A STUDY OF THE STATUS AND IMPACTS OF IRRIGATION MANAGEMENT TRANSFER TO WATER USERS' ASSOCIATIONS (WUAs) IN THE STATE OF JHARKHAND IN INDIA

A thesis submitted to the
UPES

For the award of
Doctor of Philosophy
in
Management

BY
Jay Nigam
SAP Id: 500057676

December 2023

SUPERVISOR

Dr. T. Bangar Raju, Professor

UPES
UNIVERSITY OF TOMORROW
School of Business
UPES
Dehradun-248007: Uttarakhand

A STUDY OF THE STATUS AND IMPACTS OF IRRIGATION MANAGEMENT TRANSFER TO WATER USERS' ASSOCIATIONS (WUAs) IN THE STATE OF JHARKHAND IN INDIA

A thesis submitted to the
UPES

For the award of
Doctor of Philosophy
in
Management

BY
Jay Nigam
SAP Id: 500057676

December 2023

SUPERVISOR

Dr. T. Bangar Raju, Professor

School of Business
UPES
Dehradun-248007: Uttarakhand

DECLARATION

I, Jay Nigam declare that the PhD thesis entitled "**A Study of the Status and Impacts of Irrigation Management Transfer to Water Users' Associations (WUAs) in the State of Jharkhand in India**" has been prepared by me under the guidance of Dr. T. Bangar Raju, Professor, School of Business, University of Petroleum and Energy Studies. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

Jay Nigam
Research Scholar
SAP Id: 500057676
School of Business,
University of Petroleum and Energy Studies

Date: 18th December 2023

CERTIFICATE

I certify that Jay Nigam (SAP Id: 500057676) has prepared his thesis entitled "**A Study of the Status and Impacts of Irrigation Management Transfer to Water Users' Associations (WUAs) in the State of Jharkhand in India**", for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out work at the School of Business, University of Petroleum & Energy Studies.

Supervisor:

Dr. T Bangar Raju
Professor
School of Business
University of Petroleum and Energy Studies

Date: 18th December 2023

ABSTRACT

A Study of the Status and Impacts of Irrigation Management Transfer to Water Users' Associations (WUAs) in the State of Jharkhand in India

This study investigates the status and impacts of transferring irrigation management to water user associations (WUAs) in rural Jharkhand, India, with the goal of improving rural livelihoods through increased income from irrigated farming. It examines the efficacy of Participatory Irrigation Management involving WUAs to enhance irrigation systems and suggests ways to ensure the financial sustainability of these groups.

This research identifies five key barriers to irrigation efficiency, emphasising financial constraints, capacity building, legal and institutional aspects, resource availability, and the external environment. The study's analytical framework involving AHP, FAHP, and DEMATEL helps prioritise issues related to canal irrigation and recommends that to address these barriers, government funding, capacity-building initiatives, and a supportive legal framework are required. Data Envelopment Analysis (DEA) serves as a means for evaluating the technical efficiency of DMUs (Decision-Making Units) tasked with the management of irrigation canals. This analysis reveals discrepancies in efficiency scores, offering insights into areas where policy improvements can be implemented. Furthermore, this study explores the influence of socio-personal, economic, communication, and psychological factors on canal irrigation efficiency using multiple regression analysis performed in Smart PLS. It notes shifts in power dynamics and positive changes in cropping patterns and irrigated areas following WUA formation, although the outcomes vary among social groups. This research provides valuable insights for policymakers and researchers facing similar challenges, aiming to enhance rural income through improved irrigated farming and sustainable irrigation management. This underscores the need for financial support, capacity building, and a strong legal framework for empowering WUAs.

In summary, this study advances the understanding of the handover of irrigation management to WUAs in Jharkhand, India, by offering insights into irrigation efficiency enhancement and policy improvement. It serves as a resource for policymakers and researchers dealing with rural irrigation challenges and provides recommendations to foster equitable and sustainable irrigation practices. However, this study acknowledges its limitations, such as its specific contextual focus and the need for further research on different irrigation systems and variables.

ACKNOWLEDGEMENT

I am deeply thankful for the guidance and encouragement provided by my research mentor, Dr. T. Bangar Raju, Professor at the School of Business, UPES, Dehradun, for his able direction, constant support, and continuous encouragement from the beginning, which enabled me to complete the research work and helped me reach this milestone. I am thankful to the core for guiding me all through, helping me resolve methodological issues, completing the statistical analysis, and balancing my perspective from time to time.

I wish to express my profound gratefulness to the UPES authorities for granting me this research opportunity. Additionally, I convey my sincere appreciation to the members of the Fellow Research Committee for their valuable guidance.

I am deeply thankful to NABARD for allowing me to pursue the research work.

It is my pleasure to acknowledge and express my deep appreciation to experts, irrigation bureaucrats, NGOs, and the participants of this study, who generously shared their insights with me by sparing their valuable time.

I want to thank all those who have helped, in big or small ways, to complete my research work.

I doubt that I would have embarked on this doctoral sojourn without the unwavering support of my family. I extend my deepest gratitude to my wife, Dr. Smita Jain, and my son, Kabeer Jay, for being my unwavering sources of inspiration and encouragement throughout my research journey.

Jay Nigam
Research Scholar
SAP Id: 500057676
School of Business,
University of Petroleum and Energy Studies

Date: 18th December 2023

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CADWM	Command Area Development & Water Management
CES	Comprehensive Efficiency Scores
CPR	Common Pool Resource
CWC	Central Water Commission
d_LS	Squared Euclidean Distance
d_G	Geodesic Distance
DEA	Data Envelopment Analysis
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DMUs	Decision-Making Units
EXPROM	Extension of the PROMETHEE
GCA	Gross Command Area
GDP	Gross Domestic Product
GVA	Gross Value Added
HTMT	Heterotrait Monotrait
IAD	Institutional Analysis and Devvelopment
IP	Input-oriented model
IMT	Irrigation Management Transfer
MATLAB	Matrix Laboratory
MCDM	Multi-Criteria Decision-Making
NFI	Normal Fit Index
O&M	Operation and Maintenance
OP	Output-oriented model
PIM	Participatory Irrigation Management
PLS	Partial Least Square
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
SBM	Slack-based method

SBM	Slack-based model
SEM	Structural Equation Modelling
SFA	Suitability, Feasibility, and Acceptability
SRMR	Standardised Root Mean Square Residual
VIF	Variance Inflation Factors
VRS	Variable Returns to Scale
VRSIP	Variable Returns to Scale–Input-oriented model
VRSOP	Variable Returns to Scale–Output-oriented model
WUA	Water Users' Association

CHAPTER 1

INTRODUCTION

Chapter 1
Introduction

1.1. Background

Globally, approximately 2.4 billion individuals rely on irrigated farming to sustain their food supply and livelihoods. With an annual population growth of 90 million people, It is expected that the global population will reach eight billion by 2025. With only 17 percentage of the world's total cultivated land area being used, irrigation is essential to allow the production of approximately 40% of the world's food (Döll & Siebert, 2002). The publication "Economic Survey 2022-23" by the Indian Government's Ministry of Finance, indicated that in 2022, India achieved a significant milestone during its 75th year of independence by ascending to the position of the world's fifth-largest economy when measured in current U.S. dollars. As of March 2023, India’s anticipated nominal GDP is projected to be around $3.5 trillion, underscoring the country's impressive economic growth and global standing. This economic achievement reflects India's continued development and emergence as a prominent player in the international economic stage. The agricultural industry functions as the main provider of employment, engaging 54.6 percent of the nation’s workforce. Additionally, this sector makes a substantial contribution to the country's GDP, accounting for 18.6 percent of the overall economic output. (Annual Report 2022-23, DAFW, Govt of India). Only 46% of India's cropped land is irrigated, yet this contributes to approximately 56% of agricultural output, and 60% of the nation's food grain production originates from areas with irrigation (Nagdev, 2012, p. 138). Annual rainfall changes account for a sizable portion of the annual variance in India's GDP growth during the previous century. India, accounting for around 17% of humanity, has access to a mere 4% of the global freshwater resources. In addition, the allocation of water resources within a nation is uneven. In accordance with international standards, a nation is categorised as water-stressed when the per capita water availability surpasses 1700 cubic meters, and it is labelled as water-scarce if it falls below 1000 cubic meters. India now has a water shortage, with just 1544 cubic metres of water available per person, and is moving toward becoming water-scarce (MOWRRD&GR, 2019). Although the country's limited water resources face growing pressure, this scarcity is not evident in water utilization patterns. India uses 2-4 times more water than other significant agricultural nations, such as China, Brazil, and the USA, to yield a single unit of primary food crops (Hoekstra & Chapagain, 2008). This indicates that if India were to achieve the water use efficiency levels seen in these countries, there is the potential to conserve a minimum of 50% of the water presently utilised for irrigation. Currently, the domestic and industrial sectors each use approximately 12% and 4% of the entire amount of water that is available, with irrigation using approximately 84% of the total amount. It is projected that irrigation will continue to be the primary consumer of water. To address this situation and expand the irrigated area, boosting the efficiency of water use in agriculture and other industries is crucial. This will help conserve water resources. (NITI, 2015).

The efficiency of agriculture is significantly influenced by the crucial role of water, whether it is supplied through irrigation or received as rainfall. This is especially evident when considering improvements in agricultural productivity resulting from the increased utilization of various inputs such as irrigation, fertilisers, and pest control techniques. For instance, a study conducted among paddy farmers in Andhra Pradesh highlighted that the absence of reliable irrigation leads to reduced fertiliser usage, and ultimately, lower crop yields (Raju, 2004). Similarly, the ability to engage in entrepreneurial agricultural activities is closely linked to water resources. Irrigation is a key component of integrated farm management in modern agriculture. It is important to evaluate agricultural efficiency based on Total Factor Productivity criteria, which account for disparities in crop yields and technological efficiencies across different crops and farms (NITI, 2017).

