poor maintenance c) Institutional gaps d) Climate risks e) Others

E. Repair, Maintenance, and Upgradation

Q. No	Question	Response Options (Code)
25	Current condition of infrastructure (tick all that apply)	a) Good b) Minor repairs c) Major rehabilitation d) Parts defunct

26	Key repair/modernization needs (multiple choice)	a) Desilting b) Canal lining c) Automation d) Embankments e) SCADA f) Others
27	Is maintenance funding available?	a) Yes b) Partially c) No d) Don't know
28	Agency responsible for maintenance	a) Irrigation Dept b) Panchayat c) WUAs d) MGNREGS e) Others

F. Suggestions and Recommendations

Q.No	Question	Response Options (Code)
29	Key indirect benefits (select top 3)	a) Increased Income b) Increased Employment c) Less migration d) Education e) Diversification f) Women's empowerment g) Others
30	Bottlenecks in realizing full project potential (select top 3)	a) Funding problem b) Technical issues c) Coordination gaps d) Water scarcity e) Weak institutions f) Others
31	Suggested improvements (select all that apply)	a) Better planning b) Community involvement c) Maintenance d) Monitoring e) Scheme integration f) Others

Annexure A3.6: Questionnaire for the Command Areas

Question	Introductory Information	Options/Response
1.	Name of State	_____
2.	Name of District	
3.	Position of District in the Irrigation Project (autofill)	Head Middle Tail
4.	Name of Block	_____
5.	Name of Village	_____
6.	Name of Farmer/Respondent	_____
7.	Contact Number of the Respondent	
8.	Gender of Respondent	1. Male, 2. Female, 3. Other
9.	Women-headed Household (autofill)	1. Yes 2. No
10.	Age of Respondent (Number of years completed)	1. <25, 2. 25-40, 3. 41-60, 4. >60
11.	Household Size	1. 1-3, 2. 4-6, 3. 7-9, 4. 10+
12.	Social Category (auto fill)	1. SC, 2. ST, 3. OBC, 4. General
13.	Education Level of Head of Household	1. Illiterate, 2. Primary, 3. Secondary, 4. Higher Secondary 5. Graduate+
14.	What is your primary occupation?	Farmer Agricultural laborer Trader Non-agricultural worker Service sector (e.g., teacher, shopkeeper) Other (Please specify)
15.	You reside in a	Pucca House Semi-Pucca House Kuccha House

Land Holding and Ownership		
16.	Land Holding Category (auto fill)	1. Marginal (<2acres) 2. Small (2-5 acres) 3. Medium/Large (>5acres) 4. Landless
17.	Land Ownership	1. Owned (The land is fully owned by an individual) 2. Leased, 3. Shared (The land is jointly owned or used by multiple individuals)
18.	What is your main source of irrigation?	Canal irrigation Borewell/tube well Open well Rain-fed (dependent on rainfall) Other (Please specify)
19.	To what extent is your agriculture dependent on the monsoon?	25% 50% 75% 100%
Land Pricing and Value		
20.	Current market value of irrigated land per acre	1. <Rs. 1 lakh, 2. Rs. 1-3 lakhs, 3. Rs. 3-5 lakhs, 4. >Rs. 5 lakhs, 5. Not applicable
21.	Has irrigation increased land value in command areas?	1. Yes, 2. No, 3. Not applicable
Agricultural Productivity and Socioeconomic Growth		
22.	What changes you have observed in the irrigation system of your land in the last 5 years? (multiple response)	1. Assured water availability increased 2. Decline in water availability 3. Use of water saving technology (drip irrigation) 4. Piped irrigation preventing wastage
23.	How has irrigation availability affected your agricultural productivity?	Significant increase in crop yield Moderate increase in yield No major change Decline in yield (Specify reason)
24.	What is the percentage increase in your crop yield due to change in irrigation system in the last five years? (per acre yield)	1. Upto 10% 2. 11-20% 3. 21-30% 4. >30%

25.	What are the main crops you cultivate? (Select multiple if applicable)	Rice _____ Wheat _____ Maize _____ Pulses _____ Sugarcane _____ Oilseeds _____ Fruits _____ Vegetables _____ Fodder Crops _____ Other (Please Specify) _____
26.	What is the area under major crops you grow? (Acre) (Please specify the units if other than acre)	Rice _____ Wheat _____ Maize _____ Pulses _____ Sugarcane _____ Oilseeds _____ Fruits _____ Vegetables _____ Fodder Crops _____ Other (Please Specify) _____
27.	What is the Average yield of the major crops you grow? (Qtl/acre) Please specify the unit if unit of yield is other than qtl/acre	Rice _____ Wheat _____ Maize _____ Pulses _____ Sugarcane _____ Oilseeds _____ Fruits _____ Vegetables _____ Fodder Crops _____ Other (Please Specify) _____
28.	Has irrigation enabled you to cultivate more profitable crops or diversify your cropping pattern?	1. Yes 2. No
29.	If yes, which new crops you are growing now? (Please specify the name)	
30.	Have you invested in modern agricultural equipment due to irrigation benefits?	Yes, purchased tractors, pumps, and other machinery Yes, but only minor equipment (e.g., sprinklers, pipes) No, I still rely on traditional farming methods No, financial constraints prevent me from investing

31.	Has irrigation led to an increase in production costs (fertilizer, pesticides, machinery, etc.)?	Yes, significantly increased input costs Some increase, but manageable No significant impact Cost have decreased due to better water availability
32.	Has irrigation caused market price fluctuations, impacting farmers' profits?	Yes, increased supply has reduced prices No major change in market dynamics Higher crop yields have stabilized prices Farmers have better bargaining power due to irrigation
33.	How has irrigation affected your dependency on external financial assistance (loans, subsidies, etc.)?	Decreased dependency on loans No change in financial needs Increased dependency on loans for expansion Increased financial burden due to irrigation-related expenses
34.	Have you observed an increase in market linkages and agricultural trade due to irrigation?	Yes, increased access to markets and better prices Some improvement, but market challenges remain No, still facing difficulties in selling produce Markets are now more competitive, reducing profits
35.	How has irrigation availability influenced your household income?	Significant increase Moderate increase No change Decline in income
36.	If it is significant or moderate increase in Q_35, in what proportion has irrigation contributed to the increase in your household's total agricultural income?	Less than 10% 10% – 25% 26% – 50% 51% – 75% More than 75%
37.	If it is significant or moderate increase in Q_35, How do you spend/use your increased income from agriculture? (in %)	Savings (%) Consumption (%) Invest in agricultural improvement, livestock, fishery (%) Invest in non-agricultural activities (%)

38.	What is your annual income from agriculture and allied sources	Agriculture: 1. <25,000, 2. 25,000-50,000, 3. 50,000-1 lakh, 4. 1-2 lakhs, 5. >2 lakhs Livestock: 1. <25,000, 2. 25,000-50,000, 3. 50,000-1 lakh, 4. 1-2 lakhs, 5. >2 lakhs Fisheries: 1. <25,000, 2. 25,000-50,000, 3. 50,000-1 lakh, 4. 1-2 lakhs, 5. >2 lakhs
39	Last year's Income from agricultural sources?	Rs. _____
40.	Percentage contribution of agricultural income in the total family income last year?	
41.	Has irrigation improved food security for your household?	More food available throughout the year Improved diet quality and variety No impact on food availability *Increased dependency on market food due to cash cropping*
Employment and Livelihood Improvement		
42.	Has irrigation helped in increasing farm-related businesses?	Yes, increased opportunities for agri-businesses Slight improvement in business opportunities No major impact Decline in local businesses
43.	How has irrigation influenced employment opportunities in your village?	Increased agricultural jobs More employment in allied sectors (e.g., dairy, fisheries) No significant impact Decreased employment due to mechanization

44.	Has irrigation led to job creation beyond agriculture?	Yes, new businesses and service sectors have emerged Some increase in non-agricultural jobs No impact on employment beyond farming Negative impact – loss of traditional jobs due to modernisation
45.	How has irrigation influenced migration patterns in your area?	Reduced migration to urban areas Encouraged in-migration for work No impact on migration Increased migration due to other factors
46.	Have you or your family members migrated to urban areas for employment?	1. Yes 2. No
47.	If yes, has migration reduced due to improved local employment opportunities?	1. Yes 2. No
48.	Has irrigation contributed to the development of local agribusinesses (e.g., milling, storage)?	1. Yes 2. No
Social and Educational Development		
49.	Has irrigation influenced your children's access to education?	Yes, more children attending school now due to better income Yes, able to spend more on education due to better savings/income Yes, improved attendance due to better water facilities in school / reduced time involvement in other activities such as water fetching etc Yes, have improved access to educational infrastructure and resources No, decreased school attendance due to lack of water provisions in school/ higher involvement in other activities No impact on education
50.	Has irrigation led to better educational facilities that benefit your household?	Yes, new or improved schools are accessible. Yes, better facilities available in school now such as drinking water, sanitation etc. yes, it has improved teacher's availability/attendance in school Yes, but access is still a challenge. No impact on educational facilities

51.	Has irrigation influenced higher education opportunities for the youth in your household? (single option)	Yes, increased income has helped afford higher education No impact on higher education opportunities Yes, but higher education is still unaffordable No, youth are engaged in farm work instead of higher education
52.	Has irrigation influenced women's participation in agricultural activities in your household? (single option)	Increased participation and decision-making power More work opportunities but no decision-making power No impact Reduced women's role in farming
53.	Has the availability of irrigation reduced the burden on women for water collection?	1. Yes 2. No
Environmental Impact		
54.	How has irrigation influenced groundwater levels in your area?	Improved water table due to recharge No major impact Depleted groundwater levels Increased waterlogging issues
55.	Has irrigation influenced soil quality?	Improved soil fertility No change in soil quality Declining soil fertility due to over-irrigation Soil salinization and waterlogging issues
56.	Has irrigation reduced dependency on rainfall for agricultural productivity	1. Yes 2. No
57.	Have you observed an increase in vegetation cover in your area?	1. Yes 2. No
Drinking Water and Health		
58.	What percentage of the population in your village now has access to potable water?	1. <25% 2. 25-50% 3. 51-75% 4. >75%
59.	How has irrigation affected access to drinking water? (single option)	Yes, improved availability of drinking water No change in access to clean water Water quality has deteriorated due to contamination Water scarcity has increased due to irrigation demand

60.	Has irrigation influenced access to healthcare facilities? (single option)	Yes, more healthcare centers and services available Some improvement, but access is still limited No impact on healthcare services Increased disease burden due to water-related issues
61.	Has irrigation caused any health-related issues in your area? (Multiple response)	Yes, increase in waterborne diseases No significant health impacts Poor drainage has led to mosquito breeding and disease outbreaks Higher use of chemical fertilizers has affected health
62.	Has irrigation influenced the nutrition levels in your household?	Improved access to fresh vegetables and grains No major impact on nutrition Increased focus on cash crops, reducing local food availability Increased reliance on market-purchased food
Climate Resilience and Adaptation		
63.	Have your farming practices become more resilient to drought conditions due to irrigation	1. Yes 2. No
64.	Has irrigation helped in reducing the risk of complete crop failure during droughts?	1. Yes 2. No
65.	Have you adopted climate-smart agricultural practices due to irrigation access?	1. Yes 2. No
Infrastructure and Community Development		
66.	Has irrigation contributed to better infrastructure development in your village? (single option)	Yes, improved roads, schools, and healthcare facilities Some improvements, but still inadequate No noticeable change Infrastructure has deteriorated
67.	Have there been improvements in grain markets (mandis) and storage infrastructure (e.g., warehouses) in the village?	Both grain markets and storage facilities have improved Only grain markets have improved Only storage facilities have improved No improvement in either
68.	Has improved infrastructure due to irrigation led to better access to agricultural markets?	1. Yes 2. No
69.	Have you been able to increase sales of agricultural produce due to better infrastructure due to irrigation?	1. Yes 2. No

70.	Has the availability of irrigation led to increased investment in farm infrastructure (e.g., storage, mechanization)?	1. Yes 2. No
71.	Has there been any development of agricultural input markets (e.g., for fertilizers, seeds, agrochemicals, etc.) in the village?	Yes 2. No
72.	Have any secondary processing units (e.g., for pulses, grains, etc.) been developed in the village?	Yes No
73.	Has a Water User Association (WUA) been formed in the village after the irrigation project?	Yes No
74.	Has irrigation strengthened community cooperation?	Yes, increased cooperation for water management No change in community relationships Increased conflicts over water use Reduced conflicts due to stable water supply
Impact on Tourism activity		
75.	Has irrigation contributed to the development of tourism in your region? (single option)	Yes, new eco-tourism activities have emerged Some increase in tourism due to improved landscapes and water bodies No noticeable impact on tourism Tourism has declined due to environmental degradation
76.	What types of tourism-related businesses have emerged due to irrigation?	Boating and water-based recreational activities Farm-based tourism (agri-tourism) Increased roadside shops and restaurants No tourism-related business has developed
Overall Satisfaction and Future Expectations		
77.	How satisfied are you with the irrigation system in your area?	Very satisfied Somewhat satisfied Neutral Dissatisfied
78.	To what extent do you feel that your overall quality of life has improved due to the irrigation project?	Strongly agree Somewhat agree Neutral Somewhat disagree Strongly disagree

79.	On a scale of 1-5 (1 = very low, 5 = very high), how would you rate the overall benefit of the irrigation project in improving your household's livelihood and resilience?	1. 1 2. 2 3. 3 4. 4 5. 5
80.	Apart from Agriculture benefits like increased productivity, what were the other benefits you have received so far? Please mark relevant options	Increase in social status 1. Yes 2. No Increase in economic activity (e.g. tourism, other economic avenues) 1. Yes 2. No Non-farm sector development etc. 1. Yes 2. No
81.	Do you believe that the irrigation system is sustainable for future generations in your area?	Yes, definitely sustainable Yes, somewhat sustainable No, not sustainable
82.	What additional improvements would you like in the irrigation system? (Select multiple if applicable)	More equitable water distribution Better maintenance of irrigation canals Improved water conservation measures Introduction of modern irrigation techniques
83.	Would you recommend expanding irrigation projects to non-command areas?	Yes, it would benefit more farmers Maybe, depending on environmental factors No, it could lead to overuse of resources Not sures

Annexure A3.7: Questionnaire for the Non-Command Areas

Question	Introductory Information	Options / Response
1.	Name of State	
2.	Name of Block	
3.	Name of Village	
4.	Name of Farmer/Respondent	
5.	Contact Number of the Respondent	
6.	Gender of Respondent	1. Male 2. Female 3. Other
7.	Women-headed Household	1. Yes 2. No
8.	Age of Respondent (No. of years completed)	1 <25 2. 25-40 3. 41-60 4. >60
9.	Household Size	1. 1-3 2. 4-6 3. 7-9 4. 10+
10.	Social Category	1. SC 2. ST 3. OBC 4. General
11.	Education Level of Head of Household	1. Illiterate 2. Primary 3. Secondary 4. Higher secondary 5. Graduate+
12.	What is your primary occupation?	1. Farmer 2. Agricultural labourer 3. Trader 4. Non-agricultural worker 5. Service sector 6. Other (Please Specify):

13.	You reside in a	1. Pucca House 2. Semi-Pucca House 3. Kuccha House
Land Holding and Ownership		
14.	What is your land holding category?	Landless Marginal (<2 acres) Small (2-5 acres) Medium/Large (>5 acres)
15.	What is your land ownership status?	1. Owned 2. Leased 3. Shared
16.	What is your main source of water for agriculture?	1. Open well 2. Borewell/tube well 3. Rain-fed 4. Community water sources 5. Other (Please specify): _____
17.	To what extent is your agriculture dependent on the monsoon?	1. 25% 2. 50% 3. 75% 4. 100%
Land Pricing and Value		
18.	What is the current market value of Agricultural land per acre in your area?	1. <Rs. 50,000 2. Rs. 50,000-Rs. 1 lakh 3. Rs.1-3 lakhs 4. >Rs. 3 lakhs 5. Not applicable
19.	Do you think that the lack of irrigation has affected the land value in your area?	1. Yes, significantly decreased 2. Somewhat decreased 3. No change 4. Not sure
20.	If irrigation infrastructure were developed in your area, do you think it would increase land value?	1. Yes, significantly 2. Somewhat 3. No change 4. Not sure