India embarked on an ambitious mission to double the average income of agricultural households by the year 2022, marking the 75th year of its independence. This formidable endeavor, which necessitates a significantly accelerated annual growth rate of 10.4%, calls for robust measures to leverage all potential avenues for income growth among farmers, both within and beyond the agricultural sector. To address these challenges successfully, effective water management techniques must be implemented for available surface and groundwater resources. Optimal utilization of these water resources is crucial for meeting the objectives of this

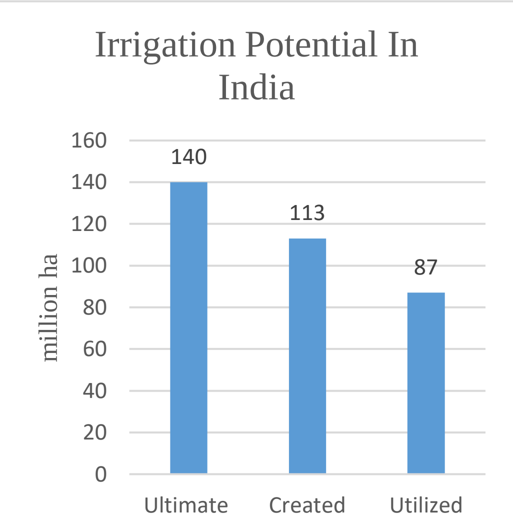


Figure 1.1 : Irrigation Potential in India

ambitious goal. Agriculture depends heavily on water, and the effective management of this resource is essential for achieving the desired income growth for farming households. This underscores the importance of sustainable and judicious water use in the pursuit of agricultural and economic development (NITI 2017). The primary challenge confronting irrigated agriculture is finding ways to enhance food production with reduced water usage, while simultaneously increasing farmers' income. Over the years, India's irrigation infrastructure has increased significantly. Four significant gaps must be addressed in the irrigation industry. These include (a) disparity in irrigation efficiency, (b) variations in the cultivated area, (c) differences in soil fertility, and (d) variations in productivity. The area gap is addressed with the focus of these four gaps (Hanumantha Rao, 2002). The distance between a project's potential for irrigation and the actual irrigation is known as the "area gap." From the pre-plan era to the completion of the 11th Plan, the combined irrigation potential created (IPC) from all irrigation projects increased significantly. This rose from 22.6 million hectares to 113 million hectares. The opportunity for additional this irrigation potential only accounts for 81% of India's overall irrigation potential, which limits the expansion of large-scale irrigation infrastructure, which is estimated to be 140 million hectare. Thus, enhancing the use of the current irrigation potential must be given top attention. Figure 1.1 illustrates the country's irrigation potential. Irrigation Potential Utilised (IPU) is now at 77% of the IPC (113 million hectares), or 87 million hectares.

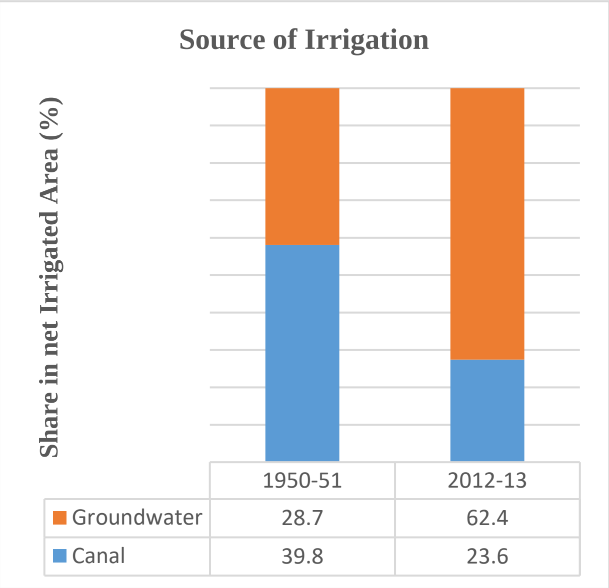


Figure 1.2 : Source of Irrigation

The irrigation sources in India have changed significantly over time. Between 1950-1951 and 2012-2013, groundwater usage for irrigation increased notably from 28.7% to 62.4%, while the percentage of irrigated land served by canals dropped from 39.8% to 23.6%, as indicated in Figure 1.2. This change was due to the irrigation's increased dependability and efficiency, which usually attains irrigation efficiency levels ranging from 70-80%, in contrast to canal irrigation, which ranges from 25-45%. Although groundwater has been shown to be a beneficial resource for increasing irrigation, its unrestricted usage, especially owing to the growth of tube wells, has generated sustainability issues. Initiated in the fiscal year 1973–74, the Command Area Development Programme seeks to close the gap in Irrigation Potential Created (IPC) and actual irrigation potential utilization (IPU). However, the program faced challenges, including a shortage of skilled manpower and dearth of non-plan funds for irrigation departments, which contribute to the under exploitation of the generated irrigation potential. (NITI, 2015).

The irrigation sector in India faces several significant challenges:

- Low Irrigation Efficiency: The efficiency of irrigation systems in India is relatively low, typically ranging from 25% to 45%. This means that a significant amount of water intended for irrigation is lost or is not effectively used in the process.
- Uncontrolled Water Delivery: There are issues with unregulated water delivery that can lead to uneven distribution and inefficient utilization of water resources.
- Tail-End Water Deprivation: Tail-end areas often suffer from water scarcity or deprivation, as they receive less water than areas closer to the source. This inequality can negatively affect agriculture in these regions.
- Low-Cost Recovery: The cost recovery for irrigation services is inadequate, with a per-hectare cost of Rs. 50 against the operation and maintenance requirement of Rs. 250 per hectare (Vaidyanathan Committee Report 1991). This means that the revenue generated from users is insufficient to cover the expenses required to effectively maintain and operate irrigation systems.
- Poor Percentage Recovery via Tariffs: The proportion of working costs for irrigation projects that are recovered through irrigation water rates, or "gross receipts," has historically been low across the board. It has ranged from less than 20% to less than 30%. The inability to recover costs hampers the sustainability and upkeep of the irrigation infrastructure.
- Inadequate Maintenance: There lack of proper maintenance of irrigation infrastructure, causing physical buildings, seepage losses, siltation, waterlogging, and soil salinity problems.
- Under-Utilization of Created Potential: Despite the substantial irrigation potential created (IPC), which stands at 113 million hectares, only approximately 77% of this potential is utilised. This underutilization reflects the challenges in effectively harnessing available resources for agricultural purposes.

Addressing these issues is essential for improving agricultural productivity, increasing water use efficiency, and securing long-term and environmentally responsible management of water resources in India's irrigation sector, as explained in Figure 1.3. These problems result from improper management of irrigation infrastructure. The following are some of the main difficulties in managing irrigation systems.

- Inequitable Water Distribution and Service Quality: Uneven distribution of water resources and inadequate service quality leads to reduced agricultural yields and incomes for farmers. This disparity can create economic and social inequities within farming communities.
- Inefficient Water Use and Long-Term Environmental Consequences: Ineffective water management practices result in inefficiencies and waste, which not only impacts crop yields and income but also has long-term environmental consequences. Excessive water use can lead to groundwater depletion and other environmental issues.
- Institutional Constraints and Lack of Farmer Engagement: Institutional limitations, including highly centralised structures and top-down approaches by irrigation departments, hinder their ability to establish effective communication and collaboration with farmers. This lack of engagement makes it challenging to address the needs of agricultural communities.
- Inadequate financial resources for O&M: The financial constraint can result in the deterioration of infrastructure, thereby negatively impacting agricultural productivity. The impact of inadequate funding allocated for O&M of irrigation systems, compounded by existing water pricing policies and subsidies for irrigation water, is apparent.
- Deteriorating Public Irrigation Systems: The poor condition of government-owned irrigation systems is due to a lack of coordination between agricultural and irrigation departments. This lack of coordination affects planning and maintenance. Also, there's often no clear connection between the quality of irrigation services, the revenue earned, and incentives for maintenance staff.

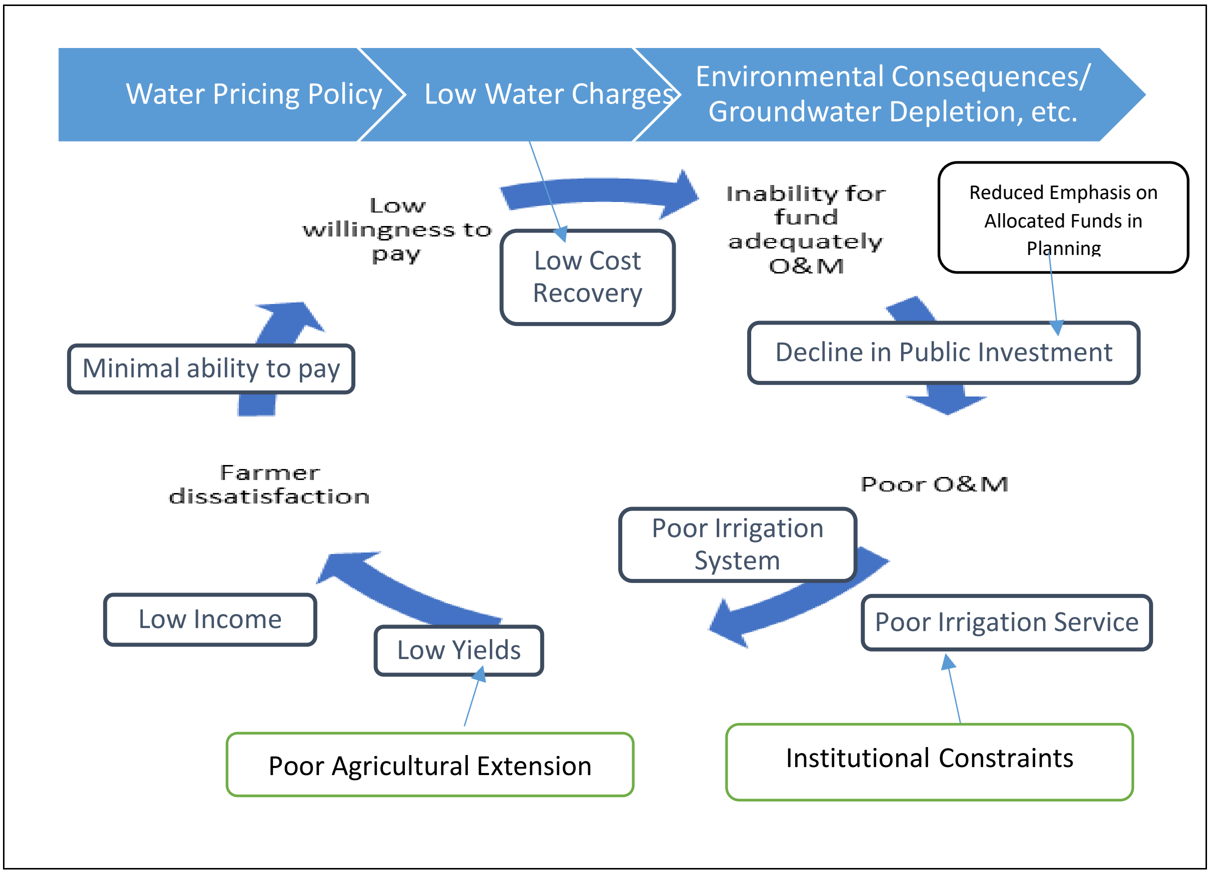


Figure 1.3 : The Vicious Circle in Indian Irrigation

Source: World Bank (1999)

1.2. Business Problem

Water is a vital resource for maintaining life, and in India, guaranteeing its sustainable usage and efficient management has become a major concern. Due to a growing population, expanding urban areas, fast industrialization, and the concurrent need to increase agricultural output, the nation is facing increasing problems. Owing to these factors, conflicting demands for water supplies have been created. Inadequate management of the existing infrastructure is to blame many of the problems with Indian irrigation systems. An inadequate water quantity within the irrigation system leads to reduced agricultural productivity. The inefficient timing of water delivery also results in decreased productivity. Uneven distribution of irrigation water, particularly disadvantaged farmers at the tail end of canals, leads to productivity loss. Poor water flow monitoring contributes to overall system inefficiency, causing production declines, user dissatisfaction, and lower water charge collection. A lack of coordination with the irrigation department affects the water charge collection and proper system operation and maintenance. A low water charge collection results in insufficient system maintenance, user dissatisfaction, production losses, and decreased revenue. The inability to address conflicts between Water User Associations (WUAs) and their members results in operational inefficiencies in the system, reducing water charge collections, causing asset and capital losses, and negatively impacting production. Finally, poor operation and maintenance result in capital and asset losses, further reducing the system's effectiveness. These challenges highlight the crucial role of effective irrigation management in sustaining agricultural productivity and production. Collectively, these flaws lead to poor irrigation efficiency in canal-irrigation systems. The shortcomings and resulting consequences are outlined in Table 1.1.