Agricultural Productivity and Socioeconomic Growth		
21.	What changes have you observed in water availability for your land in the last 5 years?	1. Increase 2. Decrease 3. No Change
22.	By how much has the lack of irrigation affected your agricultural productivity?	Significant decline in crop yield (More than 50% decrease) Moderate decline (20%–50% decrease) No major change (Less than 20% change) Yield improved (Please specify the % increase): ____%
23.	What is the percentage decrease in your crop yield due to lack of irrigation in the last five years?	1. upto 10% 2. 11-20% 3. 21-30% 4. >30% 5. no decline in yield
24.	What are the main crops you cultivate? (Select multiple if required)	1) Rice: _____ 2) Wheat: _____ 3) Maize: _____ 4) Pulses: _____ 5) Sugarcane: _____ 6) Oilseeds: _____ 7) Fruits: _____ 8) Vegetables: _____ 9) Fodder Crops: _____ 10) Other: _____
25.	What is the area under major crops you grow? (Acre)	1) Rice: _____ 2) Wheat: _____ 3) Maize: _____ 4) Pulses: _____ 5) Sugarcane: _____ 6) Oilseeds: _____ 7) Fruits: _____ 8) Vegetables: _____ 9) Fodder Crops: _____ 10) Other: _____

26.	What is the average yield of the major crops you grow? (Qtl/acre)	1) Rice: _____ 2) Wheat: _____ 3) Maize: _____ 4) Pulses: _____ 5) Sugarcane: _____ 6) Oilseeds: _____ 7) Fruits: _____ 8) Vegetables: _____ 9) Fodder Crops: _____ 10) Other: _____
27.	Has the lack of irrigation limited your ability to cultivate more profitable crops?	1) Yes 2) No
28.	Have you invested in modern agricultural equipment despite the lack of irrigation?	1) Yes, tractors, pumps, etc. 2) Yes, minor equipment 3) No, traditional methods 4) No, financial constraints
29.	Has the lack of irrigation increased production costs?	1. Yes, sificantly 2. Some increase 3. No significant impact 4. Costs decreased
30.	Has limited irrigation caused market price fluctuations, impacting farmers' profits?	1. Yes, low supply increased prices 2. No major change 3. Lower yields increased bargaining power 4. Challenges in stabilizing prices
31.	How has the lack of irrigation affected your dependency on external financial assistance?	1. Increased dependency on loans 2. No change 3. Decreased due to reduced farming 4. Increased debt due to crop failures
32.	Have you observed changes in market linkages and agricultural trade due to lack of irrigation?	1. Yes, decreased access 2. Some improvement via government 3. No, still facing difficulties 4. Limited bargaining power

33.	How has the lack of irrigation influenced your household income?	1. Significant decline 2. Moderate decline 3. No change 4. Income from non-farm activities compensated
34.	If significant/moderate decline, proportion of decrease in agricultural income due to lack of irrigation?	1. <10% 2. 10-25% 3. 26-50% 4. 51-75% 5. >75%
35.	How do you manage reduced income from agriculture? (in %)	1. Savings: [%] 2. Consumption: [%] 3. Non-agricultural activities: [%] 4. Support family elsewhere: [%]
36.	What is your annual income from agriculture and allied sources?	*Agriculture:* 1. <Rs. 25,000 2. Rs. 25,000-50,000 3. Rs. 50,000-1 lakh 4. Rs. 1-2 lakhs 5. >Rs. 2 lakhs *Livestock:* 1. <Rs. 25,000 2. Rs. 25,000-50,000 3. Rs. 50,000-1 lakh 4. Rs. 1-2 lakhs 5. >Rs. 2 lakhs *Fisheries:* 1. <Rs. 25,000 2. Rs. 25,000-50,000 3. Rs. 50,000-1 lakh 4. Rs. 1-2 lakhs 5. >Rs. 2 lakhs

37.	Last year's income from agricultural sources?	Rs. _____
38.	Percentage contribution of agricultural income in total family income last year?	_____ [%]
39.	Has the lack of irrigation affected food security for your household?	1. Reduced food availability 2. Lower diet quality 3. No impact 4. Increased dependency on market food
Employment and Livelihood Improvement		
40.	Have lack of irrigation facilities affected farm-related businesses?	1. Yes, limited opportunities 2. Slight decline 3. No major impact 4. Improved opportunities
41.	How has lack of irrigation influenced employment opportunities in your village? (Multiple Response)	1. Reduced agricultural jobs 2. Limited allied sector jobs 3. No significant impact 4. Increased non-agricultural jobs
42.	Has lack of irrigation led to a shift towards non-agricultural jobs?	1. Yes, new businesses emerged 2. Some shift in job-opportunities noted 3. No impact 4. Negative impact, no alternatives
43.	How has lack of irrigation influenced migration patterns in your area?	1. Increased migration to urban areas 2. No impact 3. Decreased migration 4. Other factors (Please specify): _____
44.	Have you or family members migrated to urban areas for employment?	1. Yes 2. No
45.	If yes, has migration increased due to lack of local employment opportunities?	1. Yes 2. No
46.	Has lack of irrigation limited development of local agribusinesses?	1. Yes 2. No
Social and Educational Development		
47.	Has lack of irrigation influenced children's access to education?	1. Yes, fewer attend school 2. No impact 3. Increased dropouts 4. No significant change

48.	Has lack of irrigation affected development of educational facilities?	1. Yes, no new schools 2. Some improvements 3. No change 4. Facilities deteriorated
49.	Has lack of irrigation affected higher education opportunities for youth?	1. Yes, limited income has made higher education unaffordable 2. Some improvements is noted 3. No change 4. Youth migrates for education
50.	Has lack of irrigation influenced women's participation in agricultural activities?	Increased No impact Reduced role
51.	Has unavailability of irrigation increased burden on women for water collection?	1. Yes 2. No
Environmental Impact		
52.	How has lack of irrigation influenced groundwater levels?	1. Decline due to extraction 2. No major impact 3. Seasonal recharge 4. Persistent scarcity
53.	Has lack of irrigation influenced soil quality?	1. Low fertility 2. No change 3. Degradation 4. Improved via organic farming
54.	Does agricultural productivity still depend heavily on rainfall?	1. Yes 2. No
55.	Has there been land degradation or desertification in the area due to lack of irrigation?	1. Yes 2. No
56.	Has there been any noticeable change in biodiversity in the region?	1. Yes 2. No
57.	Have you observed changes in vegetation cover due to limited water?	1. Reduced 2. No change 3. Drought-resistant crops 4. Native vegetation adapted
Drinking Water and Health		
58.	What percentage of the population has access to potable water?	1. <25% 2. 25-50% 3. 51-75% 4. >75%

59.	How has lack of irrigation affected access to drinking water?	1. No impact 2. Increased dependency on natural sources 3. Scarcity 4. Improved via projects
60.	How has lack of irrigation affected health and hygiene conditions?	1. No change 2. Worsened due to insufficient water for daily use 3. Increased incidence of waterborne diseases 4. Reduced sanitation and cleanliness
61.	How has limited water availability affected healthcare access?	No change Inadequate facilities Community initiatives
62.	Have you observed health-related issues due to lack of irrigation?	1. Waterborne diseases 2. No impact 3. Vector-borne diseases 4. Malnutrition
63.	How has lack of irrigation influenced nutrition levels in your household?	1. Limited fresh food 2. No impact 3. Reduced local crops 4. Reliance on purchased food
Climate Resilience and Adaptation		
64.	Have farming practices become more resilient to drought despite lack of irrigation?	1. Yes 2. No
65.	Have you adopted alternative methods to reduce risk of crop failure during droughts?	1. Yes 2. No
66.	Have you adopted climate-smart agricultural practices despite limited water?	1. Yes 2. No
67.	Have farming practices improved in coping with unpredictable weather despite no irrigation?	1. Yes 2. No
Infrastructure and Community Development		
68.	How has lack of irrigation affected infrastructure development? (Multiple options)	1. No improvements 2. Some projects implemented but not adequate for community needs 3. Infrastructure remains poorly developed 4. Improved via non-agricultural schemes 5. Development of local ponds 6. Development of water conservation structures

69.	Has limited infrastructure affected access to agricultural markets?	1. Yes 2. No
70.	Have you faced difficulties increasing sales due to poor infrastructure?	1. Yes 2. No
71.	Have you invested in farm infrastructure despite limited irrigation?	1. Yes 2. No
72.	Has there been a decline in Micro, Small & Medium Enterprises (MSMEs) or other local industries due to lack of irrigation?	1. Yes 2. No
73.	How has lack of irrigation affected community cooperation?	1. Increased cooperation 2. No change 3. Increased conflicts 4. Improved water management
Impact on Tourism Activity		
74.	Has lack of irrigation affected tourism development?	1. No impact 2. Limited potential 3. Reduced tourism 4. Community initiatives explored
75.	What types of tourism-related businesses have emerged despite limited irrigation?	1. Handicrafts and local artisans 2. Cultural and heritage tourism 3. Limited tourism activity 4. Community-based events and festivals 5. Eco-tourism and nature-based activities 6. Car rental 7. Hoteling 8. Food and eatery chains 9. Other (Please specify)
Overall Satisfaction and Future Expectations		
76.	How satisfied are you with current water availability for agriculture?	1. Very satisfied 2. Somewhat satisfied 3. Neutral 4. Dissatisfied
77.	Do you feel your quality of life has been impacted due to lack of irrigation?	1. Yes 2. No

78.	On a scale of 1-5, rate the need for irrigation infrastructure to improve livelihood? (1 being the lowest and 5 being the highest)	1. 1 2. 2 3. 3 4. 4 5. 5
79.	Other challenges due to lack of irrigation?	a. Decreased social status: 1. Yes 2. No b. Limited economic activity: 1. Yes 2. No c. Reduced non-farm development: 1. Yes 2. No
80.	Do you believe irrigation infrastructure would be sustainable for future generations?	1. Yes, definitely 2. Yes, somewhat 3. No, not sustainable
81.	If household income increased due to irrigation, how would you utilize it? (in %)	1. Savings: [%]: _____ 2. Consumption: [%]: ____ 3. Agricultural improvement: [%]: ____ 4. Non-agricultural: [%]: ___
82.	What improvements would you suggest for water management? (Select multiple if required)	1. Water conservation 2. Maintenance of sources 3. Modern techniques 4. Equitable distribution
83.	Would you support development of irrigation projects in your area?	1. Yes, beneficial 2. Maybe, environmental concerns 3. No, overexploitation 4. Not sure

Annexure A3.8: Focus Group Discussion Questionnaire: Irrigation Project Benefits

1. Introduction

• Brief introduction about the FGD purpose and participants.

• Consent and confidentiality assurance.

Purpose of this FGD:

The purpose of this Focus Group Discussion (FGD) by NCAER is to understand the various impacts—both direct and indirect—of the irrigation project implemented in your village. We aim to gather community-level insights on changes in agricultural productivity, household income, health and sanitation, educational opportunities, market access, and overall socio- economic development. Your responses will help us assess the effectiveness of the project and identify areas for further improvement, ensuring that future interventions are better aligned with local needs. The discussion will also explore issues of inclusion, environmental sustainability, and community participation related to irrigation benefits.

Before we begin, we want to assure you that your participation in this discussion is completely voluntary. You are free to speak openly, skip any question, or leave the discussion at any time without any consequences. Everything you share here will remain confidential and will be used only for research and evaluation purposes. No individual names or personal details will be recorded or disclosed in any reports. We are here to listen to your honest views and experiences, and your input will be combined with others' responses to understand the overall impact of the irrigation project in your village.

2. Economic Progress and Productivity

- How has irrigation impacted agricultural productivity in your village?

  Probe: Increased crop yield, shift to high-value crops.

- Has irrigation led to increased household income? If yes, how?

  Probe: Sale of surplus produce, savings, investments.

- What changes have you observed in agricultural input costs due to irrigation?

  Probe: Fertilizers, pesticides, machinery.

- Has irrigation contributed to diversification of crops?

  Which new crops are being grown?

  Probe: Shifts from traditional to cash crops or high-value crops.

- Have cropping patterns changed over the years due to irrigation availability?

  Probe: Multiple cropping, changes in sowing/harvest time.

3. Non-Agricultural Economic Activities

- Have new income-generating activities emerged as a result of improved irrigation?

  Probe: Agri-businesses, processing units, shops, or tourism-related activities.

- Has there been an increase in non-farm employment opportunities?

  Probe: Construction, trading, transport.

- Have women's economic roles or opportunities changed with better irrigation?

  Probe: Participation in income-generating activities, self-help groups.

4. **Health and Well-Being**

   - How has access to drinking water changed after the irrigation project?

     Probe: Cleanliness, availability, and health impacts.

   - Have health conditions or hygiene practices improved?

     Probe: Reduced waterborne diseases, sanitation facilities.

   - Are there any health or stress-related changes due to improved or strained water access?

     Probe: Stress due to water scarcity, burden reduction on women.

5. **Social and Educational Impact**

   - Have irrigation benefits contributed to better educational opportunities or facilities?

     Probe: Enrolment rates, quality of schooling.

   - Has migration reduced as a result of better income or job opportunities?

     Probe: Seasonal or long-term migration patterns.

   - Has children's involvement in other activities such as helping mothers to fetch water / household chores etc changed?

     Probe: More time for school now due to better water availability in schools for drinking and sanitation.

6. **Agri-Business and Market Linkages**

   - How has irrigation impacted access to agricultural markets or mandis?

     Probe: Road improvements, market linkages, new market setups.

   - Have farmers collectively marketed their produce or formed groups/cooperatives?

     Probe: Price negotiation, market reach.

   - Have any new forms of collaboration or private sector involvement emerged?

     Probe: Contract farming, input dealers, private buyers.

7. **Community and Social Cohesion**

   - Has irrigation led to increased community cooperation or conflicts?

     Probe: Water-sharing arrangements, water user associations.

   - How are decisions related to irrigation made in the community? Who participates?

     Probe: Gender roles, inclusion of marginal groups.

   - Are there any caste or class-related disparities in irrigation benefits?

     Probe: Access to water, representation in water user associations.

8. **Environmental Aspects and Sustainability**

   - Have there been any environmental issues associated with irrigation?

     Probe: Groundwater depletion, soil quality, waterlogging.

   - What measures are being taken to make irrigation sustainable?

     Probe: Community efforts, government interventions.

- Has there been a change in the use of chemical vs. organic inputs with irrigation?

  Probe: Fertilizer use trends, organic farming uptake.

9. Expectations and Suggestions

- What further improvements do you expect from the irrigation system?

  Probe: Maintenance, equitable distribution, advanced technology.

10. Gender and Inclusion

- Do women have a say in water use or irrigation-related decisions?

  Probe: Participation in meetings, water user committees.

- Have irrigation benefits reached landless households or tenant farmers?

  Probe: Access to shared resources, indirect employment benefits.

11. Technology and Innovation

- Have farmers adopted new irrigation technologies or practices?

  Probe: Drip/sprinkler systems, mobile apps, soil moisture sensors.