Table 1.1: Deficiencies and its Impacts of Canal Irrigation

Type of deficiency	Impact
Inadequate water quantity in the irrigation system	Reduced productivity and production
Timeliness inefficiencies in water flow	Reduced productivity and production
Inequitable distribution of irrigation water	Deprivation of irrigation water for less powerful farmers at the tail end, resulting in productivity and production losses
Water flow in the irrigation system is not adequately monitored	The irrigation system as a whole is inefficient, resulting in lost productivity, unsatisfied users, and poor water fee collections.
Cooperation issues with the irrigation department	Low water fee collections and insufficient irrigation system maintenance and repair
Low collection of water charges	Insufficient maintenance, poor operation of the irrigation system, user dissatisfaction, production loss, and inadequate collection of water charges
Inability to resolve disputes within WUAs	Overall inefficiency of the irrigation system, leading to low collection of water charges, asset loss, capital loss, and production loss
The irrigation system is poorly maintained and operated.	Capital loss and asset loss

In India, the government is mainly responsible for maintaining and managing irrigation systems. However, their effectiveness depends on having enough money to run them well. Even though public funds have been used to build extensive water infrastructure, it has been hard to get the most out of these projects because of a lack of money. There's a growing understanding that the general public should not have to bear the burden of running and managing these systems. Instead, the system should be able to make enough money from the users to cover its costs. However, in reality, the money collected is often not enough to cover the everyday costs of running the systems. In India, the 2012 National Water Policy Statement proposes the implementation of water charges for different types of water usage. These charges are intended to cover not only the initial Maintenance and Operation expenses but also a portion of the Capital Costs associated with providing water services. Enforcing water rates is vital for controlling water consumption and ensuring that irrigation systems are managed efficiently and effectively. Examining the financial facets of medium and major Irrigation Projects in India between 2000-01 and 2017-18 unveils notable patterns. Over this timeframe, there was a consistent rise in Capital Expenditure, going from Rs. 6821.63 crores in 2000-01 to Rs. 61782.18 crores in 2017-18 for these projects, as depicted in Figure 1.4. Similarly, Annual Working Expenses grew substantially, rising from Rs. 8762.42 crore in 2000-01 to Rs. 19265.04 crore in 2017-18. However, during the same timeframe, Annual Gross Receipts did not exhibit a corresponding increase. This financial analysis highlights a concerning issue: an unhealthy and negative gap between Annual Gross Receipts and Annual Working Expenses. In 2000-01, this gap was Rs. 8008.93 crore, and by 2013-14, it had significantly expanded to a staggering Rs. 17516.65 crore, as detailed in Table 1.2 (CWC, 2020).

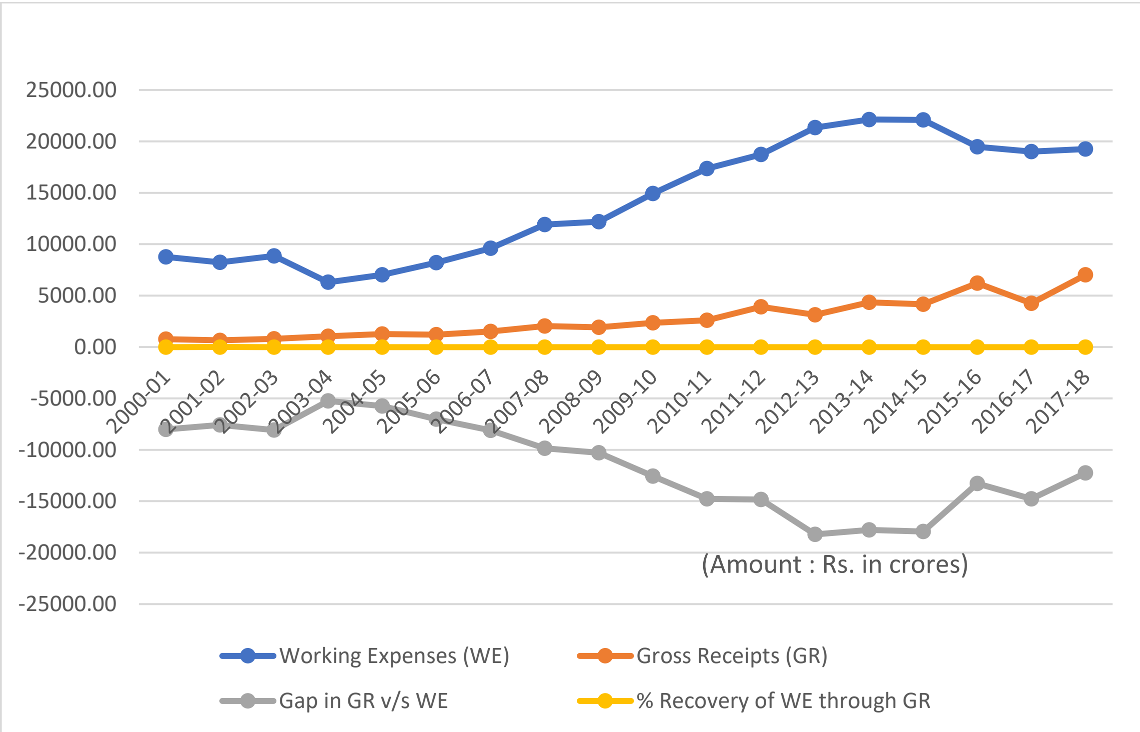


Figure 1.4 : Trends in Capital Outlay, Expenses, and Receipts Across India

Table 1.2 : Major and Medium Irrigation Projects' Financial Aspects in India from 2000–01 to 2017-18

(Amounts in Rs. in Crore)

Sl. No .	Year	Capital Outlay		Working Expenses (WE)	Total Expenditure	Gross Receipts (GR)	% Recovery of WE through GR	Gap in GR v/s WE
		During the year	At the end of the year					
1	2	3	4	5	6=(3+5)	7	8 = (7/5) X 100	9=(7-5)
1	2000-01	6821.63	78197.22	8762.42	15584.05	753.52	8.60%	-8008.90
2	2001-02	7649.38	85846.70	8239.19	15888.56	652.25	7.92%	-7586.94
3	2002-03	10161.31	96007.86	8845.90	19007.21	783.39	8.86%	-8062.51
4	2003-04	14463.44	110472.71	6293.60	20757.04	1047.60	16.65%	-5246.00
5	2004-05	17652.23	128444.65	7018.31	24670.55	1264.15	18.01%	-5754.16
6	2005-06	21964.79	150409.65	8216.06	30180.85	1194.70	14.54%	-7021.35
7	2006-07	26542.23	168979.77	9604.43	36146.66	1504.66	15.67%	-8099.77
8	2007-08	30879.23	199861.52	11898.88	42778.11	2044.92	17.19%	-9853.96
9	2008-09	36230.56	236092.07	12196.86	48427.41	1903.97	15.61%	-10292.89
10	2009-10	32074.86	268164.22	14920.92	46995.78	2351.11	15.76%	-12569.81
11	2010-11	32303.61	300464.06	17363.58	49667.19	2597.52	14.96%	-14766.05
12	2011-12	33895.28	334359.04	18720.10	52615.38	3892.87	20.80%	-14827.23
13	2012-13	36097.64	370908.34	21348.87	57446.51	3128.30	14.65%	-18220.57
14	2013-14	36666.20	407574.54	22126.76	58792.96	4348.74	19.65%	-17778.02
15	2014-15	38535.84	449110.29	22097.82	60633.66	4155.10	18.80%	-17942.72
16	2015-16	50458.03	496704.51	19483.24	69941.27	6218.30	31.92%	-13264.94
17	2016-17	62015.20	557910.02	19005.66	81020.85	4243.95	22.33%	-14761.70
18	2017-18	61782.18	619692.20	19265.04	81047.21	7010.89	36.39%	-12254.15

Source: Financial Aspects of Irrigation Projects in India (CWC) December 2020.

Irrigation is essential for agricultural productivity because it has a significant impact on crop output, farm revenue, and the overall agricultural environment. These results are attained by increasing agricultural yield, promoting the growth of high-value cash crops, and increasing cropping intensity. In addition, irrigation serves as a catalyst, encouraging farmers to embrace contemporary farming methods and spend money on high-yield seed types, synthetic fertilisers, natural manures, and modern cultivation methods. It is crucial to remember that merely having irrigation infrastructure does not ensure greater production and agricultural profitability. Several crucial characteristics of irrigation services must be addressed to maximise yields in irrigated regions. These include ensuring that there is a timely and sufficient supply of water, matching water distribution to the various demands of crops at various growth stages, and promoting equitable water distribution regardless of the farm's position within the irrigation network, whether it is at the head, middle, or tail end, as well as whether its size is small or large.

There is widespread agreement that publicly managed irrigation systems frequently fail to achieve their maximum potential owing to a rigid and bureaucratic top-down approach, inadequate upkeep and modernization, substandard water service provision, and a deficit in transparency and accountability. In the last thirty years, two significant strategies, Participatory Irrigation Management (PIM) and Irrigation Management Transfer (IMT), have emerged. These approaches are designed to enhance agricultural productivity and farmers' income, while also guaranteeing the enduring financial and physical viability of irrigation systems. In numerous nations, governments, often with backing from major organizations like the Asian Development Bank (ADB) and the World Bank, have chosen to delegate the responsibility of overseeing irrigation systems to user groups. This approach is viewed as a practical solution for public agencies burdened by the significant financial demands of the irrigation sector. Irrigation Management Transfer (IMT) means shifting the control and responsibility for managing irrigation systems from the government to WUAs or private groups. In essence, IMT represents a shift towards more decentralised, participatory, and user-driven irrigation management with the goal of enhancing the effectiveness and long-term viability of irrigation systems and granting more influence to local stakeholders. It has the potential to lead to better resource allocation, increased accountability, and improved agricultural outcomes.