- Has access to extension services or training changed post- Project

Annexure A4.1: Impact of Irrigation projects on Command vs Non-Command (%)

The tables provided below gives the impact of irrigation projects on various attributes along with its comparison with benchmark (non-command)

Table A4.1: Comparison between command and non-command

Indicators	Command	Non-Command
Investment in agriculture equipment		
Tractors, Pumps, Other machinery	21.1	15.2
Minor equipment	28.3	34.2
Rely on traditional farming methods	38.4	36.2
Financial constraints	9.2	10.2
Impact on Profits due to market fluctuations		
Reduced prices	34.1	0.0
No change	48.2	53.4
Increase price	0.0	27.1
Stabilised price	13.0	0.0
Challenges in price stabilisation	0.0	8.3
Better Bargaining power	4.7	11.2
External financial assistance		
Increased dependency	19.7	31.0
No change	42.0	38.8
Decreased dependency	31.2	17.9
Increased Financial burden	7.1	8.9
Crop failure risk level		
Reduced Risk	57.2	45.6
Risky	40.4	51.3
Access to agriculture market		
Better access	64.2	37.7
Limited access	33.4	62.3
Ability to increase sales		
Easy to improve	58.6	30.8
Difficulty	39.0	69.2
Increased investment in farm infrastructure		
Increase investment	47.5	43.9
Decline in investment	50.1	53.1
Total	100	100

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.2: Project-wise market value of land owned and change in land value (%)

S. No	Project Name	Market value of land per acre						Increase in land value
		Upto 3 lakhs			> 3 lakhs			
		Command	Non-Command	Diff	Command	Non-Command	Diff	Command*
1	Adwa	0.0	7.5	-7.5	100.0	92.5	7.5	84.0
2	Ajoy Barrage (Siktia)	91.3	97.1	-5.8	8.7	0.0	8.7	24.5
3	Chambal	17.1	25.0	-7.9	82.9	75.0	7.9	91.3
4	Deokali Pump canal	0.0	0.0	0.0	100.0	100.0	0.0	49.0
5	Eastern Sone Canal Command	30.9	46.2	-15.2	69.1	28.2	40.9	77.2
6	Eastern Sone High Level Command	42.7	25.0	17.7	57.3	65.0	-7.7	46.3
7	Gangapur	1.0	12.5	-11.5	99.0	87.5	11.5	100.0
8	Ghod Project	0.0	0.0	0.0	100.0	100.0	0.0	100.0
9	Girna Project	7.3	12.5	-5.2	92.7	87.5	5.2	90.0
10	Haripur reservoir	12.6	20.0	-7.4	87.4	80.0	7.4	75.0
11	Harishchandra sagar	6.0	35.0	-29.0	94.0	65.0	29.0	79.0
12	Hathmati	2.5	81.6	-79.0	97.5	18.4	79.0	76.9
13	Hemavathy	30.8	65.0	-34.2	69.2	35.0	34.2	98.1
14	Hirakud	21.0	97.5	-76.5	79.0	2.5	76.5	97.5
15	IGNP	17.2	60.0	-42.8	82.8	35.0	47.8	74.4
16	Integraed Kollang	63.5	100.0	-36.5	36.5	0.0	36.5	21.7
17	Itiadoh	33.6	43.6	-10.0	66.4	46.2	20.3	78.8
18	Jamuna	20.0	63.9	-43.9	80.0	16.7	63.3	41.9
19	Jayakwadi (Satge 1)	5.3	40.5	-35.3	94.7	54.1	40.7	90.6
20	Kakrapar	89.7	75.0	14.7	10.3	22.5	-12.2	98.1
21	Kallada	1.3	100.0	-98.7	98.7	0.0	98.7	99.4
22	Kanchi Irrigation Scheme	28.5	70.0	-41.5	71.5	20.0	51.5	79.4
23	Karjan	93.9	100.0	-6.1	6.1	0.0	6.1	100.0
24	Kharif project Hindon Krishi	11.8	0.0	11.8	88.2	100.0	-11.8	76.0
25	Krishna	0.0	25.0	-25.0	100.0	75.0	25.0	100.0
26	Kuttiyadi	1.0	70.0	-69.0	99.0	30.0	69.0	97.0
27	Loktak Lift	12.2	2.6	9.6	87.8	69.2	18.6	50.5
28	Lower Bhavani	45.3	30.0	15.3	54.7	70.0	-15.3	52.0

S. No	Project Name	Market value of land per acre						Increase in land value
		Upto 3 lakhs			> 3 lakhs			
		Command	Non-Command	Diff	Command	Non-Command	Diff	Command*
29	Makhu canal system	0.0	2.5	-2.5	100.0	97.5	2.5	100.0
30	Matatila	0.0	5.0	-5.0	100.0	95.0	5.0	80.0
31	Mayurakshi (Jharkhand)	7.0	59.0	-52.0	93.0	38.5	54.5	94.0
32	Meshwo (Reservoir)	0.0	25.7	-25.7	100.0	65.7	34.3	87.0
33	Nagarjuna Sagar	33.3	12.1	21.3	66.7	87.9	-21.3	48.5
34	Nagarjuna Sagar Right bank canal	13.9	42.5	-28.6	86.1	52.5	33.6	90.0
35	Nagarjuna Sagar TG	31.9	54.7	-22.8	68.1	45.3	22.8	81.8
36	Ong Diversion Weir	4.0	87.5	-83.5	96.0	10.0	86.0	96.0
37	Penna	15.0	5.1	9.9	85.0	94.9	-9.9	98.0
38	Potteru	51.0	100.0	-49.0	49.0	0.0	49.0	100.0
39	Ravi canal	2.0	22.5	-20.5	98.0	77.5	20.5	89.0
40	Rewari Project	12.3	17.5	-5.2	87.7	82.5	5.2	86.3
41	Sakri lower valley	0.0	10.0	-10.0	100.0	90.0	10.0	48.1
42	Salauli	0.0	0.0	0.0	100.0	100.0	0.0	100.0
43	Sharda Sahayak	0.0	5.0	-5.0	100.0	95.0	5.0	74.4
44	Shetrunji	92.0	100.0	-8.0	8.0	0.0	8.0	100.0
45	Sidmukh	2.0	12.5	-10.5	98.0	85.0	13.0	91.0
46	Sri Hind Canal	0.6	12.5	-11.9	99.4	87.5	11.9	100.0
47	Sri ram sagar	55.3	57.5	-2.2	44.7	42.5	2.2	69.1
48	Tanda Pumpcanal	0.0	12.5	-12.5	100.0	87.5	12.5	63.0
49	Tungabhadra (LBC anf Dam)	30.9	50.0	-19.1	69.1	47.5	21.6	85.9
50	Uderusthan	38.8	10.0	28.8	61.2	90.0	-28.8	81.4
51	Ukai	99.4	100.0	-0.6	0.6	0.0	0.6	98.8
52	Upper Ganga	1.3	2.5	-1.3	98.8	97.5	1.3	94.4
53	Upper Wardha	10.4	10.8	-0.4	89.6	78.4	11.2	86.2
54	Wan	5.5	0.0	5.5	94.5	100.0	-5.5	84.0
55	Western Sone and Chausa Command	14.6	0.0	14.6	85.4	97.5	-12.1	48.8
56	Western Sone High Level Command	17.5	32.5	-15.0	82.5	67.5	15.0	80.0
57	Western Yamuna	6.9	5.0	1.9	93.1	95.0	-1.9	95.6

Notes: * For all the projects in non-command area, no-one mentioned increase in land value; difference in percentage points

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.3: Project-wise changes in irrigation system of land in last 5 years (%)

Changes in irrigation system of land in last 5 years							
S. No	Project Name	Increased assured water supply			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	79.0	2.5	76.5	21.0	97.5	-76.5
2	Ajoy Barrage (Siktia)	23.1	2.8	20.4	76.9	97.2	-20.4
3	Chambal	75.9	20.0	55.9	24.1	80.0	-55.9
4	Deokali Pump canal	77.0	2.5	74.5	23.0	97.5	-74.5
5	Eastern Sone Canal Command	50.6	7.7	42.9	49.4	92.3	-42.9
6	Eastern Sone High Level Command	32.7	22.5	10.2	67.3	77.5	-10.2
7	Gangapur	82.8	12.5	70.3	17.2	87.5	-70.3
8	Ghod Project	89.0	17.5	71.5	11.0	82.5	-71.5
9	Girna Project	53.0	0.0	53.0	47.0	100.0	-53.0
10	Haripur reservoir	84.4	10.0	74.4	15.6	90.0	-74.4
11	Harishchandra Sagar	20.2	0.0	20.2	79.8	100.0	-20.2
12	Hathmati	91.9	0.0	91.9	8.1	95.0	-86.9
13	Hemavathy	63.5	30.0	33.5	36.5	70.0	-33.5
14	Hirakud	98.8	30.0	68.8	1.3	70.0	-68.8
15	IGNP	47.5	7.5	40.0	52.5	92.5	-40.0
16	Integraed Kollang	32.6	5.9	26.7	67.4	94.1	-26.7
17	Itiadoh	88.7	17.5	71.2	11.3	80.0	-68.7
18	Jamuna	21.7	19.4	2.3	78.3	80.6	-2.3
19	Jayakwadi (Satge 1)	87.2	42.5	44.7	12.8	47.5	-34.7
20	Kakrapar	99.4	2.5	96.9	0.6	95.0	-94.4
21	Kallada	37.3	30.0	7.3	62.7	70.0	-7.3
22	Kanchi Irrigation Scheme	67.5	2.5	65.0	32.5	97.5	-65.0
23	Karjan	99.0	45.0	54.0	1.0	55.0	-54.0
24	Kharif project Hindon Krishi	54.0	0.0	54.0	46.0	100.0	-54.0
25	Krishna	95.0	2.5	92.5	5.0	97.5	-92.5
26	Kuttiyadi	39.2	45.0	-5.8	60.8	55.0	5.8
27	Loktak Lift	36.8	5.0	31.8	63.2	90.0	-26.8
28	Lower Bhavani	76.5	22.5	54.0	23.5	75.0	-51.5
29	Makhu canal system	35.0	7.5	27.5	65.0	92.5	-27.5
30	Matatila	53.1	0.0	53.1	46.9	100.0	-53.1
31	Mayurakshi (Jharkhand)	96.0	7.7	88.3	4.0	92.3	-88.3
32	Meshwo (Reservoir)	98.9	0.0	98.9	1.1	82.1	-80.9
33	Nagarjuna Sagar	31.4	25.0	6.4	68.6	46.3	22.3
34	Nagarjuna sagar Right bank canal	78.9	30.0	48.9	21.1	70.0	-48.9
35	Nagarjuna Sagar TG	81.1	13.8	67.3	18.9	67.5	-48.6
36	Ong Diversion Weir	96.9	20.0	76.9	3.1	77.5	-74.4
37	Penna	82.8	67.5	15.3	17.2	12.5	4.7

Changes in irrigation system of land in last 5 years							
S. No	Project Name	Increased assured water supply			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
38	Potteru	100.0	42.5	57.5	0.0	57.5	-57.5
39	Ravi canal	16.0	0.0	16.0	84.0	100.0	-16.0
40	Rewari Project	41.7	2.5	39.2	58.3	97.5	-39.2
41	Sakri lower valley	18.8	2.5	16.3	81.2	97.5	-16.3
42	Salauli	100.0	0.0	100.0	0.0	100.0	-100.0
43	Sharda Sahayak	83.1	0.0	83.1	16.9	100.0	-83.1
44	Shetrunji	99.0	27.5	71.5	1.0	72.5	-71.5
45	Sidmukh	11.0	10.0	1.0	89.0	90.0	-1.0
46	Sri Hind Canal	33.1	10.0	23.1	66.9	90.0	-23.1
47	Sri ram sagar	87.4	52.5	34.9	12.6	47.5	-34.9
48	Tanda Pumpcanal	83.0	2.5	80.5	17.0	97.5	-80.5
49	Tungabhadra (LBC anf Dam)	67.3	10.0	57.3	32.7	90.0	-57.3
50	Uderusthan	63.1	2.5	60.6	36.9	97.5	-60.6
51	Ukai	100.0	5.1	94.9	0.0	94.9	-94.9
52	Upper Ganga	82.5	0.0	82.5	17.5	100.0	-82.5
53	Upper Wardha	80.1	5.1	75.0	19.9	89.7	-69.9
54	Wan	27.7	2.5	25.2	72.3	97.5	-25.2
55	Western Sone and Chausa Command	43.3	0.0	43.3	56.7	100.0	-43.3
56	Western Sone High Level Command	71.0	7.5	63.5	29.0	92.5	-63.5
57	Western Yamuna	65.4	15.0	50.4	34.6	85.0	-50.4

Notes: differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.4: Project-wise changes in agriculture productivity (%)

S. No	Project Name	Increase			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	58.0	0.0	58.0	42.0	100.0	-58.0
2	Ajoy Barrage (Siktia)	47.9	0.0	47.9	52.1	100.0	-47.9
3	Chambal	83.5	5.0	78.5	16.5	95.0	-78.5
4	Deokali Pump canal	51.0	7.5	43.5	49.0	92.5	-43.5
5	Eastern Sone Canal Command	66.9	2.6	64.3	33.1	97.4	-64.3
6	Eastern Sone High Level Command	51.3	2.6	48.7	48.7	97.4	-48.7
7	Gangapur	75.8	20.0	55.8	24.2	80.0	-55.8
8	Ghod	80.8	0.0	80.8	19.2	100.0	-80.8
9	Girna	58.0	0.0	58.0	42.0	100.0	-58.0
10	Haripur reservoir	73.1	0.0	73.1	26.9	100.0	-73.1
11	Harishchandra sagar	41.0	5.0	36.0	59.0	95.0	-36.0
12	Hathmati	87.1	0.0	87.1	12.9	100.0	-87.1
13	Hemavathy	93.7	0.0	93.7	6.3	100.0	-93.7
14	Hirakud	95.6	0.0	95.6	4.4	100.0	-95.6
15	IGNP	47.5	0.0	47.5	52.5	100.0	-47.5
16	Integraed Kollang	14.1	5.9	8.2	85.9	94.1	-8.2
17	Itiadoh	82.2	0.0	82.2	17.8	100.0	-82.2
18	Jamuna	20.4	11.1	9.3	79.6	88.9	-9.3
19	Jayakwadi (Satge 1)	75.6	8.3	67.3	24.4	91.7	-67.3
20	Kakrapar	99.4	2.7	96.7	0.6	97.3	-96.7
21	Kallada	96.2	0.0	96.2	3.8	100.0	-96.2
22	Kanchi Irrigation Scheme	80.0	0.0	80.0	20.0	100.0	-80.0
23	Karjan	100.0	0.0	100.0	0.0	100.0	-100.0
24	Kharif project Hindon Krishi	58.0	17.1	40.9	42.0	82.9	-40.9
25	Krishna	79.0	0.0	79.0	21.0	100.0	-79.0
26	Kuttiyadi	95.9	0.0	95.9	4.1	100.0	-95.9
27	Loktak Lift	45.3	6.1	39.3	54.7	93.9	-39.3
28	Lower Bhavani	43.9	2.6	41.3	56.1	97.4	-41.3
29	Makhu canal system	70.0	0.0	70.0	30.0	100.0	-70.0
30	Matatila	48.8	0.0	48.8	51.3	100.0	-48.8
31	Mayurakshi (Jharkhand)	99.0	2.6	96.4	1.0	97.4	-96.4
32	Meshwo (Reservoir)	100.0	0.0	100.0	0.0	100.0	-100.0
33	Nagarjuna Sagar	48.8	0.0	48.8	51.2	100.0	-48.8
34	Nagarjuna sagar Right bank canal	51.2	2.5	48.7	48.8	97.5	-48.7
35	Nagarjuna Sagar TG	84.9	0.0	84.9	15.1	100.0	-84.9
36	Ong Diversion Weir	96.0	0.0	96.0	4.0	100.0	-96.0
37	Penna	83.8	0.0	83.8	16.2	100.0	-83.8
38	Potteru	99.0	0.0	99.0	1.0	100.0	-99.0
39	Ravi canal	33.0	0.0	33.0	67.0	100.0	-33.0

S. No	Project Name	Increase			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
40	Rewari Project	55.8	2.5	53.3	44.2	97.5	-53.3
41	Sakri lower valley	32.5	0.0	32.5	67.5	100.0	-32.5
42	Salauli	66.7	10.5	56.1	33.3	89.5	-56.1
43	Sharda Sahayak	52.5	17.5	35.0	47.5	82.5	-35.0
44	Shetrunji	96.0	0.0	96.0	4.0	100.0	-96.0
45	Sidmukh	53.0	10.0	43.0	47.0	90.0	-43.0
46	Sri Hind Canal	65.6	0.0	65.6	34.4	100.0	-65.6
47	Sri ram sagar	68.4	0.0	68.4	31.6	100.0	-68.4
48	Tanda Pumpcanal	51.0	2.5	48.5	49.0	97.5	-48.5
49	Tungabhadra (LBC anf Dam)	77.6	2.5	75.1	22.4	97.5	-75.1
50	Uderusthan	59.2	0.0	59.2	40.8	100.0	-59.2
51	Ukai	100.0	0.0	100.0	0.0	100.0	-100.0
52	Upper Ganga	83.1	0.0	83.1	16.9	100.0	-83.1
53	Upper Wardha	71.4	0.0	71.4	28.6	100.0	-71.4
54	Wan	22.3	0.0	22.3	77.7	100.0	-22.3
55	Western Sone and Chausa Command	40.9	0.0	40.9	59.1	100.0	-40.9
56	Western Sone High Level Command	79.0	2.5	76.5	21.0	97.5	-76.5
57	Western Yamuna	65.4	5.0	60.4	34.6	95.0	-60.4

Notes: differences in percentage points.
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.5: Project-wise changes in market linkages and agricultural trade (%)

S. No	Project Name	Increase			Decline/ limited linkages		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	62.0	27.5	34.5	38.0	72.5	-34.5
2	Ajoy Barrage (Siktia)	41.6	14.3	27.3	58.4	85.7	-27.3
3	Chambal	87.3	10.0	77.3	12.7	90.0	-77.3
4	Deokali Pump canal	73.0	35.0	38.0	27.0	65.0	-38.0
5	Eastern Sone Canal Command	64.4	34.2	30.2	35.6	65.8	-30.2
6	Eastern Sone High Level Command	62.0	30.8	31.3	38.0	69.2	-31.3
7	Gangapur	90.0	30.0	60.0	10.0	70.0	-60.0
8	Ghod	92.0	30.0	62.0	8.0	70.0	-62.0
9	Girna	95.0	37.5	57.5	5.0	62.5	-57.5
10	Haripur reservoir	78.8	22.5	56.3	21.3	77.5	-56.3
11	Harishchandra sagar	67.0	10.0	57.0	33.0	90.0	-57.0
12	Hathmati	91.7	18.9	72.8	8.3	81.1	-72.8
13	Hemavathy	93.0	80.0	13.0	7.0	20.0	-13.0
14	Hirakud	96.9	22.5	74.4	3.1	77.5	-74.4
15	IGNP	67.5	0.0	67.5	32.5	100.0	-67.5
16	Integraed Kollang	15.4	14.7	0.7	84.6	85.3	-0.7
17	Itiadoh	88.3	29.7	58.5	11.7	70.3	-58.5
18	Jamuna	11.8	2.9	9.0	88.2	97.1	-9.0
19	Jayakwadi (Satge 1)	86.5	42.1	44.4	13.5	57.9	-44.4
20	Kakrapar	99.4	17.9	81.4	0.6	82.1	-81.4
21	Kallada	86.7	47.5	39.2	13.3	52.5	-39.2
22	Kanchi Irrigation Scheme	71.3	0.0	71.3	28.8	100.0	-71.3
23	Karjan	100.0	22.5	77.5	0.0	77.5	-77.5
24	Kharif project Hindon Krishi	68.0	26.8	41.2	32.0	73.2	-41.2
25	Krishna	86.0	17.5	68.5	14.0	82.5	-68.5
26	Kuttiyadi	99.0	90.0	9.0	1.0	10.0	-9.0
27	Loktak Lift	75.6	32.5	43.1	24.4	67.5	-43.1
28	Lower Bhavani	38.8	66.7	-27.9	61.2	33.3	27.9
29	Makhu canal system	76.8	32.5	44.3	23.2	67.5	-44.3
30	Matatila	55.0	7.5	47.5	45.0	92.5	-47.5
31	Mayurakshi (Jharkhand)	89.8	2.6	87.2	10.2	97.4	-87.2
32	Meshwo (Reservoir)	93.1	56.3	36.9	6.9	43.8	-36.9
33	Nagarjuna Sagar	54.0	41.4	12.6	46.0	58.6	-12.6
34	Nagarjuna sagar Right bank canal	59.2	15.4	43.8	40.8	84.6	-43.8
35	Nagarjuna Sagar TG	75.2	78.3	-3.2	24.8	21.7	3.2
36	Ong Diversion Weir	96.9	10.3	86.7	3.1	89.7	-86.7
37	Penna	71.4	53.3	18.1	28.6	46.7	-18.1
38	Potteru	97.0	32.5	64.5	3.0	67.5	-64.5

S. No	Project Name	Increase			Decline/ limited linkages		
		Command	Non-Command	Diff	Command	Non-Command	Diff
39	Ravi canal	63.0	0.0	63.0	37.0	100.0	-63.0
40	Rewari Project	76.5	17.9	58.5	23.5	82.1	-58.5
41	Sakri lower valley	66.7	25.0	41.7	33.3	75.0	-41.7
42	Salauli	100.0	36.8	63.2	0.0	63.2	-63.2
43	Sharda Sahayak	70.0	22.5	47.5	30.0	77.5	-47.5
44	Shetrunji	96.0	22.5	73.5	4.0	77.5	-73.5
45	Sidmukh	66.7	5.1	61.5	33.3	94.9	-61.5
46	Sri Hind Canal	81.9	17.5	64.4	18.1	82.5	-64.4
47	Sri ram sagar	84.0	55.0	29.0	16.0	45.0	-29.0
48	Tanda Pumpcanal	68.7	32.5	36.2	31.3	67.5	-36.2
49	Tungabhadra (LBC anf Dam)	76.0	20.0	56.0	24.0	80.0	-56.0
50	Uderusthan	74.2	30.0	44.2	25.8	70.0	-44.2
51	Ukai	100.0	7.7	92.3	0.0	92.3	-92.3
52	Upper Ganga	88.8	22.5	66.3	11.3	77.5	-66.3
53	Upper Wardha	80.6	17.1	63.4	19.4	82.9	-63.4
54	Wan	76.1	32.5	43.6	23.9	67.5	-43.6
55	Western Sone and Chausa Command	75.5	35.9	39.6	24.5	64.1	-39.6
56	Western Sone High Level Command	81.0	47.5	33.5	19.0	52.5	-33.5
57	Western Yamuna	72.3	7.7	64.6	27.7	92.3	-64.6

Notes: differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.6: Project-wise changes in household income (%)

S. No	Project Name	Increase			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	53.0	25.0	28.0	47.0	75.0	-28.0
2	Ajoy Barrage (Siktia)	56.8	2.8	54.1	43.2	97.2	-54.1
3	Chambal	86.8	7.5	79.3	13.2	92.5	-79.3
4	Deokali Pump canal	47.0	0.0	47.0	53.0	100.0	-47.0
5	Eastern Sone Canal Command	68.1	0.0	68.1	31.9	100.0	-68.1
6	Eastern Sone High Level Command	50.3	5.0	45.3	49.7	95.0	-45.3
7	Gangapur	78.0	2.5	75.5	22.0	97.5	-75.5
8	Ghod	84.0	7.5	76.5	16.0	92.5	-76.5
9	Girna	66.0	0.0	66.0	34.0	100.0	-66.0
10	Haripur reservoir	70.6	0.0	70.6	29.4	100.0	-70.6
11	Harishchandra sagar	45.0	0.0	45.0	55.0	100.0	-45.0
12	Hathmati	94.4	2.6	91.7	5.6	97.4	-91.7
13	Hemavathy	91.1	0.0	91.1	8.9	100.0	-91.1
14	Hirakud	98.1	0.0	98.1	1.9	100.0	-98.1
15	IGNP	56.0	5.0	51.0	44.0	95.0	-51.0
16	Integraed Kollang	16.3	0.0	16.3	83.7	100.0	-16.3
17	Itiadoh	78.8	5.0	73.8	21.2	95.0	-73.8
18	Jamuna	14.6	0.0	14.6	85.4	100.0	-14.6
19	Jayakwadi (Satge 1)	77.7	2.6	75.1	22.3	97.4	-75.1
20	Kakrapar	100.0	7.7	92.3	0.0	92.3	-92.3
21	Kallada	99.4	0.0	99.4	0.6	100.0	-99.4
22	Kanchi Irrigation Scheme	84.4	12.5	71.9	15.6	87.5	-71.9
23	Karjan	100.0	0.0	100.0	0.0	100.0	-100.0
24	Kharif project Hindon Krishi	61.0	9.8	51.2	39.0	90.2	-51.2
25	Krishna	78.0	20.0	58.0	22.0	80.0	-58.0
26	Kuttiyadi	100.0	0.0	100.0	0.0	100.0	-100.0
27	Loktak Lift	57.8	27.0	30.8	42.2	73.0	-30.8
28	Lower Bhavani	35.7	7.7	28.0	64.3	92.3	-28.0
29	Makhu canal system	69.7	7.5	62.2	30.3	92.5	-62.2
30	Matatila	40.6	0.0	40.6	59.4	100.0	-40.6
31	Mayurakshi (Jharkhand)	99.0	5.1	93.9	1.0	94.9	-93.9
32	Meshwo (Reservoir)	97.7	0.0	97.7	2.3	100.0	-97.7
33	Nagarjuna Sagar	33.3	0.0	33.3	66.7	100.0	-33.3
34	Nagarjuna sagar Right bank canal	43.9	2.5	41.4	56.1	97.5	-41.4
35	Nagarjuna Sagar TG	79.3	61.7	17.6	20.7	38.3	-17.6
36	Ong Diversion Weir	96.9	0.0	96.9	3.1	100.0	-96.9
37	Penna	53.6	6.7	46.9	46.4	93.3	-46.9

S. No	Project Name	Increase			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
38	Potteru	100.0	0.0	100.0	0.0	100.0	-100.0
39	Ravi canal	30.0	15.0	15.0	70.0	85.0	-15.0
40	Rewari Project	68.0	7.5	60.5	32.0	92.5	-60.5
41	Sakri lower valley	25.6	0.0	25.6	74.4	100.0	-25.6
42	Salauli	83.3	0.0	83.3	16.7	100.0	-83.3
43	Sharda Sahayak	46.9	20.0	26.9	53.1	80.0	-26.9
44	Shetrunji	100.0	0.0	100.0	0.0	100.0	-100.0
45	Sidmukh	62.0	7.5	54.5	38.0	92.5	-54.5
46	Sri Hind Canal	66.9	5.0	61.9	33.1	95.0	-61.9
47	Sri ram sagar	59.3	87.5	-28.2	40.7	12.5	28.2
48	Tanda Pumpcanal	49.0	7.5	41.5	51.0	92.5	-41.5
49	Tungabhadra (LBC anf Dam)	75.3	2.5	72.8	24.7	97.5	-72.8
50	Uderusthan	61.1	0.0	61.1	38.9	100.0	-61.1
51	Ukai	99.4	0.0	99.4	0.6	100.0	-99.4
52	Upper Ganga	81.9	0.0	81.9	18.1	100.0	-81.9
53	Upper Wardha	73.0	2.9	70.1	27.0	97.1	-70.1
54	Wan	36.8	0.0	36.8	63.2	100.0	-36.8
55	Western Sone and Chausa Command	38.4	0.0	38.4	61.6	100.0	-38.4
56	Western Sone High Level Command	74.0	2.5	71.5	26.0	97.5	-71.5
57	Western Yamuna	70.3	0.0	70.3	29.7	100.0	-70.3

Notes: differences in percentage points.
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.7: Project-wise employment and business opportunities (%)

S. No	Project Name	Increase in employment opportunities in agriculture	Business/ Job opportunities in non-agriculture sector			Improvement in farm business		
		Command*	Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	18.0	43.0	60.0	-17.0	48.0	62.5	-14.5
2	Ajoy Barrage (Siktia)	27.4	22.4	13.9	8.6	29.9	22.2	7.7
3	Chambal	52.2	61.9	57.5	4.4	70.6	17.5	53.1
4	Deokali Pump canal	17.0	35.0	75.0	-40.0	45.0	22.5	22.5
5	Eastern Sone Canal Command	31.3	50.6	39.5	11.2	50.6	36.8	13.8
6	Eastern Sone High Level Command	19.5	41.9	70.0	-28.1	27.5	37.5	-10.0
7	Gangapur	68.0	54.0	42.5	11.5	84.0	30.0	54.0
8	Ghod	89.0	63.0	45.0	18.0	88.0	17.5	70.5
9	Girna	59.0	47.0	2.5	44.5	62.0	15.0	47.0
10	Haripur reservoir	63.1	61.9	42.5	19.4	71.9	33.3	38.5
11	Harishchandra sagar	19.2	41.0	15.0	26.0	34.0	10.0	24.0
12	Hathmati	57.3	28.5	47.5	-19.0	46.8	7.9	38.9
13	Hemavathy	74.8	79.2	85.0	-5.8	90.6	7.5	83.1
14	Hirakud	89.9	91.3	55.0	36.3	93.1	27.5	65.6
15	IGNP	21.3	39.4	25.0	14.4	41.3	10.0	31.3
16	Integraed Kollang	7.6	13.0	0.0	13.0	7.6	0.0	7.6
17	Itiadoh	80.0	72.5	35.9	36.6	74.4	16.2	58.2
18	Jamuna	6.5	15.1	0.0	15.1	7.5	2.9	4.7
19	Jayakwadi (Satge 1)	73.4	48.4	37.5	10.9	69.2	39.5	29.7
20	Kakrapar	98.8	98.1	50.0	48.1	97.5	17.5	80.0
21	Kallada	89.9	93.7	57.5	36.2	100.0	12.8	87.2
22	Kanchi Irrigation Scheme	47.5	32.5	37.5	-5.0	63.8	57.5	6.3
23	Karjan	100.0	99.0	75.0	24.0	100.0	5.0	95.0
24	Kharif project Hindon Krishi	47.0	59.0	46.3	12.7	58.0	19.5	38.5
25	Krishna	82.0	60.0	17.5	42.5	86.0	22.5	63.5
26	Kuttiyadi	93.9	94.9	100.0	-5.1	100.0	40.0	60.0
27	Loktak Lift	14.0	27.3	52.5	-25.2	17.2	56.4	-39.2
28	Lower Bhavani	35.7	38.8	70.0	-31.2	35.7	12.5	23.2
29	Makhu canal system	49.5	93.9	80.0	13.9	54.5	17.5	37.0
30	Matatila	33.3	62.5	72.5	-10.0	44.4	42.5	1.9
31	Mayurakshi (Jharkhand)	77.0	58.0	38.5	19.5	85.0	48.7	36.3

S. No	Project Name	Increase in employment opportunities in agriculture	Business/ Job opportunities in non-agriculture sector			Improvement in farm business		
		Command*	Command	Non-Command	Diff	Command	Non-Command	Diff
32	Meshwo (Reservoir)	65.2	66.0	28.2	37.8	69.0	21.2	47.8
33	Nagarjuna Sagar	52.3	42.0	58.8	-16.8	37.5	35.0	2.5
34	Nagarjuna Sagar Right bank canal	44.4	51.8	35.0	16.8	53.8	15.0	38.8
35	Nagarjuna Sagar TG	57.5	50.0	23.8	26.3	60.8	41.9	18.9
36	Ong Diversion Weir	96.0	95.0	67.5	27.5	95.0	79.5	15.5
37	Penna	58.6	83.8	75.0	8.8	81.8	39.4	42.4
38	Potteru	94.0	94.0	52.5	41.5	89.0	27.5	61.5
39	Ravi canal	4.0	68.0	37.5	30.5	27.0	25.0	2.0
40	Rewari Project	28.6	54.4	72.5	-18.1	43.7	17.5	26.2
41	Sakri lower valley	0.6	35.0	37.5	-2.5	8.1	35.0	-26.9
42	Salauli	95.8	91.7	89.5	2.2	91.7	5.3	86.4
43	Sharda Sahayak	38.8	55.0	65.0	-10.0	56.3	47.5	8.8
44	Shetrunji	96.0	93.0	67.5	25.5	94.0	0.0	94.0
45	Sidmukh	43.0	47.0	10.0	37.0	46.0	7.5	38.5
46	Sri Hind Canal	38.8	81.3	42.5	38.8	44.4	7.5	36.9
47	Sri ram sagar	56.0	57.0	45.0	12.0	56.3	35.0	21.3
48	Tanda Pumpcanal	29.0	42.0	50.0	-8.0	54.0	12.5	41.5
49	Tungabhadra (LBC anf Dam)	67.0	76.3	52.5	23.8	75.3	37.5	37.8
50	Uderusthan	19.7	43.5	77.5	-34.0	33.5	37.5	-4.0
51	Ukai	100.0	99.4	69.2	30.1	98.8	2.6	96.2
52	Upper Ganga	75.0	86.9	75.0	11.9	80.0	42.5	37.5
53	Upper Wardha	61.6	56.6	28.2	28.4	59.1	20.5	38.6
54	Wan	36.5	42.0	7.5	34.5	31.0	35.0	-4.0
55	Western Sone and Chausa Command	17.6	33.1	15.0	18.1	26.3	38.5	-12.2
56	Western Sone High Level Command	46.0	53.0	35.0	18.0	52.0	30.0	22.0
57	Western Yamuna	33.3	46.9	52.5	-5.6	48.1	20.0	28.1