The main reason for promoting participation in irrigation is that when people are involved, they are more committed to ensuring water services are effective, which directly affects the profitability of their farming. Presently, there is a broad consensus that encouraging community involvement, especially through Water User Associations (WUAs), is essential and represents one of the most successful approaches for guaranteeing the enduring sustainability of irrigated agriculture. In the best-performing instances, WUAs demonstrated efficiency, accountability, and responsiveness. Several additional reasons support the promotion of Participatory Irrigation Management (PIM), as listed below (adapted from FAO, 2007):

i. Cost and Burden Reduction: PIM is expected to alleviate the financial burden, reduce staffing requirements, and address technical and management challenges typically faced by governments in irrigation management. By involving local stakeholders such as farmers, these responsibilities can be shared more effectively.

ii. Enhanced Agricultural Productivity: PIM can significantly enhance the agricultural productivity and economic viability of irrigation systems. This aligns with farmers' core concerns, which may not always be bureaucratic entities' primary focus. Farmers have a vested interest in managing irrigation systems to expand irrigated areas, increase cropping intensity, diversify crops, improve yields, and enhance economic return.

iii. Increased Farmer Investment: When farmers have a say in how irrigation services are managed, who provides them, and how much they cost, they are more likely to invest in the system. This is because they understand the system better and are more willing to contribute financially.

iv. Accountability and Efficiency: PIM, driven by farmer interests and results, can lead to better governance in irrigation management. Farmers' organizations can enhance accountability by ensuring more efficient and equitable water distribution, improved canal maintenance, and effective dispute resolution, all of which directly benefit the farming community.

v. Collective Action: The collective organization for managing irrigation not only improves water distribution but also establishes a basis for joint efforts in associated domains. This encompasses the adoption of contemporary agricultural techniques and effective management of resources. This becomes particularly crucial in regions with numerous marginal landholdings, where traditional farming practices may not be economically viable.

vi. Building Social Capital: The PIM process contributes to the development of social capital at a local level. Establishing Water User Associations (WUAs), imparting skills, nurturing leadership, and enhancing the capacity for collective action contribute to building stronger social bonds and the ability to address shared challenges effectively.

To provide effective and dependable services, WUAs must be financially independent, cost-effective, transparent, well-managed, and user-focused. The following are the main goals of establishing WUAs:

i. Targeted Investments in Canal Infrastructure: Increased farmer participation ensures that investments in canal infrastructure and other services related to irrigated agriculture are demand driven. This approach leads to more effective allocation of resources. Farmers, as the primary stakeholders, can identify and prioritise infrastructure needs based on their actual requirements and local conditions. Consequently, investments become more purposeful and yield improved results.

ii. Optimised Resource Utilization: Using water and land more effectively helps farmers produce more crops, leading to increased profits. When water and land are used optimally, crop yields are maximised, leading to increased profitability. This outcome aligns with the core objectives of both the farmers and irrigation authorities.

iii. Equitable Water Distribution: The Farmers' participation ensures that water is distributed equitably among all users, regardless of where they are situated in relation to the irrigation project's head reach, middle reach, or tail end. This equity in water distribution helps mitigate disparities and ensures that all farmers have access to the necessary water resources, thereby promoting fairness and sustainability in the system.

iv. Sustainability through Proper Maintenance: Effective farmer involvement in irrigation management enhances infrastructure sustainability This is achieved through better cost recovery mechanisms and improved financial performance. Farmers are more likely to pay for the system's upkeep and maintenance because they directly benefit from it, which eases the strain on government organizations and ensures the irrigation infrastructure's long-term survival.

According to the 2012 National Water Policy Statement, Water Users Associations (WUAs) have legal permission to collect and keep some of the water fees, control the volume or quantity of water allocated, and manage the maintenance of the distribution network in their area. WUAs are permitted to establish their own rates within parameters set by Water Regulatory Authorities.

A participatory approach to irrigation management is strongly emphasised by the reformed "Command Area Development & Water Management" (CADWM) Programme. The creation of Water User Associations (WUAs) is now a condition for receiving Central Assistance to the State. To support this strategy, new Participatory Irrigation Management (PIM) rules were created. In addition, for CADWM projects to be considered complete, the administration and control of irrigation systems must be transferred to water user associations. During the 2016-17 period, approximately 1232 WUAs were established in several states, including Punjab, Odisha, Maharashtra, Madhya Pradesh, Karnataka, Jammu and Kashmir, Gujarat, and Assam. In the subsequent year, 2017-18, 1370 WUAs were created in states such as Rajasthan, Punjab, Odisha, Manipur, Maharashtra, Karnataka, Jharkhand, Gujarat, Chhattisgarh, Bihar, and Assam. (MoWRRD & GR, 2019). This shift towards participatory management through WUAs signifies a fundamental change in irrigation governance. This approach encourages local water users to actively participate in decision-making, resource allocation, and maintenance. It promotes more efficient and equitable water management. Additionally, it aligns with broader goals such as sustainable agricultural development and effective water resource use.

Traditionally, the irrigation system has been owned by the government in large parts, notably surface irrigation. According to various assessment studies of large and medium irrigation systems, the water utilization efficiency in India is between 30 and 35 percent at the project level. The potential for irrigation is thought to increase by 10–15 million acres, with only a 5% increase in irrigation efficiency (MOWR, 2016). The performance of local water institutions significantly affects how effectively water is managed. Improving institutional restructuring is crucial to promote PIM and the formation of WUAs. The concepts of PIM and WUAs are underscored in the National Water Policy, which emphasises the active involvement of people at all levels and stages of irrigation projects. As of the most recent statistics available, there are a total of 56,539 WUAs responsible for overseeing approximately 13.16 million hectares of irrigated land. This indicates a significant opportunity for employing participatory methods in irrigation management. The success of this interactive strategy is vital and should be thoroughly assessed. It involves evaluating not only the number of WUAs established, but also their functionality, efficiency, and ability to engage local stakeholders effectively. Such an assessment will help gauge the extent to which participatory irrigation management has contributed to better water resource utilization, equitable distribution, and improved agricultural productivity. The success of these initiatives has far-reaching implications for sustainable water management and agricultural development. (Raising Agricultural Productivity and Making Farming Remunerative for Farmers, an Occasional Paper, NITI Aayog, 2015)

Cost Calculation:

India has a gross cropped area of 198.36 million hectares. Only 46% of India's cropped land is irrigated, yet this contributes to approximately 56% of agricultural output, and of the nation's food grain output originates from areas with irrigation (Nagdev, 2012, p. 138). Studies assessing medium and large irrigation systems in India found that the efficiency of water use at the project level is around 30 to 35 percent. According to estimates, the irrigation potential might expand by 10 to 15 million acres, even with a 5% increase in irrigation efficiency (MOWR 2016). Data on Agriculture and related sectors' share of the nation's total GVA at current prices are presented in Table 1.3, and the data on the Production of Food grains are given in Table 1.4.

Table 1.3 : Agriculture And Related Sectors' Share of the Nation's Total GVA at Current Prices

Items	Year			
	2014-15	2015-16*	2016-17#	2017-18@
Farming and related industries' GVA (Rs. in Crore)	2093612	2227533	2496358	2670147
Agriculture and related industries' percentage of the whole economy's GVA	18.2	17.7	17.9	17.2
Share of crops	11.2	10.6	10.6	10.0
Share of livestock	4.4	4.6	4.8	4.9
Share of forestry & logging	1.5	1.5	1.4	1.2
Share of fishing	1.0	1.1	1.1	1.1

Source: According to the press release on the provisional estimates of the annual national income for 2018–19 and the quarterly estimates of the GDP for the fourth quarter (Q4) of 2018–19, both of which were issued by the Central Statistics Office (CSO), Ministry of Statistics and Programme Implementation (MoSPI), on May 31, 2019. @ First Revised Estimates of National Income, Consumption Expenditure, Saving, and Capital Formation for 2017–18, published on January 31, 2019.

Table 1.4 : Production of Food Grains

2016–17	2017–18	2018–19
275.11 million tonne	285.01 million tonne	283.37 million tonne

Source: Department of Agriculture, Cooperation, and Farmers' Welfare, Government of India, 3rd AE of Production of Food Grains 2018–19.

Better governance and administration of India's irrigation systems, expected from successful implementation of PIM and IMT, would increase irrigation efficiency. This would unlock additional irrigation potential and lead to higher agricultural productivity per unit of land, mainly because of irrigation.

Drawing on the available data from 2017 from Table 1.3, we can assess the Gross Value Added (GVA) resulting from the incremental agricultural production attributed to the effective adoption of PIM and IMT in India. In essence, this calculation seeks to quantify the economic benefits derived from the successful implementation of these participatory irrigation strategies, which encompass improved water resource management, enhanced crop yields, and an overall positive impact on the agricultural sector's economic output. The following calculations/inferences were drawn from the information presented above.

A. Basic Information

a. GVA of agriculture and allied sectors = Rs.24,96,358 crore

b. Agriculture and related industries' percentage of the economy's overall GVA = 17.9 %

c. Crop share in the GVA of agriculture and related industries in the GVA of the entire economy = 10.6 %

d. Food grain production = 275.11 million tonne

e. Gross cropped area = 198.36 million ha

B. Gross Value Added from the Crops

= Rs. 24, 96,358 crore X (10.6/17.9) = Rs.14, 78,290 crore

[Calculated using the proportion of crops in the GVA of agricultural and related industries, B = a × (c/d)]

C. Agricultural Output per Irrigated Area

60% Production of food grains from an irrigated area = 60% of 275.11 = 165.07 million tonne

Irrigated area 46% of cropped area = 46% of 198.36 = 91.25 million ha

Production per unit of irrigated area = 165.07 / 91.25 = 1.81 tonne per ha

D. Production per Unit of Un-irrigated Area:

40% Food grain production from un-irrigated area = 40% of 275.11 = 110.04 million tonne

Un-irrigated area 54 % of cropped area = 54% of 198.36 = 107.11 million ha

Production per unit of un-irrigated area = 110.04 / 107.11 = 1.03 tonne per ha

E. Incremental Increase in Production Due to Irrigation

= 1.81 - 1.03 = 0.78 tonne per ha

F. Increase in Production Due to Additional Irrigation Potential.

The irrigation potential can be increased by 10–15 million hectares or approximately 12.5 million ha, assuming that successful PIM and IMT will lead to an improvement in irrigation efficiency of at least 5%. Increase in production due to additional irrigation potential.

= 12.5 million ha X 0.78 tonne per ha = 9.75 million tonne.

G. GVA Out of Incremental Production

= 9.75 million tonne X (Rs. 14, 78,290 crore /275.11 million tonne)

= Rs.52, 391 crore per year.

1.3. Problem Statement

Ineffective irrigation system management in India leads to below-average irrigation efficiency, which, in turn, causes a decline in agricultural productivity and production. These deficiencies encompass a range of issues such as inefficient water distribution, inadequate maintenance of irrigation infrastructure, and difficulties in resolving water-related disputes. These problems collectively lead to inefficient water use, uneven access to irrigation resources among farmers, and a failure to maximise the potential of agricultural land. Consequently, crop yields are lower than they could be, and the overall agricultural production falls short of its potential.

CHAPTER 2

LITERATURE REVIEW

Chapter 2
Literature Review

The study reviewed existing literature on Participatory Irrigation Management (PIM) and Irrigation Management Transfer (IMT) in India to identify business problems. This review was followed by another examination of the literature to determine if the identified issues had already been studied. The initial review suggested that the identified phenomenon had been researched a) but in different contexts b) differently from different perspectives, but none in India covered a holistic contextualised conceptual framework and a conceptual lens integrating all the major perspectives. Hence, a literature review of the major perspectives on this phenomenon was conducted.

2.1. Existing Studies

Agriculture plays a fundamental role in driving India's economic and social development, contributing 20.2% of GDP and employing 54.6% of the workforce, particularly in rural areas, where 68.9% of the population resides. Irrigated agriculture plays a crucial role in this scenario, providing the bulk (55%–65%) of the food grain production and a significant portion of commercial crop output. Investments in irrigation water management systems have brought tangible and intangible benefits to people nationwide. Developing and managing water resources are crucial for India's economic progress and social advancement. The predominant use of water is for irrigation purposes, making up more than 80% of its usage. (Agricultural Statistics at a Glance 2020, GoI). The potential for increased agricultural output in India hinges on strategies to enhance crop yields, cropping intensity (the frequency of cropping), and the diversification of crops towards higher-value varieties. Irrigation stands out as the primary driver of agricultural growth in the country, playing an indispensable role in ensuring future agricultural expansion. The overall agricultural output sees a contribution of over 55 percent from irrigated agriculture. Its effectiveness will significantly influence important development goals like economic growth, creating jobs, ensuring food security, and reducing poverty (Bhatia, 2006).

Water management in India is mostly controlled by the government, with agencies like irrigation departments, municipal bodies, and water boards overseeing the harnessing, regulation, and delivery of water. These government bodies not only manage water allocation and distribution but also set fees, influence crop patterns, and handle operation and maintenance (O&M) tasks. However, these large bureaucratic institutions have struggled to effectively manage water. They have not been able to maintain the extensive distribution networks, expand into unserved areas, ensure transparency, or guarantee a fair and efficient distribution of water (World Bank 2004, Briscoe 1992). Therefore, enhancing the management institutions and policies related to water services can help ensure fairer and more efficient distribution and use of available water among various users.

Various assessments indicate that grasping the policy direction is crucial when evaluating changes in the irrigation segment. In 2007, the World Bank found that the irrigation project might not be sustainable because the fees users paid were not enough to cover the costs of running and maintaining it. In 1997, the Andhra Pradesh government tried to give more control of irrigation to local committees, but these groups struggled financially because they couldn't raise enough money on their own. They relied heavily on World Bank funding, but even then, it is argued that a significant portion of the funds (about 80%) went towards debt servicing rather than operational needs (Jairath, 2001). In its 2007 report, the World Bank rated the overall outcome of the irrigation sector's development objective as "unsatisfactory." The failure in the irrigation sector worsened the agrarian crisis in Andhra Pradesh, a state known for having one of the highest incidents of farmer suicides (Kumar, 2017).

The concept of PIM introduced during planned development gained significant attention in 1997 with the enactment of The Andhra Pradesh Farmers Management of Irrigation Systems Act by the Government of Andhra Pradesh. This act became a standard for other states to follow. However, despite these efforts, the actual implementation of PIM has not been satisfactory. Only 8.68 million hectares of land are covered by PIM, with 41,247 associations formed, which is a small fraction considering that about 58 million hectares of land are irrigated in India. Even when associations are formed, they are not always responsible for collecting water charges. In Andhra Pradesh, there are 10,000 WUAs, which cover the total surface irrigated area of 4.8 million hectares. The WUAs were set up with clear tasks, duties, and authority. The revenue department collects water fees, and the Collector divides 50% among the WUAs and the rest goes to the state government. In Bihar, WUAs can collect charges and keep 70% of the amount, but they currently achieve only about 35% efficiency in collection, far below the expected full collection from their members. (Shekhar, 2006).

Early impact evaluations of these reforms, conducted mostly two to four years after the formation of WUAs, have shown encouraging results. A preliminary evaluation by the Operations Evaluation Department (OED) in 1999 indicated positive outcomes within two years of the establishment of WUAs. It noted improvements in irrigated areas, more equitable water distribution, and savings in maintenance and rehabilitation efforts. Another study by Van Koppen et al. (2002) found enhanced water access and a slight increase in irrigated areas, while there weren't any major changes in the types of crops grown, crop yields, or incomes, various other studies on the shift of management to WUAs in Andhra Pradesh also indicate positive early impacts. These include improvements in the irrigation system, expanded irrigated areas, more equitable water distribution, enhanced water availability in tail-end areas, increased crop yields, lower disputes over water allocation, more transparency and, an increase in land values (Rao et al. 2002, Raj 2002, Pangare 2002).

As governments encountered challenges in managing irrigation systems, involving users in their development became crucial. This shift, known as Participatory Irrigation Management (PIM), emerged as a key component of irrigation sector reforms. The formation and empowerment of WUAs have received significant support globally (Peter, 2004).

Governments worldwide are facing fiscal constraints, prompting a shift towards involving stakeholders more in management. As literacy rates rise and farmers become more knowledgeable and proactive, there is a growing push for participatory approaches. However, implementing Participatory Irrigation Management (PIM) is challenging. Devolving management to farmers is complex, and experiences with such programs have varied. In many cases, farmers expect the government to provide water, so any shift towards more farmer involvement represents a major shift in the relationship between society and the state. Success in PIM largely hinges on strong Water Users Associations (WUAs) taking over management responsibilities. Otherwise, if the state withdraws without effective WUAs in place, it can create a gap and reduce investment in irrigation systems (Meinzen-Dick, 2000).

With limited supplies and shifting demands, we require management strategy that improves efficiency and allows water to be moved voluntarily to meet changing societal demands. This entails a system where water can be transferred based on changing demands, done willingly rather than mandated. India needs to establish revamped public water management systems that prioritize the following principles:

i. Developing a comprehensive set of rules and incentives, such as water entitlements, contracts, and pricing, to govern water usage;
ii. Encouraging competition in the irrigation and water services market;
iii. Empowering users with clear and enforceable water rights;
iv. Promoting transparency and ending the practice of secrecy in water management.
v. Establishing a participatory and incentive-based approach to regulating services and water resources;
vi. Securing Financial Sustainability in the Water Sector;
vii. Investing significantly in training of water resource professionals with diverse skills;
viii. Giving high priority to environmental conservation in water management; and
ix. Giving priority to local communities as the main beneficiaries of water projects.

(The World Bank, 2007).

Several studies conducted by researchers in India have aimed to assess the performance of Water User Associations (WUAs) across different states. However, drawing broad conclusions about the impacts of WUAs from these studies is challenging due to several factors. These factors include the conditions before responsibilities were transferred to Water User Associations (WUAs), how much users were involved, the scale and specifics of Irrigation Management Transfer (IMT), the actual transfer mechanism, the laws governing these transfers, how costs were split between irrigation departments and users, the outside help given in forming and running WUAs, the time elapsed between the transfer and impact studies, the approaches used for data collection and impact assessment, and the potential biases of the researchers conducting the evaluation.

Jairath (2002) critically assessed the reported benefits of PIM in Andhra Pradesh. While government figures and some researchers claimed overall benefits, Jairath cautioned against certain assumptions. For instance, improvements in irrigated areas could potentially compromise the quality of irrigation, leading to inadequate water supply. Additionally, any increase in irrigated area may be unsustainable. Claims of increased crop yields were also questioned, with Jairath arguing that crop yield changes are influenced by multiple factors, not solely PIM. Field data from two canal sites indicated no increasing trend in rice yields. Although PIM can enhance control over water use, claims of improved equity in water distribution have not been substantiated by field investigations. The success of Water User Associations (WUAs) in executing maintenance and repair activities using government funds has been notable, but their effectiveness in regulating water distribution equitably has been weak. This could hinder their ability to collect water fees and may impede their long-term viability as organizations (Malik, 2006).

The assessment in a study by Pant (2000), although not the result of a widespread database, shows WUAs in a favourable light. WUAs are now generating higher revenue from users, and most WUAs are running at a profit. This increase in profit might have started because of subsidies for managing the organization. But even after these subsidies stopped, WUAs that have been around for more than three years are still making a profit.

A study conducted over two years from 1994 to 1996 by the International Irrigation Management Institute (IIMI) in Colombo and the Indian Institute of Management (IIM) in Ahmedabad examined 12 Irrigation Management Transfers (IMTs) in canal irrigation systems. The study focused on IMT policies and activities in six Indian states: Tamil Nadu, Kerala, Maharashtra, Gujarat, Haryana, and Bihar. The evaluation identified high-performing WUAs in Maharashtra and Tamil Nadu, while some WUAs in Gujarat and Tamil Nadu were rated as poor performers. Average performance was observed in two Gujarat WUAs. Financial analysis showed that all but one of the sampled WUAs were profitable in at least half of the studied years. Most WUAs charged farmers higher rates for water than the state did, but full fee collection was not always achieved. Maintenance costs exceeded state grants but represented While maintenance costs exceeded state grants, they accounted for less than 5% of the net income from high-value crops within the jurisdiction of the WUAs. (Brewer 2000).

Ganapathy et al. (2008) analysed the progression of PIM. In addition, this study attempted to determine the limitations in the operation of PIM. The study emphasised that a serious contribution from farmers and training programs for WALMI is essential for the successful functioning of PIM. From the results of the research, it was clear that there was not any significant difference between the functional and non-functional Water Users' Committees (WUCs) relating to socio-economic position, resource usage effectiveness and water management practices. The reason for the lack of finances in WUCs was that farmers were unconcerned about paying charges for water on a regular basis. Accordingly, this study emphasised that this indifference should be addressed by means of an efficient training program for farmers. The study recommended that various training and exposure trips on several aspects of PIM must be planned for farmers, together with authorised persons.