Notes- *No response for increase in non-command area; differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.8: Project-wise reduction in migration and contribution to local agri-business development (%)

S. No	Project Name	Migration reduced			Contribution to local agri-business		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	12.1	5.0	7.1	23.0	2.5	20.5
2	Ajoy Barrage (Siktia)	7.5	22.9	-15.3	12.9	52.8	-39.9
3	Chambal	29.4	5.0	24.4	29.4	27.5	1.9
4	Deokali Pump canal	17.0	17.5	-0.5	33.0	12.5	20.5
5	Eastern Sone Canal Command	15.0	26.3	-11.3	30.6	26.3	4.3
6	Eastern Sone High Level Command	5.6	2.5	3.1	23.1	27.5	-4.4
7	Gangapur	62.0	25.0	37.0	59.0	40.0	19.0
8	Ghod	61.0	2.5	58.5	63.0	42.5	20.5
9	Girna	44.0	5.0	39.0	42.0	27.5	14.5
10	Haripur reservoir	55.0	5.0	50.0	58.8	34.2	24.5
11	Harishchandra sagar	5.0	20.0	-15.0	8.0	85.0	-77.0
12	Hathmati	35.7	2.6	33.1	19.6	78.9	-59.3
13	Hemavathy	37.7	22.5	15.2	71.7	35.0	36.7
14	Hirakud	51.9	7.5	44.4	80.0	37.5	42.5
15	IGNP	5.0	0.0	5.0	12.5	35.0	-22.5
16	Integraed Kollang	1.1	0.0	1.1	6.5	97.1	-90.5
17	Itiadoh	64.9	15.8	49.1	63.8	55.3	8.5
18	Jamuna	0.0	0.0	0.0	9.7	100.0	-90.3
19	Jayakwadi (Satge 1)	65.8	22.5	43.3	51.6	30.8	20.8
20	Kakrapar	98.8	10.0	88.8	78.1	27.5	50.6
21	Kallada	6.3	2.5	3.8	32.3	70.0	-37.7
22	Kanchi Irrigation Scheme	23.1	7.5	15.6	6.9	12.5	-5.6
23	Karjan	97.0	10.0	87.0	72.7	35.0	37.7
24	Kharif project Hindon Krishi	37.0	29.3	7.7	53.0	4.9	48.1
25	Krishna	53.0	2.5	50.5	44.0	25.0	19.0
26	Kuttiyadi	29.6	5.0	24.6	69.4	12.5	56.9
27	Loktak Lift	6.5	0.0	6.5	9.1	27.5	-18.4
28	Lower Bhavani	20.4	27.5	-7.1	57.1	55.0	2.1
29	Makhu canal system	0.0	5.0	-5.0	14.1	10.0	4.1
30	Matatila	25.6	0.0	25.6	53.1	17.5	35.6
31	Mayurakshi (Jharkhand)	24.0	2.6	21.4	1.0	20.5	-19.5
32	Meshwo (Reservoir)	43.8	20.6	23.2	16.0	22.2	-6.2
33	Nagarjuna Sagar	35.1	27.6	7.5	12.0	48.3	-36.3
34	Nagarjuna sagar Right bank canal	40.9	23.1	17.9	59.3	33.3	26.0
35	Nagarjuna Sagar TG	59.9	0.0	59.9	89.9	35.0	54.9
36	Ong Diversion Weir	94.9	0.0	94.9	97.0	20.5	76.5
37	Penna	81.8	13.3	68.5	9.1	63.3	-54.2
38	Potteru	68.0	5.0	63.0	97.0	37.5	59.5

S. No	Project Name	Migration reduced			Contribution to local agri-business		
		Command	Non-Command	Diff	Command	Non-Command	Diff
39	Ravi canal	2.0	0.0	2.0	1.0	0.0	1.0
40	Rewari Project	19.5	10.3	9.2	14.6	7.7	6.9
41	Sakri lower valley	0.0	0.0	0.0	13.1	7.5	5.6
42	Salauli	8.3	0.0	8.3	70.8	15.8	55.0
43	Sharda Sahayak	26.9	2.5	24.4	30.6	0.0	30.6
44	Shetrunji	80.0	25.0	55.0	59.0	65.0	-6.0
45	Sidmukh	2.0	17.5	-15.5	8.0	32.5	-24.5
46	Sri Hind Canal	0.6	5.0	-4.4	29.4	17.5	11.9
47	Sri ram sagar	31.3	0.0	31.3	49.7	12.5	37.2
48	Tanda Pumpcanal	23.0	5.0	18.0	33.0	7.5	25.5
49	Tungabhadra (LBC anf Dam)	43.3	16.7	26.6	61.9	55.0	6.9
50	Uderusthan	11.5	0.0	11.5	24.2	22.5	1.7
51	Ukai	80.6	41.0	39.6	79.4	7.7	71.7
52	Upper Ganga	72.5	2.5	70.0	81.3	37.5	43.8
53	Upper Wardha	61.8	7.9	53.9	37.7	43.6	-5.9
54	Wan	10.4	2.5	7.9	36.0	22.5	13.5
55	Western Sone and Chausa Command	2.5	2.5	0.0	14.4	32.5	-18.1
56	Western Sone High Level Command	3.0	10.0	-7.0	30.0	40.0	-10.0
57	Western Yamuna	30.2	2.5	27.7	23.1	10.0	13.1

Notes: differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.9: Project-wise improvement in education/ healthcare facilities & women participation (%)

S. No	Project Name	Improvement in educational facilities			Improvement in healthcare facilities			Increase in women participation		
		Command	Non Command	Diff	Command	Non Command	Diff	Command	Non Command	Diff
1	Adwa	95.0	50.0	45.0	9.0	0.0	9.0	66.0	65.0	1.0
2	Ajoy Barrage (Siktia)	78.9	41.7	37.2	18.5	0.0	18.5	33.6	5.6	28.0
3	Chambal	85.6	35.0	50.6	23.1	15.0	8.1	44.7	20.0	24.7
4	Deokali Pump canal	95.0	72.5	22.5	8.0	0.0	8.0	47.0	30.0	17.0
5	Eastern Sone Canal	83.6	55.3	28.4	31.3	7.9	23.4	38.1	10.5	27.6
6	Eastern Sone High Level	73.8	32.5	41.3	18.8	7.5	11.3	28.1	30.0	-1.9
7	Gangapur	96.0	67.5	28.5	45.0	10.0	35.0	99.0	75.0	24.0
8	Ghod	97.0	65.0	32.0	35.0	32.5	2.5	100.0	60.0	40.0
9	Girna	92.0	57.5	34.5	45.0	0.0	45.0	92.0	60.0	32.0
10	Haripur reservoir	89.9	35.0	54.9	35.2	0.0	35.2	70.0	25.0	45.0
11	Harishchandra Sagar	51.0	25.0	26.0	19.2	0.0	19.2	36.0	15.0	21.0
12	Hathmati	99.2	18.4	80.8	14.7	5.3	9.5	64.0	5.0	59.0
13	Hemavathy	99.4	95.0	4.4	43.4	0.0	43.4	83.6	40.0	43.6
14	Hirakud	98.1	42.5	55.6	58.2	0.0	58.2	89.2	27.5	61.7
15	IGNP	71.3	25.0	46.3	6.3	0.0	6.3	40.0	22.5	17.5
16	Integraed Kollang	16.3	0.0	16.3	2.2	5.9	-3.7	9.8	0.0	9.8
17	Itiadoh	83.9	35.9	48.0	66.0	10.3	55.8	80.0	35.9	44.1
18	Jamuna	28.0	0.0	28.0	0.0	13.9	-13.9	9.8	0.0	9.8
19	Jayakwadi (Satge 1)	85.4	72.5	12.9	26.8	40.0	-13.2	89.2	52.5	36.7
20	Kakrapar	100.0	15.0	85.0	97.5	2.5	95.0	98.8	2.5	96.3
21	Kallada	100.0	33.3	66.7	19.0	5.0	14.0	100.0	10.0	90.0
22	Kanchi Irrigation	80.6	37.5	43.1	16.4	0.0	16.4	63.1	27.5	35.6
23	Karjan	100.0	40.0	60.0	97.0	7.5	89.5	100.0	7.5	92.5
24	Kharif project Hindon Krishi	79.0	78.0	1.0	33.3	0.0	33.3	57.6	43.9	13.7
25	Krishna	100.0	37.5	62.5	50.0	37.5	12.5	100.0	42.5	57.5
26	Kuttiyadi	100.0	95.0	5.0	41.8	0.0	41.8	100.0	72.5	27.5
27	Loktak Lift	48.9	12.5	36.4	2.1	5.0	-2.9	55.9	40.0	15.9
28	Lower Bhavani	68.4	87.5	-19.1	38.8	0.0	38.8	40.8	60.0	-19.2
29	Makhu canal	89.9	60.0	29.9	30.3	5.0	25.3	16.2	2.5	13.7
30	Matatila	83.1	12.5	70.6	39.0	0.0	39.0	54.4	37.5	16.9
31	Mayurakshi (Jharkhand)	93.0	59.0	34.0	14.0	7.7	6.3	89.0	15.4	73.6

S. No	Project Name	Improvement in educational facilities			Improvement in healthcare facilities			Increase in women participation		
		Command	Non Command	Diff	Command	Non Command	Diff	Command	Non Command	Diff
32	Meshwo (Reservoir)	100.0	31.4	68.6	43.3	0.0	43.3	51.1	12.8	38.3
33	Nagarjuna Sagar	64.6	48.3	16.3	36.9	0.0	36.9	51.4	33.8	17.6
34	Nagarjuna Sagar Right bank canal	88.7	10.0	78.7	58.2	7.5	50.7	55.0	52.5	2.5
35	Nagarjuna Sagar TG	69.0	70.0	-1.0	40.4	56.7	-16.3	77.2	38.8	38.5
36	Ong Diversion Weir	99.0	5.1	93.9	84.0	0.0	84.0	98.0	50.0	48.0
37	Penna	64.6	10.0	54.6	43.4	3.3	40.1	74.7	70.0	4.7
38	Potteru	100.0	38.5	61.5	55.0	0.0	55.0	91.0	32.5	58.5
39	Ravi canal	95.0	10.0	85.0	6.0	0.0	6.0	31.0	30.0	1.0
40	Rewari Project	76.6	35.0	41.6	33.5	2.5	31.0	23.4	27.5	-4.1
41	Sakri lower valley	44.4	12.5	31.9	3.8	0.0	3.8	5.6	47.5	-41.9
42	Salauli	100.0	100.0	0.0	95.8	68.4	27.4	100.0	100.0	0.0
43	Sharda Sahayak	96.9	82.5	14.4	6.9	0.0	6.9	82.5	65.0	17.5
44	Shetrunji	100.0	37.5	62.5	79.8	0.0	79.8	96.0	5.0	91.0
45	Sidmukh	81.0	17.5	63.5	4.0	0.0	4.0	35.0	5.0	30.0
46	Sri Hind Canal	92.5	60.0	32.5	45.3	0.0	45.3	16.3	0.0	16.3
47	Sri ram Sagar	62.8	45.0	17.8	47.7	50.0	-2.3	87.9	62.5	25.4
48	Tanda Pumpcanal	91.0	40.0	51.0	6.0	5.0	1.0	48.0	20.0	28.0
49	Tungabhadra (LBC anf Dam)	82.3	47.5	34.8	47.4	2.5	44.9	77.3	37.5	39.8
50	Uderusthan	68.2	35.0	33.2	21.9	5.0	16.9	25.6	30.0	-4.4
51	Ukai	100.0	43.6	56.4	97.5	0.0	97.5	100.0	5.1	94.9
52	Upper Ganga	93.8	22.5	71.3	71.3	0.0	71.3	85.0	27.5	57.5
53	Upper Wardha	74.7	46.2	28.5	36.4	12.8	23.5	84.4	48.7	35.7
54	Wan	83.3	75.0	8.3	14.7	30.0	-15.3	73.4	85.0	-11.6
55	Western Sone and Chausa Command	56.3	7.5	48.8	11.9	12.5	-0.6	20.6	15.0	5.6
56	Western Sone High Level Command	84.0	32.5	51.5	20.0	10.0	10.0	57.0	22.5	34.5
57	Western Yamuna	79.2	52.5	26.7	22.2	5.0	17.2	21.4	7.5	13.9

Notes: differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.10: Project-wise benefits in environmental conditions (%)

S. No	Project Name	Reduce dependency on rainfall			Increase in groundwater level			Improvement in soil quality		
		Command	Non-Command	Diff	Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	30.0	0.0	30.0	8.0	27.5	-19.5	43.0	0.0	43.0
2	Ajoy Barrage (Siktia)	11.6	36.1	-24.5	0.0	20.0	-20.0	5.5	0.0	5.5
3	Chambal	63.1	27.5	35.6	50.3	2.5	47.8	48.8	2.5	46.3
4	Deokali Pump canal	56.0	35.0	21.0	24.0	15.0	9.0	34.0	7.5	26.5
5	Eastern Sone Canal Command	58.1	21.6	36.5	39.4	5.3	34.1	45.6	0.0	45.6
6	Eastern Sone High Level Command	30.6	12.5	18.1	16.9	15.0	1.9	25.6	0.0	25.6
7	Gangapur	53.0	0.0	53.0	64.0	75.0	-11.0	62.0	2.5	59.5
8	Ghod	39.0	0.0	39.0	69.0	56.4	12.6	40.0	5.0	35.0
9	Girna	48.0	0.0	48.0	35.0	50.0	-15.0	34.7	0.0	34.7
10	Haripur reservoir	75.6	10.0	65.6	56.0	12.5	43.5	67.5	0.0	67.5
11	Harishchandra Sagar	14.0	25.0	-11.0	10.0	10.0	0.0	16.0	0.0	16.0
12	Hathmati	65.8	29.7	36.1	49.2	55.3	-6.1	27.4	0.0	27.4
13	Hemavathy	85.5	17.9	67.6	17.0	17.5	-0.5	24.5	0.0	24.5
14	Hirakud	88.8	12.5	76.3	74.8	2.5	72.3	87.3	0.0	87.3
15	IGNP	16.3	22.5	-6.3	16.9	27.5	-10.6	10.6	0.0	10.6
16	Integraed Kollang	21.7	79.4	-57.7	2.2	2.9	-0.8	12.0	2.9	9.0
17	Itiadoh	80.6	35.9	44.7	73.7	10.5	63.2	74.5	0.0	74.5
18	Jamuna	9.7	100.0	-90.3	2.2	11.1	-9.0	0.0	0.0	0.0
19	Jayakwadi (Satge 1)	57.9	12.8	45.0	70.9	64.1	6.8	40.1	7.9	32.2
20	Kakrapar	98.1	0.0	98.1	98.8	20.0	78.8	98.1	2.5	95.6
21	Kallada	100.0	62.5	37.5	9.5	15.0	-5.5	1.9	5.0	-3.1
22	Kanchi Irrigation Scheme	51.3	5.0	46.3	59.4	25.0	34.4	61.3	5.0	56.3
23	Karjan	100.0	17.5	82.5	97.0	7.5	89.5	96.0	0.0	96.0
24	Kharif Hindon Krishi	53.0	7.3	45.7	32.0	4.9	27.1	43.0	0.0	43.0
25	Krishna	39.0	0.0	39.0	80.0	67.5	12.5	38.0	0.0	38.0
26	Kuttiyadi	100.0	2.5	97.5	30.6	2.5	28.1	17.3	0.0	17.3
27	Loktak Lift	26.3	5.1	21.1	6.5	35.0	-28.5	7.6	0.0	7.6
28	Lower Bhavani	43.9	20.0	23.9	36.7	30.0	6.7	25.5	2.5	23.0
29	Makhu canal system	46.5	32.5	14.0	51.5	55.0	-3.5	67.7	32.5	35.2