The current focus of the Indian government on water management could benefit from further attention to key aspects such as involving stakeholders in decision-making, creating incentives, ensuring equitable water use, promoting transparency, engaging the private sector, fostering competition, enhancing accountability, securing adequate funding, and safeguarding the environment. This lack of focus has led to problems in providing public irrigation and water supply services. People pay very little for water, which means there's not enough money for running things properly. This has led to a lot of corruption. There are too many staff compared to other countries, and most money is spent on running things, not fixing or improving them. There's a big backlog of work that needs to be done. The government's approach seems to be to build things, then ignore them until they need to be rebuilt, reflecting a philosophy of build-neglect-rebuild (Mohanty, 2005).

Mukherji et al. (2009) observed that despite years of implementation and numerous case studies, there is limited evidence on the impact of IMT and PIM. Their study highlights the need for more research in this area. They conducted a systematic review of 108 case studies of IMT/PIM from 20 Asian countries, focusing on those post-1994 through extensive bibliographic searches. Each case study was analyzed based on various parameters, including location, technical specifications, socio-economic and agricultural indicators, and implementation-related factors. The majority of cases (64%) were classified as failures. The review revealed that successful collaborative action in public irrigation systems is highly context-specific and requires intensive processes, making replication difficult and costly. The authors argue that the lack of replicability is not due to poor implementation or enabling conditions, but rather to conceptual weaknesses in the IMT model itself. So, they recommend a new approach to managing publicly owned irrigation systems.

2.1.1. Irrigation Water Use Efficiency and Agricultural Performance

In India, a significant challenge facing water resource infrastructure is its inefficiency and the resulting losses within the system. This issue is widespread across various sectors including agriculture, industry, and domestic use. Rough estimates suggest that enhancing efficiency could potentially reduce current losses by as much as 40 percent. However, efficient water management practices remain more of an exception than a norm (Varughese, 2006).

In India, challenges in water management arise from both physical, financial and institutional constraints. Physically, there is inadequate maintenance leading to the deterioration of surface systems and their ineffective control structures. Institutionally, the public sector manages water without being accountable to users like farmers. The correlation among the irrigation service offered, income, costs, and staff incentives is not well-synchronized. State Irrigation Departments (IDs) have maintained their traditional government structure without much alteration. Financially, low water charges require continual state government subsidies for operations and maintenance, with most funds going towards staff salaries rather than actual maintenance. Incentives for efficient water use are lacking, with irrigation water charges based on area rather than volume (World Bank, 2006).

During the planning stages, irrigation efficiency is typically assumed to be around 55 to 60%, but actual efficiency on the ground is often closer to 30% or even lower. There is a dearth of scientific research on the irrigation efficiency of major irrigation systems. The Planning Commission commissioned two studies by a consultancy services agency called WAPCOS Ltd. on the Upper Ganga Canal and the Western Yamuna Canal in Uttar Pradesh and Haryana, respectively. The studies showed overall efficiencies of around 45 to 48%, which may be somewhat high. Another recent study, based on potential evapotranspiration and irrigation withdrawals, looked at how well irrigation works in India. They found that, on average, the efficiency of irrigation was about 37.7%. The efficiencies ranged from 26 to 27% for some basins (Cauvery, Godavari, Krishna, Mahanadi) and 43 to 47% for others (Indus, Ganga). India's low irrigation efficiencies stem from various factors, including low water rates, insufficient maintenance of canal systems, the absence of scheduled water supply, and the implicit "use it or lose it" policy. An estimated 20 to 25 million hectares of irrigation networks need modernization because they have been neglected and not properly maintained (Shekhar, 2006).

The relationship between cropping intensity and the percentage of gross area irrigated is a crucial factor in agricultural productivity and income generation. Cropping intensity, which measures the intensity of land use for crop production, is influenced by the extent of irrigation available to farmers. Several studies have shown a clear and positive link between these two variables. Narain and Roy (1980) found that an increase in net irrigated area led to a corresponding increase in cropping intensity. This indicates that farmers tend to cultivate more intensely when they have access to irrigation facilities. Moreover, they noted that smallholders are more likely to maximize their land use efficiency when irrigation is available. However, Irrigation's complementary role reduced its impact on cropping intensity in areas with higher rainfall. Dhawan (1989) also observed a positive relationship between gross irrigated area and overall crop intensity. This suggests that as the percentage of land under irrigation increases, farmers tend to intensify their cropping patterns. The significance of irrigation in enhancing agricultural productivity is further supported by the data showing that the overall agricultural output sees a contribution of over 55 percent from irrigated agriculture (Bhatia, 2006).

Research suggests that irrigation significantly boosts Total Factor Productivity (TFP), implying that it enhances productivity beyond its direct input value. However, this conclusion could be affected by limitations in the method of measurement of the value of the input, viz., irrigation (Evenson et al., 1999).

Irrigation significantly affects India's economic progress and social advancement. Movement of labour to regions with better prospects has reduced inequalities in rainfed agriculture. Moreover, India's agricultural pricing policy contributes to balancing regional development disparities caused by the concentration of irrigation in specific areas. The policy involves buying surplus wheat from regions like the northwest and rice from the south. These commodities are then sold at fixed rates in urban and deficient rural areas. Two studies conducted by Dhawan (1988) and Rao et al. (1988) investigated the impact of irrigation on farm output stability and its protective function during droughts found that irrigated farming significantly reduces output instability (Bhatia, 2006).

Although some inequalities in irrigation water allocation are unavoidable, especially when considering the distribution of land holdings, additional inequities arise from allocating water to farmers within a canal's command area. Factors such as the lack of appropriate institutions, unclear water distribution rules, poorly maintained distribution networks, and negligence or corruption among irrigation department staff contribute to these inequities. Recent studies in six major states, including Tamil Nadu, Orissa, Maharashtra, Karnataka, Haryana, and Gujarat, have revealed that deprivation of water is not limited to farmers towards the tail end, i.e., terminal point of the canal; farmers at the head and middle sections also face water scarcity. This problem persists regardless of whether water is scarce or surplus. For example, in Gujarat, both the Sabarmati and Mahi projects exhibit significant water deprivation among farmers. The table presented below illustrates the level of water deprivation in Gujarat, examining two contrasting scenarios: the Sabarmati project, characterized by water deficiency, and the Mahi project, characterized by water surplus.

Table 2.1 : Extent of Tail-enders and Others Deprived

Different Parts of the Main Canal	Tail-enders (% of the Command Area)		Other Deprived (% of the Command Area)	
	Sabarmati (Dharoi)	Mahi	Sabarmati (Dharoi)	Mahi
Head (Initial reach)	30	8	28	28
Middle	36	18	24	56
Tail (Terminal reach)	41	4	19	10
Overall	37	7	22	20

(Malik R.P.S., 2006)

2.1.2 Definition of Irrigation Efficiency

The efficiency of canal irrigation can vary in definition based on the perspective and objectives of the analysis. Technically, is a measure of how well the water supplied for irrigation is used for crop growth. Some definitions may include losses due to evaporation, seepage, or runoff as part of the input or output, whereas others may exclude them. Some definitions may also distinguish between different types of canal irrigation efficiency, such as conveyance efficiency, application efficiency, or crop water use efficiency, depending on the level of analysis and scope of the irrigation system. For this study, based on the stakeholder and expert consultations, the canal irrigation efficiency is taken to mean the timely water availability in adequate quantity, and the increase in irrigated area reduced the cost of maintenance.

2.1.3. Involving Users in Irrigation Management

The management of complete irrigation systems in developing nations, including India, is the responsibility of irrigation departments, yet they often fall short in ensuring equitable distribution and efficiency. Publicly managed irrigation sectors face a triple crisis encompassing financial, technical, and public perception issues (Mollinga, 1999). It is widely recognized that reforming these agencies alone is insufficient to enhance service delivery or system performance significantly. Various pilot initiatives have been undertaken to improve irrigation management, with outcomes varying based on local conditions. What we've learned suggests that a partnership between irrigation authorities and water stakeholders is more likely to improve irrigation services. (Shah et al., 2002). Consequently, there is a growing advocacy for user involvement in the irrigation water management as a central aspect of alternative management strategies. Both PIM and IMT have been proposed as solutions to address the shortcomings of publicly managed irrigation systems.

Investments in water resource infrastructure can lead to fair sharing of gains, but modifications to water utilization and distribution policies can also have significant impacts on economic growth and poverty alleviation. However, there is limited empirical evidence linking these policy changes to outcomes. In 1992, Mexico implemented a new water management law, granting users greater control and introducing tradable water rights. This change has had dramatic effects in some areas, including substantial reductions in aquifer pumping and changes from cultivating high-value crops by switching low-value crops and, each unit of water generating demand for more agricultural labour, creating opportunities for the poor (The World Bank, 1999).

India has made big investments in water infrastructure over the past five decades, but large-scale public sector operations often lack accountability and citizen ownership. This leads to neglect, financial losses, and environmental degradation due to inefficiencies and water losses. Despite a history of successful local water management, there has been a shift towards centralized, engineering-driven projects. The Constitution of India acknowledges water as a matter within the jurisdiction of the states, allowing for potential decentralization to local communities. The 73rd and 74th Amendments grant authority to Panchayats and urban local governments for the management of water resources, fostering ownership and payment for water use. Revisiting water ownership and rights, along with simplifying water transfer and reuse mechanisms, are crucial for effective water management (Varughese, 2006).

India does not have a comprehensive legal framework that fully defines water rights, but existing laws provide a foundation for some aspects of these rights. However, there is a need for additional changes to transition from informal, implicit, partial, and ambiguous arrangements to a more robust legal and institutional framework that supports ‘Water Rights and Entitlements’ crucial for effective water management. A thorough examination of the development and present state of water rights across various tiers, including local, sectoral, state, regional, and national levels is essential to understand the existing potential and the necessary modifications (Sleth, 2006).

2.1.4. Understanding PIM

There are multiple definitions of Participatory Irrigation Management (PIM). Vermillion (1997) describes PIM as "the involvement of irrigation users in all aspects and all levels of irrigation management." The term "involvement" encompasses a spectrum, from lighter forms like information sharing, consultation, and joint problem assessment, to more profound forms such as shared decision-making, collaboration, and full user control. "Users" in this context refer to those who utilize the water for irrigation. The World Bank uses the term "userism" to capture the core of PIM, emphasizing that it is management of the users, by the users, and for the users. PIM is closely linked to the concept of WUAs.

PIM encompasses all stages of an irrigation project, from inception and design through construction, oversight, funding, rule establishment, operation, upkeep, monitoring, and assessment. It applies to all levels of the irrigation system, including tertiary, secondary, and primary levels, as well as project levels and sector levels. WUAs can adopt diverse organizational structures and roles to meet local or regional needs. (Hooja and Joshi, 2000), as illustrated in Figure 2.1.

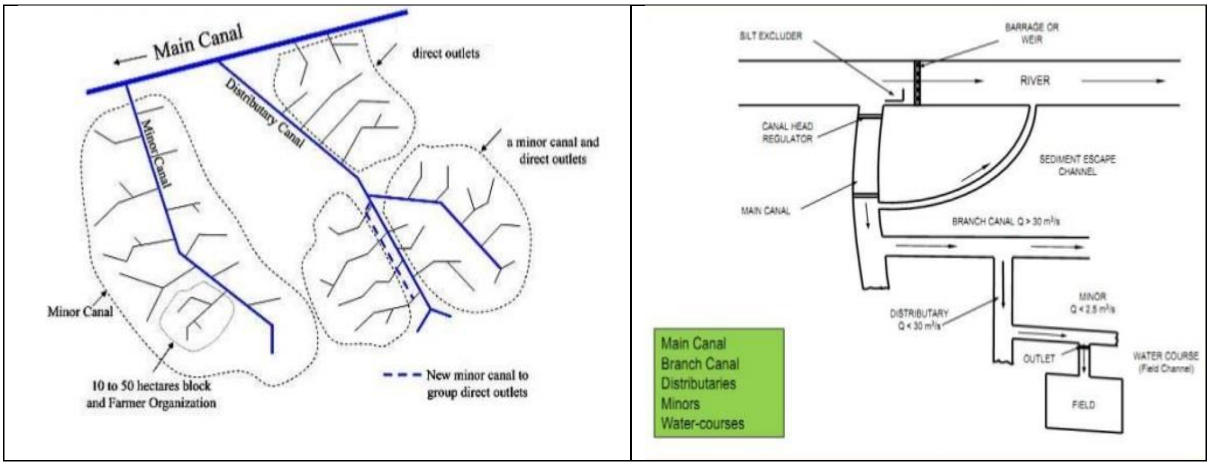


Figure 2.1: Distribution System for Canal Irrigation

PIM programs aim to enhance farmers' participation in management of irrigation system, as a supplement to or as a replacement for state involvement. Typically, these approaches result in some form of shared or cooperative management of irrigation systems. In such arrangements, the state tends to handle more tasks at higher system levels, while farmers' organizations take on more responsibilities at lower levels (Meinzen-Dick et al., 1997). Another perspective defines PIM as the involvement of farmers in managing at least one level above the canal outlet, along with all related issues concerning that watercourse. This management is typically executed through Water Users' Associations (WUAs) or similar informal groups. The organizational forms and functions of WUAs can vary based on regional or local requirements (Hooja and Joshi, 2000).

Participatory Irrigation Management (PIM) encompasses a range of changes, including reconfiguring control over water, redefining governance boundaries, and establishing new entities such as Water Users' Associations (WUAs). However, the extent and nature of these changes can vary significantly. This variation stems from the diverse functions that can be transferred to farmers, the degree to which these functions are transferred, and the desired organizational setup post-transfer. Water users can participate in irrigation management in many ways and at different levels. They can help with planning, design, operation, maintenance, and solving conflicts. When discussing the implementation of PIM, it generally involves a shift in the extent, manner, or intensity of user participation. This shift increases farmers' duties, responsibilities and decision-making powers in the processes of managing. (Groenfeldt and Svendsen, 2000).

The definition of participation in PIM is influenced by the context in which it is applied. Some view participation as a fundamental principle, while others see it as a practical approach or even an ultimate goal. The Learning Group on Participatory Development at the World Bank defines participation as "a process through which stakeholders influence and share control over development initiatives, and the decisions and resources which affect them" (The World Bank, 1995). Westergaard (1986) defines participation as a collective effort by previously marginalized groups and movements to strengthen control and effectively manage resources and institutions. However, it is widely acknowledged that in the context of government schemes, participation often boils down to either utilizing the provided services or contributing inputs to support the project (Smith, 1998). This kind of community participation may have the form but not the substance (citations from Dwivedi and Dwivedi, 2012).

2.1.5. Understanding IMT

Irrigation Management Transfer (IMT) involves shifting the control and decision-making power over irrigation O&M to local user groups or private organizations. This definition is wide and somewhat ambiguous. IMT can encompass various aspects, including the transfer of decision-making authority or governance, the ownership of infrastructure (often termed privatization), and the transfer of water rights from government control to WUAs. Alternatively, IMT may only involve assigning certain management responsibilities to water users, such as water distribution, maintenance of canal, and setting water levies, while the government retains final authority for granting approval over O&M plans and budgets (FAO, 1999).

Vermillion and Sagardoy (1999) characterize IMT as the reassignment of control and decision-making power regarding irrigation management from governmental bodies to non-governmental organizations (NGOs), including Water Users' Associations (WUAs). IMT can involve the complete or partial delegation of management functions, as well as full or partial authority. Its implementation can occur at various levels, such as distributary canal commands or entire irrigation systems. IMT is closely interlinked with the concept of Participatory Irrigation Management (PIM), with IMT being considered a component of PIM.

User participation in irrigation water management has historical roots and has been implemented in various forms such as PIM, WUAs, and IMT with mixed success rates globally. A World Bank review in 1989 highlighted successful cost recovery in projects where water management was entrusted to users, but the sustainability of these trends remains uncertain. While examples in countries like New Zealand, Mexico, the USA, and Turkey are often cited as successful, the effectiveness of these approaches in many developing countries is less certain (World Bank, 1990; Vermillion, 1997; Groenfeldt and Svendsen, 2000; Shah et al., 2002).

2.1.6. Functions of WUAs

At various levels, Water User Associations (WUAs) are anticipated to engage in the following activities:

i. Maintaining and repairing the irrigation systems within their operational jurisdiction;
ii. Distributing irrigation water to farmers;
iii. Collaborating with the irrigation authorities in estimating water demand and water charges collection;
iv. Dispute settlement among members and the WUAs; and
v. Overseeing irrigation water flow in the system.

(ADB 2008)

2.1.7. Benefits of WUAs

It is recognized that transferring authority and responsibilities for water resource management to local levels can encourage greater participation from water users. Decentralization and devolution of water resource management can enhance the involvement of water consumers in decision-making and investments. This is anticipated to improve management incentives and accountability, as well as enhance agricultural and economic productivity, and increase cost recovery. There are quite a few benefits of PIM and IMT. Some important benefits that can be achieved by transferring irrigation management to user groups are listed below (ADB 2008).

i. Shifting from a government-driven administration to a responsive, user-focused management approach.
ii. Decreasing the reliance on government personnel and resources in the irrigation sector, potentially offering an alternative for early-retiring government employees.
iii. Enhancing irrigation system upkeep and reducing the necessity for loan-funded rehabilitation projects.
iv. Facilitating farmers' transition to higher-value crops and the establishment of agri-business ventures through improved water services and the social capital of water user associations.
v. Increasing funds available for O&M by granting water users greater control over management and resources, enhancing incentives and accountability, and introducing new subsidies to encourage local investment.
vi. Creating incentives for preventive maintenance through a new partnership with the government, fostering group opportunities for more holistic water management, agricultural development, and marketing strategies.
vii. Fostering the empowerment of farmers by cultivating robust water users' associations that could potentially federate up to the level of an entire irrigation scheme.

Nearly all operational Water User Associations (WUAs) in various Indian states have recognized the advantages, including improved irrigation for tail-end areas, increased frequency of irrigations, higher crop productivity, and reduced water disputes. The expansion of irrigated areas, particularly in the tail-end sections, has seen an increase of about 20 percent. Additionally, better access to more frequent irrigation has led to yield improvements ranging from 15 to 25 percent. Consequently, farmers have shown willingness to pay water fees, with many expressing readiness to pay rates higher than the current ones. This trend is observed in states like Karnataka, Bihar, Gujarat, Maharashtra, and Andhra Pradesh. For instance, the Paliganj WUA in Bihar stands out as a case where the government has saved approximately Rs 800,000 annually in operation and maintenance (O&M) and staff expenses due to IMT (ADB 2008).

Another evaluation, conducted across Gujarat, Tamil Nadu, Maharashtra, and Bihar, of 13 Water User Associations (WUAs) suggests positive impacts. These include an increase in the area under irrigation, a higher percentage of farmers receiving irrigation, improved access to timely and adequate irrigation for households, crop diversification, increased crop yields, and better maintenance of distribution and field channels (Prasad 2001). Other available evidence also indicates that these associations have been successful in optimizing water use, ensuring reliability, and providing timely and adequate water to all farmers for various crops (INCID 2003).

2.1.8. Capacity Building for PIM and IMT

Capacity building is key for the success of PIM, as it involves enhancing the capacities of various actors within the irrigation sector. These actors play a vital role in shaping the effectiveness of PIM policies and programs. The capacity-building needs of key actors vary based on their roles and responsibilities. Policy makers need to build capacity and provide support to help departments shift from being construction agencies to supporting farmers' organizations. (Shah, 2000).

According to Goutham (2008), PIM denotes the contribution of farmers to various irrigation management activities, including planning, designing, operation and management, and the assessment of irrigation systems. The variations in PIM were in trend in various regions of India, with only partial success hither and thither. Moreover, the competence building of farmers with regard to training, exposure visits to successful WALMI, and Water User's Co-operative Societies (WUCSs) across the country would help in bearing the responsibilities of functioning of WUCSs by themselves. The findings showed poor awareness of PIM conception and its service as the most important restraint followed by unwillingness of WRD representatives in the transmission of irrigation management to beneficiaries, inadequate motivation, training and leadership, apathetic approach of farmers, and political intervention in the successful establishment and function of WUCSs.

2.1.9. Progress of PIM and IMT

PIM has emerged as a strategy to enhance the efficiency of irrigation systems. This shift towards user involvement has been influenced by various global factors, including outcomes from the Earth Summit, warnings from the Food and Agriculture Organization regarding the necessity to increase food production with limited water resources, and the recognition of the need for institutional enhancements. The concept of IMT has been implemented in over 25 countries worldwide. Examples from South and Southeast Asia include Sri Lanka, Nepal, Bangladesh, the Philippines, Indonesia, and India. In East Asia, notable examples are China, Taiwan, and Korea. Latin American countries such as Mexico, Brazil, Colombia, and the Dominican Republic also showcase similar approaches. Additionally, in Africa, countries like Madagascar, Morocco, Nigeria, and Senegal have implemented similar initiatives. While the specific objectives and approaches have been tailored to local circumstances, the overarching goal has always been to enhance irrigation system performance. The implementation and adaptation of IMT have varied significantly across and within countries, with different stages of development observed. Yet, local-level institutions have been central in all these contexts. These institutions typically consist of water users organized into associations within specific basins, tasked with managing the allocation of water resources in a manner that is effective, equitable, and sustainable (ADB 2008).