S. No	Project Name	Reduce dependency on rainfall			Increase in groundwater level			Improvement in soil quality		
		Command	Non-Command	Diff	Command	Non-Command	Diff	Command	Non-Command	Diff
30	Matatila	43.1	25.0	18.1	31.3	0.0	31.3	44.4	0.0	44.4
31	Mayurakshi (Jharkhand)	94.0	5.1	88.9	98.0	28.2	69.8	90.0	0.0	90.0
32	Meshwo (Reservoir)	84.0	9.7	74.3	79.5	28.6	51.0	5.7	0.0	5.7
33	Nagarjuna Sagar	27.5	32.8	-5.3	39.2	12.1	27.1	30.4	0.0	30.4
34	Nagarjuna Sagar Right bank canal	63.8	0.0	63.8	68.4	37.5	30.9	49.7	7.5	42.2
35	Nagarjuna Sagar TG	89.2	1.7	87.5	68.3	71.2	-2.9	37.7	36.7	1.0
36	Ong Diversion Weir	96.0	2.6	93.4	96.0	51.3	44.7	94.0	0.0	94.0
37	Penna	97.0	6.7	90.3	91.9	0.0	91.9	68.0	6.7	61.4
38	Potteru	98.0	10.0	88.0	69.0	12.5	56.5	91.0	0.0	91.0
39	Ravi canal	5.0	5.0	0.0	2.0	22.5	-20.5	1.0	0.0	1.0
40	Rewari Project	41.8	17.5	24.3	14.2	10.0	4.2	20.3	10.0	10.3
41	Sakri lower valley	21.3	32.5	-11.3	0.0	7.5	-7.5	7.6	0.0	7.6
42	Salauli	8.3	5.3	3.1	20.8	42.1	-21.3	12.5	0.0	12.5
43	Sharda Sahayak	55.0	12.5	42.5	34.4	15.0	19.4	39.4	0.0	39.4
44	Shetrunji	97.0	42.5	54.5	84.8	20.0	64.8	86.9	0.0	86.9
45	Sidmukh	11.0	7.5	3.5	7.0	5.0	2.0	4.0	5.0	-1.0
46	Sri Hind Canal	46.3	0.0	46.3	48.8	22.5	26.3	56.9	42.5	14.4
47	Sri ram sagar	81.5	22.5	59.0	40.5	72.5	-32.0	63.5	62.5	1.0
48	Tanda Pumpcanal	57.0	2.5	54.5	25.0	22.5	2.5	39.0	2.5	36.5
49	Tungabhadra (LBC Dam)	71.1	10.0	61.1	18.6	32.5	-13.9	41.7	0.0	41.7
50	Uderusthan	63.4	12.5	50.9	15.3	7.5	7.8	42.3	0.0	42.3
51	Ukai	96.9	20.5	76.4	99.4	5.1	94.2	95.6	0.0	95.6
52	Upper Ganga	81.9	37.5	44.4	69.4	2.5	66.9	80.0	0.0	80.0
53	Upper Wardha	61.0	21.1	40.0	61.7	15.4	46.3	46.3	2.6	43.7
54	Wan	21.0	2.6	18.4	8.4	75.0	-66.6	10.6	0.0	10.6
55	Western Sone and Chausa Command	22.5	47.5	-25.0	31.9	15.0	16.9	23.1	0.0	23.1
56	Western Sone High Level Command	58.0	32.5	25.5	49.0	5.0	44.0	50.0	0.0	50.0
57	Western Yamuna	35.0	15.0	20.0	47.8	35.0	12.8	47.2	37.5	9.7

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Table A4.11: Project-wise tourism development (%)

S. No	Project Name	Improvement in tourism development			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
1	Adwa	10.0	0.0	10.0	90.0	100.0	-10.0
2	Ajoy Barrage (Siktia)	29.0	0.0	29.0	71.0	100.0	-29.0
3	Chambal	30.8	7.5	23.3	69.2	92.5	-23.3
4	Deokali Pump canal	25.0	0.0	25.0	75.0	100.0	-25.0
5	Eastern Sone Canal Command	13.8	2.6	11.1	86.3	97.4	-11.1
6	Eastern Sone High Level Command	10.0	7.5	2.5	90.0	92.5	-2.5
7	Gangapur	47.5	7.5	40.0	52.5	92.5	-40.0
8	Ghod	29.0	12.5	16.5	71.0	87.5	-16.5
9	Girna	41.0	2.5	38.5	59.0	97.5	-38.5
10	Haripur reservoir	35.7	2.5	33.2	64.3	97.5	-33.2
11	Harishchandra sagar	13.1	5.0	8.1	86.9	95.0	-8.1
12	Hathmati	38.9	0.0	38.9	61.1	100.0	-38.9
13	Hemavathy	49.0	0.0	49.0	51.0	100.0	-49.0
14	Hirakud	69.8	0.0	69.8	30.2	100.0	-69.8
15	IGNP	11.3	0.0	11.3	88.7	100.0	-11.3
16	Integraed Kollang	12.0	0.0	12.0	88.0	100.0	-12.0
17	Itiadoh	55.8	10.3	45.5	44.2	89.7	-45.5
18	Jamuna	2.2	0.0	2.2	97.8	100.0	-2.2
19	Jayakwadi (Satge 1)	43.3	37.5	5.8	56.7	62.5	-5.8
20	Kakrapar	97.5	2.5	95.0	2.5	97.5	-95.0
21	Kallada	77.2	2.6	74.7	22.8	97.4	-74.7
22	Kanchi Irrigation Scheme	13.2	2.5	10.7	86.8	97.5	-10.7
23	Karjan	98.0	0.0	98.0	2.0	100.0	-98.0
24	Kharif project Hindon Krishi	29.6	0.0	29.6	70.4	100.0	-29.6
25	Krishna	55.0	10.0	45.0	45.0	90.0	-45.0
26	Kuttiyadi	81.6	0.0	81.6	18.4	100.0	-81.6
27	Loktak Lift	1.0	0.0	1.0	99.0	100.0	-1.0
28	Lower Bhavani	42.9	0.0	42.9	57.1	100.0	-42.9
29	Makhu canal system	5.1	2.5	2.6	94.9	97.5	-2.6
30	Matatila	18.2	0.0	18.2	81.8	100.0	-18.2
31	Mayurakshi (Jharkhand)	60.0	0.0	60.0	40.0	100.0	-60.0
32	Meshwo (Reservoir)	40.9	0.0	40.9	59.1	100.0	-40.9
33	Nagarjuna Sagar	30.9	6.9	24.0	69.1	93.1	-24.0
34	Nagarjuna sagar Right bank canal	23.5	0.0	23.5	76.5	100.0	-23.5
35	Nagarjuna Sagar TG	34.0	0.0	34.0	66.0	100.0	-34.0
36	Ong Diversion Weir	92.0	0.0	92.0	8.0	100.0	-92.0
37	Penna	32.3	3.3	29.0	67.7	96.7	-29.0

S. No	Project Name	Improvement in tourism development			Decline/ No change		
		Command	Non-Command	Diff	Command	Non-Command	Diff
38	Potteru	80.0	0.0	80.0	20.0	100.0	-80.0
39	Ravi canal	4.0	0.0	4.0	96.0	100.0	-4.0
40	Rewari Project	12.6	0.0	12.6	87.4	100.0	-12.6
41	Sakri lower valley	0.6	0.0	0.6	99.4	100.0	-0.6
42	Salauli	95.8	47.4	48.5	4.2	52.6	-48.5
43	Sharda Sahayak	23.1	0.0	23.1	76.9	100.0	-23.1
44	Shetrunji	93.9	0.0	93.9	6.1	100.0	-93.9
45	Sidmukh	11.0	12.5	-1.5	89.0	87.5	1.5
46	Sri Hind Canal	11.3	0.0	11.3	88.8	100.0	-11.3
47	Sri ram sagar	45.0	25.0	20.0	55.0	75.0	-20.0
48	Tanda Pumpcanal	18.0	0.0	18.0	82.0	100.0	-18.0
49	Tungabhadra (LBC anf Dam)	51.5	2.5	49.0	48.5	97.5	-49.0
50	Uderusthan	12.7	0.0	12.7	87.3	100.0	-12.7
51	Ukai	100.0	0.0	100.0	0.0	100.0	-100.0
52	Upper Ganga	37.9	2.6	35.3	62.1	97.4	-35.3
53	Upper Wardha	39.9	2.6	37.3	60.1	97.4	-37.3
54	Wan	37.9	17.5	20.4	62.1	82.5	-20.4
55	Western Sone and Chausa Command	12.5	5.0	7.5	87.5	95.0	-7.5
56	Western Sone High Level Command	9.0	0.0	9.0	91.0	100.0	-9.0
57	Western Yamuna	13.2	0.0	13.2	86.8	100.0	-13.2

Notes: differences in percentage points
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Annexure 5: Exploratory Assessment of Tourism-related Effects in Irrigation Project Areas

A.5.1 BACKGROUND AND CONTEXT

Irrigation infrastructure, particularly reservoirs, canal networks, and associated water bodies, may create conditions that support the emergence of recreational and tourism-related activities in surrounding areas. These include boating, fisheries-based recreation, farm-based tourism, and small-scale hospitality services.

During fieldwork, such activities were reported in select project locations, prompting an exploratory assessment of their potential contribution to local economic outcomes. However, these effects were found to be spatially concentrated and context-specific, typically limited to areas proximate to reservoirs or major hydraulic structures.

A.5.2 NATURE AND SPATIAL DISTRIBUTION OF TOURISM-RELATED ACTIVITIES

Field evidence indicates that tourism-related activities are not uniformly distributed across command areas. Rather, they are concentrated in:

- Reservoir-adjacent zones
- Dam and headworks locations
- Canal stretches with accessibility and scenic value

In contrast, large parts of the command area—particularly tail-end regions—do not exhibit such activities.

Table A.5.1: List of irrigation projects with reported tourism-related activities

S. No.	Selected Projects
	Northern Region
1	Hindon Krishi Irrigation Project
2	Deokali Irrigation Project
3	Sharda Sahayak Irrigation Project
4	Chambal Irrigation Project
5	Upper Ganga Irrigation Project
6	Haripur Reservoir Irrigation Project
	Eastern Region
1	ONG Diversion Vier Irrigation Project
2	Mayurakshi JH Irrigation Project
3	Potteru Irrigation Project
4	Hirakud Irrigation Project
5	Ajoy Barrage Siktia Irrigation Project
	Southern Region
1	Lower Bhavani Irrigation Project
2	Tungabhadra Irrigation Project
3	Nagarjuna Sagar Telangana Irrigation Project
4	Sri Ram Sagar Irrigation Project
5	Kallada Irrigation Project
6	Penna Irrigation Project
7	Hemavathy Irrigation Project
8	Kuttiyadi irrigation Project
9	Nagarjuna Sagar LBC Irrigation Project
10	Nagarjuna Sagar RBC Irrigation Project
	Western Region
1	Gangapur Irrigation Project
2	Ghod Irrigation Project
3	Hathmati Irrigation Project
4	Jayakwadi Irrigation Project
5	Kakrapar Irrigation Project
6	Karjan Irrigation Project
7	Krishna Irrigation Project
8	Meshwo Irrigation Project
9	Salauli Irrigation Project
10	Shetrunji Irrigation Project
11	Ukai Irrigation Project
12	Upper Wardha Irrigation Project

Note 1 During identification of tourism intensity for a particular project, only responses from respondents in the command area were considered; responses from respondents in the non-command area were not factored in.
Note 2: *CCA for all selected projects are mentioned in Table 3.1.*
Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

A.5.3 TYPES OF TOURISM-LINKED ECONOMIC ACTIVITIES

Based on household responses and field observations, the following categories of activities were identified:

- Water-based recreation: boating, fishing-related leisure activities

- Farm-based tourism: agri-tourism, demonstration farms
- Roadside and service economy: small eateries, shops, and visitor services

These activities are typically small-scale and locally driven, often emerging in response to increased accessibility and improved landscape conditions.

A.5.4 EXPLORATORY ANALYTICAL APPROACH

Once the projects with tourism potential were identified, a regression analysis with appropriate dummy variables was undertaken to quantify the associated income benefits arising from them. This approach enabled the isolation of the incremental contribution of tourism to household income, distinguishing it from the core irrigation-induced effects. The use of dummy variables helped capture the presence or absence of tourism-linked opportunities.

The fitted regression equation for this purpose is presented below:

$$\Delta \text{ Average HH Income}_i = \gamma 1 * D1_i + \gamma 2 * D2_i + u_i \quad \textbf{[A5.4]}$$

It is evident from the above equation A.5.4 that two project-level dummy variables were created with the following properties:

Dummy 1 (D1) taking the value 1 if tourism was present and 0 otherwise

Dummy 2 (D2) taking the value 1 if tourism was not present and 0 otherwise.

A regression analysis was henceforth conducted using the annual average household income difference between command and non-command areas for each project as the dependent variable and the tourism dummies (D1 and D2 defined above) as the independent variable.

A.5.4.1 Interpretation of Regression Results

The regression results produced two critical coefficients, γ_1 and γ_2, with γ_1 representing the average household income difference in projects with tourism development, and $\gamma 2$ capturing the same for projects without tourism. More formally:

γ_1: Average Household Income Difference Attributable to the Presence of Tourism
$\gamma 2$: Average Household Income Difference Despite of Absence of Tourism

The values of these two parameters resulting from the above regression are given in Table A.5.2.

Table A.5.2: Estimates of marginal benefits from tourism at national level

Parameter	Parameter Value (Rs.)	Coefficient of Determination (R^2)
γ_1	47693***	0.537
$\gamma 2$	32848***	0.537

Note: With *, **, and *** indicating 90%, 95%, and 99% level of significance respectively.
Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

What is essential is the difference between $\gamma 1$ and $\gamma 2$. This will provide a direct measure of the net additional income generated by tourism as a result of irrigation projects.

More specifically, [$\gamma 1$ - $\gamma 2$] will give us the net additional benefits generated from the presence of tourism for a particular project. This figure turns out to be Rs. 14,845. This approach provided a clear estimate of the additional income generated due to tourism development in the irrigation projects where it was present.

Table A.5.3 reports the national-level beta coefficients for projects with and without a tourism component. The incremental tourism benefits are simply added to the baseline beta coefficient to derive the final estimate for indirect benefits accruing to projects with tourism scope.

Table A.5.3: Comparative Estimates with and without Tourism Effects

Region	Beta without Tourism (in Rs.)	Beta with Tourism (in Rs.)
National	81,227	96,072

Source: *NCAER Study to Assess Indirect Benefits of Irrigation Projects*, 2025

The results of the above analysis should be interpreted with caution. Tourism-related effects are highly context-specific, influenced by location, infrastructure, and external economic conditions. Moreover, there exists a possibility of overlap with other dimensions such as employment generation

and market development, making attribution challenging.

In view of these limitations, tourism-related effects have not been included in the core econometric framework or in the estimation of national-level coefficients (alpha and beta) presented in the main report. The analysis presented here is therefore exploratory in nature and intended for reference only.

A.5.5 KEY OBSERVATIONS

- Tourism-related activities are present only in a subset of irrigation projects
- Their impact is localised rather than command-wide
- They are better interpreted as supplementary economic effects
- Their magnitude varies significantly depending on:
  a. Proximity to reservoirs
  b. Connectivity and infrastructure
  c. Local entrepreneurial response

A.5.6 IMPLICATIONS FOR IRRIGATION APPRAISAL

While irrigation infrastructure may enable tourism-related activities under favourable conditions, these effects:

- Cannot be generalised across projects
- Are not uniformly attributable to irrigation interventions
- Should be treated as context-specific externalities

Accordingly, their inclusion in formal project appraisal frameworks requires further methodological refinement and case-specific validation.

Annexure A6.1 Validation Exercise (Hypothetical Example)

This annexure provides a detailed step-wise that can be followed to assess and quantify the indirect benefits from a new irrigation project. Table A6.1 summarizes, in simple terms, how the broader indirect benefits of irrigation were converted into a single monetary value per household for a hypothetical example.

Table A6.1 Validation steps

Steps	Parameter	Value
Step 1	Agri-Income diffrence per hectare (Rs)	22,000
Step 2	National Alpha	0.00000838
Step 3	Composite Index	0.1843
Step 4	National Beta (Rs)	81,227
Indirect Benefit (Rs)		14,975

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Suppose the incremental agri-income difference from the irrigation project is Rs. 22,000 (before – after). This income gap is adjusted using a nationally estimated Alpha coefficient, which reflects how income gains typically translate into wider social, economic, and environmental improvements representing a subset of indirect benefits index (composite index).

The agricultural income difference per hectare reflects per-hectare direct benefits from irrigation. Whereas, the indirect benefits estimated later are per-household monetised indirect benefits. For comparability, the per-hectare income difference must be multiplied by the average landholding size (in hectares) per household. This conversion yields per-household direct benefits, enabling a like-to-like comparison with indirect benefits.

Annexure A6.2 Validation Exercise (Project-based Illustration)

This annexure strengthens the empirical validation of the proposed methodology by presenting a project-level validation exercise. From the total sample of 57 irrigation projects, five projects were randomly selected for this exercise. A step-wise approach was adopted to estimate the monetised value of indirect benefits associated with these projects.

Step 1: Computation of Annual Average Agricultural Income Differential

The first step involves estimating the annual average difference in agricultural income per hectare between command and non-command areas for each selected project. The difference in agricultural income between command and non-command areas was derived from the household survey conducted under this study.

In both areas, farmers were asked to report their agricultural income for the previous year through the question *"Last year's income from agricultural sources?"* which was included as Question 39 [40]in the Command Area questionnaire and Question 37 in the Non-Command Area questionnaire.

Reported incomes were processed using the landholding-based classification described in Chapter 5, Section 5.4. Average agricultural income was first computed separately for each landholding group in command and non-command villages and then aggregated using weights representing proportional landholding size.

Non-comman agricultural income was weighted using the proportional landholding size weights obtained in the command of that project. This removes biasness in landholding distribution arising out of irrigation implementation in the command area.

The difference between these two averages, expressed in rupees per hectare was taken as the agricultural income gain attributable to irrigation.

Table A6.2 Agricultural income difference per hectare (Rs.)

Project name	Agri-Income Difference (Rs. / Ha.)
Adwa Canal irrigation Project	8317.16
Makhu Canal Irrigation Project	2251.61
Sirhind Irrigation Project	11843.18
Sharda Sahayak Irrigation Project	1647.45
Chambal Irrigation Project	5646.87

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Step 2: Estimation of Composite Index (CI) Values

The agricultural income differentials per hectare obtained in Step 1 are multiplied by a uniform alpha coefficient to estimate the composite index (CI) for each project. The CI captures multiple indirect benefits associated with irrigation through a standardized metric.

Table A6.3 Estimated composite index value

Project name	ΔAgri-Income*	Alpha Coefficient	Calculated CI
Adwa Canal irrigation Project	8317.16	0.00000837	0.0696
Makhu Canal Irrigation Project	2251.61	0.00000837	0.0188
Sirhind Irrigation Project	11843.18	0.00000837	0.0991
Sharda Sahayak Irrigation Project	1647.45	0.00000837	0.0138
Chambal Irrigation Project	5646.87	0.00000837	0.0473

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025
*ΔAgri-Income = Change in agricultural income per hectare

Step 3: Monetisation of Indirect Benefits per Household

The estimated composite index values are multiplied by a uniform national-level beta coefficient (Rs. 81,227) to derive the monetised value of indirect benefits per household (HH). The beta coefficient converts the composite index—representing ten distinct indirect benefit dimensions—into monetary terms.

Table A6.4 Estimated monetised value of indirect benefits per household

Project name	Calculated CI	Beta Coefficient (Rs.)	Indirect Benefits (Rs. / HH)
Adwa Canal irrigation Project	0.0696	81227	5654.59
Makhu Canal Irrigation Project	0.0188	81227	1530.81
Sirhind Irrigation Project	0.0991	81227	8051.83
Sharda Sahayak Irrigation Project	0.0138	81227	1120.05
Chambal Irrigation Project	0.0473	81227	3839.14

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Step 4: Estimation of Indirect Benefits per Hectare

To facilitate comparability across projects, the indirect benefits estimated at the household level are converted into per-hectare terms. This is done by dividing the indirect benefits per household by the average landholding size of households in the command area.

Table A6.5 Estimated monetised value indirect benefits per hectatre

Project name	Indirect Benefits (Rs. / HH)	Avg landhoding size per HH (Ha.)	Indirect Benefits (Rs. / Ha)
Adwa Canal irrigation Project	5654.59	1.44	3926.79
Makhu Canal Irrigation Project	1530.81	1.55	987.61
Sirhind Irrigation Project	8051.83	1.5	5367.88
Sharda Sahayak Irrigation Project	1120.05	1.202	931.82
Chambal Irrigation Project	3839.14	1.786	2149.57

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Step 5: Indirect Benefits as a Percentage of Total Benefits.

Finally, the indirect benefits per hectare are expressed as a percentage of total benefits, defined as the sum of direct (agricultural income gains) and indirect benefits per hectare.

Indirect Benefits (%) = [Indirect Benefits per Ha. / (Direct + Indirect Benefits per Ha.)] *100

Table A6.6 Indirect benefits as a percentage of total benefits

Project name	Direct Benefits (Rs. / Ha.)	Indirect Benefits (Rs. / Ha.)	Total Benefits (Rs. / Ha.)	Indirect Benefits (%)
Adwa Canal irrigation Project	8317.16	3926.79	12243.95	32.07
Makhu Canal Irrigation Project	2251.61	987.61	3239.22	30.49
Sirhind Irrigation Project	11843.18	5367.88	17211.06	31.19
Sharda Sahayak Irrigation Project	1647.45	931.82	2579.27	36.13
Chambal Irrigation Project	5646.87	2149.57	7796.44	27.57

Source: NCAER Study to assess Indirect Benefits of Irrigation Projects, 2025

Annexure A7.1: Ranking of each parameter for all the Irrigation Projects

The table provided below departs a parameter-wise ranking of each irrigation project. It ranks the performance of each irrigation in all 10 parameters with "1" and "10" being the highest and lowest ranking respectively.

Table A7.1: Ranking of each parameter for all the Irrigation Projects

Northern Projects										
Parameter	Market Linkages	External Finances	Employment beyond agri	Local Agri-businesses	Ground Water	Soil Degradation	School Attendance	Water-borne Diseases	Migration	Community Cooperation
Upper Ganga Project	3	7	9	6	2	1	4	10	5	8
Chambal Project	1	8	9	10	4	3	2	6	7	5
Sirhind Project	3	7	4	6	8	2	1	9	10	5
Haripr Reseroir	1	8	7	6	3	2	9	10	4	5
Western Yamuna	3	8	9	7	4	2	1	10	6	5
Rewari or JNP	2	8	9	6	7	3	1	10	5	4
MakhuProject	3	8	2	7	9	4	1	6	10	5
Sidmukh Project	1	4	2	5	6	7	8	9	10	3
IGNP Project	2	8	5	9	10	1	3	4	7	6
Ravi Canal	3	8	4	7	9	1	2	10	6	5
Sharda Sahayak	2	6	8	4	9	1	10	3	5	6
Deokali Project	3	6	7	5	4	2	8	1	9	10
Hindon Krishi	2	5	6	3	9	1	10	4	8	7
Harischandra sagar	1	5	4	6	7	8	2	9	10	3
Tandapump Canal	2	8	9	4	10	3	6	1	5	7
Matatila Project	3	5	10	4	6	1	2	8	7	9
Adwa Project	2	7	8	4	9	3	10	1	6	5

Eastern Projects										
Parameter	**Market Linkages**	**External Finances**	**Employment beyond agri**	**Local Agri-businesses**	**Ground Water**	**Soil Degradation**	**School Attendance**	**Water-borne Diseases**	**Migration**	**Community Cooperation**
Eastern Sone canal	2	7	5	8	4	6	1	9	10	3
ONG Diversion Weir	6	5	9	4	1	1	3	10	8	7
Mayurakshi JH Project	4	9	5	10	2	3	1	7	8	6
Westren Sone High Level Project	3	7	5	8	6	2	1	9	10	4
Eastern Sone High Level Project	3	5	7	8	9	2	1	10	4	6
Uderusthan Project	3	7	8	6	9	1	2	10	5	4
Potteru Project	4	9	6	3	2	1	5	10	8	7
Hirakud Project	3	8	5	7	4	1	2	10	9	6
Wetsern Sone Chausa	3	6	4	7	8	2	1	9	10	5
Ajoy Barrage Project	1	4	2	5	6	7	8	9	10	3
Sakri Lower Valley	4	7	8	6	9	3	2	1	10	5
Kanchi Project	3	8	9	10	4	2	1	5	7	6

Southern Projects										
Parameter	**Market Linkages**	**External Finances**	**Employment beyond agri**	**Local Agri-businesses**	**Ground Water**	**Soil Degradation**	**School Attendance**	**Water-borne Diseases**	**Migration**	**Community Cooperation**
Lower Bhavani Project	5	6	7	4	1	2	8	9	10	3
Tungabhadra Project	3	8	5	9	4	1	2	10	6	7
Nagarjuna Sagar TG Project	4	9	8	3	2	1	5	10	6	7
Sri Ram Sagar Project	2	9	8	3	10	4	1	5	7	6
Kallada Project	2	5	1	6	3	7	8	9	4	10
Penna Project	5	9	7	10	1	2	4	8	3	6
Hemavathy Project	1	6	7	2	8	3	9	10	4	5
Kuttiyadi Project	2	9	10	4	2	5	1	6	7	8
Nagarjuna Sagar LBC	5	7	8	9	4	3	1	2	6	10
Nagarjuna Sagar RBC	9	8	4	2	10	7	1	3	5	6

Western Projects										
Parameter	**Market Linkages**	**External Finances**	**Employment beyond agri**	**Local Agri-businesses**	**Ground Water**	**Soil Degradation**	**School Attendance**	**Water-borne Diseases**	**Migration**	**Community Cooperation**
Gangapur Irrigation Project	1	8	6	5	9	3	2	10	4	7
Ghod Irrigation Project	1	7	6	5	1	4	9	10	3	8
Girna Irrigation Project	1	9	4	8	7	3	2	10	5	6
Hathmati Irrigation Project	2	3	6	7	1	8	9	10	4	5
Itiadoh Irrigation Project	3	8	5	9	2	1	7	10	6	4
Jayakwadi Irrigation Project	2	10	7	6	4	3	1	8	5	9
Kakrapar Irrigation Project	2	7	6	9	1	4	8	10	3	5
Karjan Irrigation Project	1	8	7	9	4	4	1	10	6	1
Krishna Irrigation Project	2	6	5	7	1	9	3	10	4	8
Meshwo Irrigation Project	3	5	4	8	1	9	2	10	7	6
Salauli Irrigation Project	1	4	7	3	9	6	2	10	8	5
Shetrunji Irrigation Project	2	8	6	9	1	3	4	10	7	5
Ukai Irrigation Project	3	9	4	7	1	5	1	10	8	6
Upper Wardha Irrigation Project	2	7	6	8	1	5	9	10	4	3
Wan Irrigation Project	2	7	4	5	8	1	3	9	6	10

Table A7.2: Project-level FGD insights

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
IGNP 1 Canal project	Weak linkages; poor roads; distant mandis.	High input costs; low productivity gains.	No new agri/ business activity.	Saline groundwater; fake fertilizers.	No new jobs; limited local options.	Higher enrolment; poor teaching quality.	Severe scarcity; tanker dependence	Contaminated water; rising illnesses	Low migration despite low income.	Mutual water sharing; women excluded.
Chambal kota	Selling mainly at Sultanpur/Kota mandis; no farmer groups.	High input cost; chemical-based farming.	No new enterprises; limited non-farm jobs.	Falling productivity; high chemical use.	Minimal growth; nearby fertilizer plant offers some jobs.	Improved due to school expanding to class 12	Tube well access good; groundwater declining.	Increase in diseases linked to chemicals.	Very low migration; some workers come from outside.	Water committee active; conflicts reduced.
Tanda Pump Canal	Yes, strong improvement in market access	Reduced; better income increases savings	Yes—shops, dairy, driving, small businesses	No soil issues reported	Yes—farm and non-farm jobs increased	Yes—higher education aspirations	Improved due to canal water	Yes—clean water, less burden on women	Partially; seasonal migration continues	No discrimination in water distribution; some issues due to blocked channels
Sharda Sahayak	Market access improved due to better roads, new markets, better information sources	Some dependence may be due to rising costs	Yes—shops, small factories, pvt. companies	No degradation reported	Yes—many new jobs/ businesses; women work in MNREGA	Yes—enrolments increased in school, can afford fees	Stable; tube wells available	Yes—clean water improved health	No—migration persists due to high living costs	Mixed—cooperation exists but disputes at tail end since they don't water properly
Matatila	Very weak; seasonal inaccessibility	High dependence; low farm returns	No growth; non-farm opportunities limited	Soil issues from waterlogging; no testing	No increase; migration high	Yes—better regularity in schools	No; groundwater poor	No; diseases due to hard water & waterlogging	No; migration high	Weak; inter-state conflicts over water
Deokali Pump Canal	Strong improvement; more markets & buyers	Reduced due to higher income	Yes—agri & non-farm shops, transport	Soil improved; no waterlogging	Yes—farm & non-farm jobs expanded	Yes—more children in school; higher education	Yes—recharge improved	Yes—major reduction in diseases	Yes—migration reduced	Strong cooperation; minimal conflict
Upper Ganga	No grain mandi in Haridwar still paying mandi tax; sell in Haryana; only benefit of availability of Sugarcane mill and govt allow MSP, can sell easily sugarcane crop otherwise no benefit.	Rising dependence due to high input costs	Some business growth (shops, factories)	Soil good but waterlogging in rains	Some job growth but **not irrigation-linked**	Yes—more private schooling	Mixed; no major recharge improvement	Mixed; improved health services but poor nala cleaning	No; migration continues	Everyone in village gets water without conflict; but conflicts exists between UP–Uttarakhand over water; Illigal cutting (water) should be stopped
Jalaun (Nunsai, Matatila)	Weak – poor road connectivity; farmers sell locally	High – dependence on borewells, loans for farming	Very limited; no irrigation-led business growth	Soil quality declining due to erratic water	Low – irrigation scarcity restricts income	No impact of irrigation as only 5% benefit of the project, low income causes poor affordability of fees.	Poor – groundwater low; heavy dependence on borewells	Due to salty and poor quality water, lot of diseases persists	High migration (seasonal) due to water scarcity, 95% farmers do not get any benefit of irrigation	Good unity; villagers cooperate informally despite no committees

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
Newada Adwa Pump Canal	Weak – canal stops midway; limited market access	High dependence– borrowing for farming common	Almost no agri-business growth	-	Limited – labour shortages; **few local opportunities**	Good school attendance; children go to school regularly	Partially improved via solar pumps; canal unreliable	Health issues persist; no clear reduction	Migration continues; many go to cities for work	Mixed – some cooperation but depends on water availability
Sharda Sahayak Canal	Moderate – farmers can access markets but water uncertainty limits gains	Moderate – farmers buy inputs; cropping diversification increasing costs	Some improvement (shift to sugarcane, vegetables, mustard)	Soil quality stable; no major degradation	**Some non-farm work; agriculture improved slightly** where water reaches	Attendance improved; children going for higher education	Water scarcity in summer; canal only timely during power release	Not highlighted as improved	Migration not significantly reduced	Some cooperation but tail-end farmers suffer most
Nagarjuna Sagar Project	Moderate – improved road connectivity, better access to mandis; private buyers visit village	Moderate–high – rising input costs; higher expenses on fertilizers, machinery; some loans via SHGs	Good – horticulture, turmeric, vegetables, oilseeds; small processing units emerging	Soil fertility declining due to high chemical use; waterlogging in pockets	Medium – **more work in agriculture, transport, local trading**	Improved – better income supports education	Improved – borewells recharged; better water availability	Significant improvement – cleaner sources reduce infections	Sharp reduction – local employment increased	Moderate – informal sharing; WUA inactive; tail-end disputes
Penna Project	Market linkages moderately improved; farmers now sell in Nellore/Kovur; vegetables & high-value crops reach markets; minor road improvements	Dependence increased — higher input costs (fertilizers, pesticides, machinery); more crops per year increased expenses; some take SHG/ dealer loans	Strong improvement — shift to vegetables, banana, floriculture; agri-input shops, tiffin stalls, fruit stalls, poultry, dairy emerging	Soil issues rising — some hardening/ salinity; pollution from factory waste in canals; chemical use very high; occasional waterlogging	Moderate increase — more farm labour, construction, transport services; women starting small SHG-based enterprises	Improved — higher incomes →more private schooling, tuition; education prioritised	**Improved but uneven — canal water improves recharge;** borewells more reliable; still concerns in summer	Significant reduction — better water availability, hygiene, toilet use; fewer stomach infections/fevers	**Migration reduced significantly for small/ medium farmers**; youth still migrate	Mixed — **informal cooperation in water-sharing; but tail-end farmers disadvantaged;** no formal WUA; disputes occur in scarcity
Nagarjuna Sagar RBC Project	Moderate – surplus crops go to Chirala & Ongole markets; road connectivity average; middlemen dominant	High – high costs for inputs, borewell electricity/diesel; informal credit from dealers	Low–moderate – some dairy, shops, poultry; mostly traditional crops	Soil fertility worsening due to overuse of chemicals; waterlogging minimal	Moderate – seasonal non-farm jobs (construction, driving, transport)	Slight improvement – incomes help pay fees; irregular water →irregular schooling at times	**Mixed – recharge improves during canal release;** poor in summer	Limited improvement – **some reduction in stomach/ skin issues**	Migration continues in dry years; only modest reduction	Weak–moderate – informal cooperation; no active WUA; head–tail inequality
Sriram Sagar Project	Strong – variety in crops →strong mandi linkages; mini-mandis & local collection centers emerging	Moderate – higher fertilizer/ pesticide/ machinery costs	Strong – turmeric processing, pulse/oilseed units; retail & input shops growing	Soil quality declining due to excessive chemicals; groundwater stress rising	High – agriculture, transport, retail, micro-enterprises	Strong improvement – parents invest in education; better school infrastructure	Strong improvement – irrigation improved groundwater & year-round water	Strong – clean piped water & borewells reduced diseases	Strong – significant drop in seasonal & long-term migration	Moderate – informal cooperation; tail-end issues; WUA inactive; caste disparities exist

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
Andhra Pradesh (LBC Nagarjuna Sagar)	Limited – only farmers near canal benefit; others depend on borewells	Moderate–High – rising costs for fertilizers, borewell electricity	Some improvement in dairy, small shops, but limited overall	Soil good; minor waterlogging issues in some sections	**Some jobs (dairy, small trades)** but not irrigation-driven	Good school attendance; preference for private schools	Mixed – good for canal-adjacent households; poor for others	Mixed – better sanitation but rainy-season waterlogging causes illness	Migration not reduced; limited irrigation for majority	Weak – conflicts between farmers; no effective WUO
Udhrasthan Irrigation Projects	No improvement; farmers depend on private traders.	High self-finance; informal borrowing common.	No new agri-business or non-farm expansion.	Soil stress continues; full dependence on chemicals.	No new jobs; only farm-based work available.	More children attend school; quality still poor.	Groundwater very deep; no canal recharge.	Better drinking water; fewer waterborne illnesses.	Migration unchanged; farm risk still high.	Low cooperation; canal not functioning for years.
Sakri lower Valley	No canal benefit; farmers depend on traders.	High borewell cost; self-financed farming	No new agri-business or local enterprises.	More chemical fertilizer use; weak soil health.	No new jobs; high migration for work.	Higher enrolment; poor education quality.	Groundwater falling; no canal recharge.	Water-related diseases increasing; poor cleanliness.	Migration rising due to weak irrigation.	Limited cooperation; women not involved.
Mayurakshi Murjora	Easy market access; no cooperative support.	Self-financed farming; no formal support.	No new agri-business; small tourism shops only.	High chemical use; soil fertility declining.	No new jobs; farming and labour only.	Higher enrolment; low education quality.	Groundwater decreasing; handpumps failing	Cleaner water reduces diseases; supply irregular	High seasonal migration for income.	Basic cooperation exists; women not involved.
Kanchi Irrigation	Low prices; no mandi/ APMC access.	Costs high; limited savings.	No new agri-business or shops.	High chemical use; low soil fertility.	Seasonal farm work; some private jobs.	Basic schooling; women active in SHGs	Water only July–Nov; low recharge.	Better drinking water; limited health data.	Some reduction; off-season migration continues.	Active SHGs; cooperative water-sharing.
Eastern Sone High Level	No improvement; low surplus production.	High due to borewells & rising input costs.	No new agri businesses developed.	Chemical use rising; natural manure reduced.	No growth; migration continues.	Improved teacher presence; better attendance.	Groundwater declining; summer shortages.	Clean water; no major diseases reported.	High outward migration for work.	Women's participation up; water stress persists.
Eastern Sone Command Belas(Belsar)	Roads improved; buyers visit village.	High due to borewells + chemical inputs	No new agri-business; traditional farming.	Soil affected by chemicals + silted water.	Low; poor irrigation limits jobs.	Improved; regular teachers.	Low groundwater; irregular canal flow.	Clean handpump water; tap water poor.	High due to lack of local work.	Equal water sharing; no WUA; canal repair needed.
Hirakud Project	Irrigation has boosted production, which in turn has improved their connection with nearby markets	High – heavy pesticide and input use raise costs & expenses than/ income	Growth of small businesses, started small-scale food processing activities such as rice milling.	Soil stress from pesticide-heavy cultivation, concerns for reduce soil fertility and water logging, chemical fertilizer usage has increased due to higher cropping intensity	Non-farm employment opportunities improved, in non-cropping period villagers work in construction, transport and trading businesses. Youths driving tractors or mini-trucks, others assist in input supply shops; women involved in Kirana shop, tailoring and goat rearing.	Improved, with stable farming income, families are better able to afford school-related expenses.	Water scarcity in summers reported, otherwise assured irrigation facilitated them to grow crops under risky rain fed conditions, problem in tail-end areas due to siltation	No improvement; diseases not highlighted as reduced, drinking water is there due to irrigation but poor quality concerns	Overall migration trend has declined, Irrigation has increased the demand for agricultural labour and wages as well, people prefer to stay in the village. Youth migrate temporarily for higher-paying work.	Encouraged cooperation, Farmers come together to clean minor canals and coordinate water usage during peak periods

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
Odisha (ONG Diversion Weir Project)	Better roads and use of tractors increased access to nearby mandis; market linkages with large urban centers still limited	Improved financial stability of farmers	With higher farm production, more fertilizer shops, agri-input businesses, small businesses and trade activities linked to agriculture developed	Need to monitor soil quality and prevent waterlogging in low-lying areas	Yes, non-agricultural employment increased; transport services, petty trading in agricultural goods and building warehouses and shops. Women participation high- farming, join self-help groups, small-scale trading or processing activities.	Enrolment rates increased, able to afford school fees	Groundwater depletion has not been a significant concern	Availability of drinking water has improved & reliable now; cleanliness sources improved slightly, still concerns about water quality remains, diseases declined but slightly	Yes, migration reduced slightly, with stable agricultural income, growing local employment, fewer families migrate out for work. Youth still migrate to cities for non-agricultural jobs	Improved cooperation within the community. Farmers work together to manage water distribution; men and women participate
Odisha (Poteru Project)	Weak – poor market access; long travel to sell produce	High – temporary pump sets, recurrent borrowing	Limited – no irrigation-led diversification; rainfed crops dominate	-	Low – employment opportunities minimal	School availability mentioned but no major changes	Poor – seasonal river; irrigation intermittent	Health facilities poor; no reduction in diseases	Migration remains high	Moderate cooperation but limited by water scarcity
Western Sone High Level Command Kenar Kalan	Weak – farmers mostly sell to local traders; farmers don't go to market; roads in poor condition	Moderate – farmers face burden of buying fertilizer, boring costs, poor machinery access	Very limited; only small shops (paan/bidi etc.); no mills, no agro-units	Soil quality declining; annual waterlogging damages crops	Limited; mostly farm labour; machinery shortage restricts opportunities	Enrolment increased but quality of education poor; govt school not functional	Poor – water table drops in summer; costly borewells; limited recharge	No major water-borne diseases reported, but 40% get good drinking water; high TDS	Moderate; about 10% seasonal migration for work	Cooperation exists among farmers but no committee, no WUO; water distribution requires high individual effort
Western Sone and Chausa Command Dumduma	Very weak – only 5–10% near canal benefit; farmers mostly sell at home to traders; no direct market access	High dependence due to expensive boring (250–300 ft), high fertilizer use, low income	No agri-business; no shops or units; only agriculture and labour; no alternative livelihoods	Soil quality declining; heavy chemical fertilizer use; waterlogging issues	Limited; most people migrate seasonally; no local jobs	Children attend school but quality very poor; private schools preferred	Poor – water table falling; canal water rarely reaches; village depends on borewells	No major diseases reported but water quality poor; high TDS; 40% get good water	High seasonal migration; 70–80% households migrate when agriculture stops	Very weak – no WUO, no committees; canal mismanagement; only canal-adjacent farmers get water
Ukai	Strong vegetable market access; improved road connectivity.	Low reliance on external finance; limited institutional support.	Seasonal growth in agri-activities; no new enterprises formed.	Soil quality stable; high chemical fertilizer use persists	Seasonal jobs created, especially for women; not year-round.	100% enrolment; strong community support for education.	Groundwater stable; ponds dry early; borewell access limited.	Cleaner canal-fed areas; no major decline in water-borne diseases.	Seasonal migration continues; irrigation reduces distress migration.	Good social harmony; weak cooperation in water-sharing systems.
Sheturanji	Good road access; limited organized market support.	Low external finance; small SHG loans only.	No agri-processing; minimal local business growth.	Soil moderate–poor; heavy chemical fertilizer use.	Seasonal farm work; some outside employment.	Moderate enrolment; 15% dropout rate.	Groundwater very deep; no recharge improvement.	Piped water reduced illness; disruptions still occur.	Seasonal migration continues; return during Rabi.	Weak WUA participation; no women in committees.

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
Meshow	Better market visits; no cooperative support.	Stable incomes for some; rainfall dependency remains.	Some non-farm activities; no agri-business growth.	Higher soil moisture; chemical fertilizer use continues	More crop cycles = more farm work.	Higher income supports better schooling.	Groundwater stable; some waterlogging seen.	Cleaner environment; reduced water burden on women.	Lower migration where irrigation is timely.	Good farmer cooperation; weak administrative support.
Krishna	Better market access; direct sugarcane sales.	Income higher; input costs rising.	More agri-shops; sugar factory boosts business.	Groundwater improved; chemical use increased.	More farm and factory jobs locally.	High enrolment; strong education focus.	Groundwater levels rising post-project.	Clean water supply; fewer diseases.	Local income opportunities reduce migration.	Active WUA; women not involved.
karajan	APMC access + better roads + direct buyers.	Income up; input costs rising.	Higher production; no new businesses	Better greenery; high chemical use.	More farm labour demand; few non-farm jobs.	100% enrolment; strong education quality.	Water table rising; reliable drinking water.	Safe water; fewer disease risks.	Higher crop income reduces migration	Strong WUA; equal participation; maintenance gaps.
Kakarapur	Easy crop marketing; no local input shops.	Income up; farming costs rising; SHGs weak.	No new agri-business; GIDC provides jobs.	Better soil moisture; high chemical use.	More farm work + factory employment.	100% enrolment; strong education quality	Groundwater improved; reliable drinking water.	Clean tap water reduces disease risk.	Local jobs reduce migration.	Active WUA; no women's participation.
Jayakwadi Irrigation Project	Local market developed; no cooperative	High input costs; SHGs support small savings.	No new agri-business; farming still primary.	Groundwater improved; heavy chemical use.	More farm work, especially for women.	Better incomes support schooling.	Recharge through irrigation; summer shortage.	Safe drinking water reduces disease.	Migration reduced due to farm work.	Good cooperation; weak canal maintenance.
Itiadoh	APMC access; private buyers; better roads.	Higher costs; SHG loans support women.	Rice mills + input shops; small women-led businesses.	Soil waterlogging; high chemical fertilizer use.	Two paddy seasons = steady farm work.	100% enrolment; many in private schools.	Good drinking water; stable groundwater.	Clean water; fewer diseases.	More farm jobs reduce migration.	Active WUA; women involved; poor canal/drain upkeep.
Hathmati	Better mandi access; no cooperatives.	Income up; input costs high; no active SHGs.	More crop diversification; limited non-farm business.	Good soil; mixed use of organic & chemical inputs.	More farm work; women get seasonal jobs.	100% enrolment; income supports education.	Higher water table; multiple ponds; year-round supply.	Clean water; improved sanitation.	Migration reduced due to better farm income.	Strong cooperation; no WUA; govt support weak.
Grina	Village-level buying; good road access.	Income up; input costs rising.	Maize processing; SHG-led activities.	Good soil; high chemical use.	More farm jobs; women/youth gain work.	Better incomes support schooling.	Higher well/ borewell water levels.	Clean water; fewer diseases.	Local opportunities reduce migration.	Active WUA; women excluded; maintenance issues.
Salauli Project	Good roads; strong cooperative support.	Low financial risk; government subsidies help.	Committee-led farming; no new businesses.	Stable soil; limited advisory services.	Seasonal farm jobs; declining interest in farming.	High education levels; active women participation.	Adequate water; damaged canals limit distribution.	Better water supply; improved health.	Low migration; shift toward non-farm work.	Strong cooperative system; needs better canal maintenance.

Project Name	Improvement in Market Linkages	Dependence on External Finance	Improvement in Local-Agri Businesses	Reduction in Soil Degradation	Increased Employment Opportunities	Increased School Attendance	Ground Water Recharge	Reduction in Water-Borne Diseases	Reduction in Migration	Improvement in Community Cooperation
Ghod	APMC access + village maize center.	Higher income, but rising input costs.	Maize center boosts local agri-business.	Better soil moisture; high chemical use.	More farm and youth jobs locally	Better income improves education access.	Water table rises with canal flow.	Irregular drinking water; women burdened.	Agriculture growth reduces migration.	Farmers cooperative; poor canal maintenance.
Gangapur	Direct trade + better roads + raisin export.	Income doubled; input costs rising	Raisin processing; women's farm activities.	Good productivity; chemical use increasing.	More farm jobs; youth & landless benefit.	Better income boosts education access.	Improved water access; pollution affects lift users.	Clean water; better health facilities.	Local jobs reduce youth migration.	Active WUA; canal repair needed.
Upper Wardha	Yes, due to paved roads & APMC access estb at block	Reduced (higher income & savings)	Yes – dairy, poultry, shops, transport	Soil stable; no degradation, no waterlogging	Yes, especially for landless labour	Yes, school upgraded up to 10th & afford to send to cities for higher education	Yes, water table increased	Yes, RO-filtered drinking water under JJM & access to PHC reduced illness	Yes, migration reduced	No WUO or women participation in water mgt; distribution managed by canal inspector, uneven water distribution
Wan (Beed)	Somewhat improved due to paved roads but low production limits benefits	High dependence due to low productivity	Very limited; only dairy opportunities where possible	Soil still good, but risk due to chemical use	Low opportunities; youth migration	Limited; many dropout after 10th; are unable to afford higher education	Groundwater severely depleted; farmers buy water through tankers for farming and domestic needs.	Irrigation project no longer supply water; rely on natural water sources or purchase clean drinking water, putting an extra burden on women responsible for fetching; water diseases increased due to poor water	No; due to lack of employment opportunities, high migration (20% youth migrated)	No active WUO; low cooperation; no women participation in water management activities
Loktak Lift Irrigation Project	Moderate – metal roads allow access to Imphal & nearby markets; irrigation helps year-round vegetable supply	Moderate – input costs rising (fertilizers, pesticides, energy), but higher incomes help offset	Strong improvement – year-round vegetable farming, multiple cropping, diversification into cauliflower, beans, tomatoes, gourds	-	**Mostly agriculture-based**; year-round vegetable farming increases labour demand; non-farm opportunities limited	Improved – higher incomes allow parents to afford fees; resulting in children's better school attendance	-	Significant reduction – piped water supply & stand posts improved hygiene; women's burden reduced	Migration reduced; only a few migrate seasonally for short periods	Strong – Water User Associations active; collective labour tradition; no caste/gender conflicts; equitable water distribution

Source: NCAER Study to Assess Indirect Benefits of Irrigation Projects, 2025



NCAER | SINCE 1956 QUALITY. RELEVANCE. IMPACT

NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH
NCAER India Centre, 11 Indraprastha Estate, New Delhi 110002, INDIA
Tel: + 91 11 2345 2657, 6120 2698 **Fax:** + 91 11 2337 0164
Email: info@ncaer.org www.ncaer.org