The National Water Policy of India stresses the importance of involving communities in water resource management, recognizing that beneficiary involvement is crucial for the effective upkeep of irrigation systems and the efficient use of irrigation water. This involvement includes transferring responsibility for operation, maintenance, and water charge collection to Water Users' Associations within their respective jurisdictions, through CADWM program starting from 2008-09. Under CADWM, a one-time grant of Rs. 1200/- per hectare is provided to outlet-level Water Users' Associations, shared by the Centre, State, and Farmers in a 45:45:10 ratio, respectively. This grant serves as an incentive, with the interest from it earmarked for maintenance purposes. Additionally, each Water Users' Association receives Rs. 3.00 lakh (60% Central, 40% State) as a one-time infrastructure grant for establishing offices, warehouses, or other necessary facilities. The program also offers training and support through NGOs to enhance the capacity of Water Users' Associations. Currently, 16 states, including Uttar Pradesh, Rajasthan, Sikkim, Tamil Nadu, Odisha, Kerala, Maharashtra, Madhya Pradesh, Nagaland, Karnataka, Gujarat, Assam, Chhattisgarh, Bihar, Goa, and Andhra Pradesh, have passed legislation or modified Irrigation Acts to involve farmers in irrigation management. Other states are also advancing in this area. So far, 84,779 WUAs have been established, covering 17.84 million hectares under various irrigation projects in different states. (Annual Report MoWR, GoI 2018-19).

2.2. Conceptual Framework

2.2.1 Decentralization

Decentralization is a complex concept with various interpretations and implementations. It is often intertwined with centralization and is embedded in broader state reforms rather than being a standalone policy. Implementation can be inconsistent and unplanned, with decision-makers not always fully controlling the activity (World Bank, 1999). Although decentralization includes various concepts, most definitions highlight the shift of authority from the central government to local levels (Naidoo, 2002). This transfer can be described characterized by the nature (functional activities) and extent (national to subnational) of the authority being delegated. The concept also includes the nature and extent of power being delegated, devolved, or de-concentrated. The administrative, fiscal, market, and political dimensions of decentralization pertains to the nature (functional activities) and scope (national, sub-national, local) of decentralization. Devolution, deconcentration, and delegation describe the manner and extent of power transfer.

<table>
<tr><th colspan="2">Form</th><th colspan="2">Degree of Power</th></tr>
<tr><td rowspan="4">Overlapping Functional Activities</td><td>Market</td><td rowspan="2">Devolution</td><td rowspan="4">Continuum from Highest to Lowest</td></tr>
<tr><td>Political</td></tr>
<tr><td>Fiscal</td><td>Delegation</td></tr>
<tr><td>Administrative</td><td>Deconcentration</td></tr>
</table>

Figure 2.2: Dimensions of Decentralization

Autonomy in decentralization can vary across a spectrum, ranging from low to high levels. At the lowest end is de-concentration, where there is no independent authority at the local level and decisions are made by central authorities, typically seen in administrative decentralization. In the middle is delegation, where some independent authority exists at the local level, often seen in fiscal decentralization. At the highest level is devolution, which theoretically entails complete independent decision-making authority at the local level, more commonly observed in decentralization in governance and market operations (Rondinelli and Cheema, 1983; Rondinelli, 1998; Govinda, 1997, as cited by Naidoo, 2002). These dimensions of autonomy are interconnected, and they often occur simultaneously rather than in isolation (Manor, 1997 and 1999).

In their working paper titled "Decentralization and Poverty Alleviation in Developing Countries: A Comparative Analysis," Crook and Sverrisson (2001) conducted a comparative analysis of decentralization in several developing countries across Africa, Latin America, and Asia. They found that extent of responsiveness to poverty alleviation is uncommon, often influenced by the dynamics of national-central relations. The authors highlighted that positive outcomes are typically linked to a strong commitment from the national government or a political party advocating for the interests of the poor at the local level. While they emphasized the significance of regime type, political parties, and state commitment, they did not delve into the role of bureaucracy and its components in the process of decentralization.

As a market economy evolves, the significance of private property rights becomes more pronounced. This often involves the displacement or devaluation of non-private forms of property, particularly community-based or customary rights to property and its uses. Systems such as community rights over commons and the communal governance of resources such as fisheries, bodies of water, and irrigation systems, which have been in existence for long time and have demonstrated their sustainability may be disregarded or inadequately acknowledged under the new capitalist paradigm, leading to their erosion (Sleth R.M., 2006). Dwivedi and Dwivedi (2012) noted that the level of participation in a project is contingent on the genuine interest of individuals in the project. People are more likely to actively engage in a project if they perceive a direct positive impact on their lives from its successful implementation and operation.

2.2.2. Social Capital

There is a widespread acknowledgment of the significance of social relationships in the context of development. A common theme in the literature on social capital and development is that these relationships offer avenues for leveraging other resources that enhance growth. Moreover, it is recognized that social capital is intertwined with politics, and the interactions between communities and institutions are pivotal in determining a society's development prospects. This perspective highlights that social capital can either facilitate or hinder the provision of public goods. This viewpoint also underscores how social capital helps reduce risks and vulnerabilities, particularly in environments lacking formal insurance mechanisms and financial instruments. In such contexts, individuals often rely on their social networks to safeguard themselves against various forms of adversity (Woolkock, 2002).

2.2.3. Common-Pool Resources (CPRs)

Common-pool resources (CPRs) are resources that are shared among different users, and they can be either natural or man-made. This shared usage often leads to competition for their utilization, which can result in their degradation or destruction, although this outcome is not inevitable. Numerous valuable natural resources fit into this category, often facing persistent issues of overuse. Examples include woodlands, aquatic resources, hydrological basins, biological diversity, and the atmosphere. Contrary to earlier theoretical predictions, including Hardin's significant work on the "tragedy of the commons" (1968), numerous empirical studies, particularly Ostrom's seminal work (1990), have showcased the prospect of successfully managing CPRs through endogenous means. These studies have also provided theoretical explanations for how this successful management can be achieved (Bravo, G., & Marelli, B., 2008).

A common-pool resource (CPR) is a type of good that is hard to exclude people from using and where one person's use reduces what's available for others. This means that CPRs have some features of both private goods and public goods. They are like private goods because when one person uses them, there's less for others, but they are also like public goods because it's hard to stop someone from using them. Formally, the expression common-pool resource refers to a class of goods defined by two characteristics: a difficult exclusion of potential beneficiaries and a high degree of subtractability (i.e., rivalry of consumption) (Ostrom et al., 1994, 6-8). They resemble private goods in that one person's use decreases availability for others, but they also resemble public goods because it is challenging to exclude individuals from using them. (please see Figure 2.3).

		Subtractability	
		Low	**High**
Exclusion	**Difficult**	**Public Goods**	**CPRs**
	Easy	**Toll Goods**	**Private Goods**

Figure 2.3: Classification of Goods

Managing common-pool resources (CPRs) is complex because it combines challenges from both private and public goods. Similar to private goods, when one user takes resources from a common pool (like logging in a forest or tapping water from a basin), there's less for others. However, like public goods, it's difficult to stop any user from using these resources, especially if they are endangered (like ocean fisheries). Hardin (1968) described this issue using a model similar to a public-goods game, which is like a version of the prisoner's dilemma involving multiple players. In this setup, there are no strong reasons for any user to limit their resource use, which makes it hard to prevent resource degradation or destruction (Bravo G. and Marelli, 2008).

Recently, there has been a growing connection between the literature on managing CPRs and ecological studies. The idea of the social-ecological system highlights the connection between people and their environment. It emphasizes how humans are linked to their natural surroundings. This field has generated numerous studies exploring how different management approaches affect ecosystems and their capacity to adapt to environmental feedback. Key concepts such as adaptability, resilience, and robustness, originally from ecological science, are crucial for understanding the development of complex systems. (Berkes and Folke, 1998; Berkes et al., 2003; Gunderson and Holling, 2001). Research on human-environment relationships, particularly in social-ecological systems, is currently among the most captivating areas of study. (Bravo G. and Marelli, 2008).

Theoretical exploration of large-scale resource management began in the mid-1990s as an extension of research on small-scale common-pool resources (CPRs). This approach highlighted commonalities across different levels of analysis. While this approach yielded significant initial findings, it may have overlooked important differences that arise with scale, particularly concerning the diversity of stakeholders, governance capacities, and the institutional rules governing constitutional choices, especially when considering global commons (e.g., Paavola, 2008) (Buck, 1998; Keohane and Levy, 1994).

2.3. Theoretical Frameworks and Conditions for Sustainable Management of CPRs

2.3.1. Normative Framework by Leach

Leach (2004) developed a framework to evaluate the democratic aspects of collaborative environmental policymaking processes involving devolution. This framework assesses democracy in devolution based on inclusiveness, representativeness, procedural fairness, lawfulness, deliberativeness, and empowerment. However, applying this framework to real cases reveals two main limitations in the available data. Firstly, the indicators may not consistently cover all aspects of democracy. Secondly, there is a risk of sample bias, as the selection of cases could limit the generalizability of the findings.

2.3.2. Conditions for Success of Decentralization by Manor

Manor's (1999) seminal work, "The Political Economy of Democratic Decentralization," stands as pivotal contribution for understanding decentralization's impact on economic growth, poverty reduction, and civil society development. It sheds light on the movement's implications for democratic institutions. Currently, countries worldwide are pursuing decentralization, each with unique reasons. Some people want to help the economy grow or lessen poverty in rural areas, especially where the central government hasn't done enough. Others think it can make civil society stronger and improve democracy. Some also see it as a way to give lower-level governments more responsibility instead of the central government. This reflects the perception of decentralization as a multifaceted solution to different challenges. This study adopts a political economy perspective to delve into the origins and implications of decentralization, focusing on its potential and constraints. It investigates why some countries opt against decentralization despite evidence suggesting its benefits. It also explains why many countries have embraced decentralization since the early 1980s. Moreover, the study examines evidence to determine the areas where decentralization is particularly promising and where it may not be as effective. It identifies the essential requirements for successful decentralization and its potential to enhance rural development. Furthermore, it acknowledges the objectives that decentralization is unlikely to fulfil. However, Leach and Monor follow an instrumental approach that does not focus on the underlying processes.

2.3.3. Four Contexts for Negotiating Water Rights by Bruns and Meinzen-Dick

Bruns and Meinzen-Dick (2001) examined the challenges of water resource management in many developing countries, where water allocation has been primarily controlled by irrigation agencies. In these contexts, water rights are often not formally recognized or are poorly defined in state law, and the legal system, including the courts, is often weak, distrusted, or difficult to access for resolving disputes. These four contexts serve as a framework for discussing different aspects of negotiating water rights in environments characterized by legal pluralism. These are

(a) renegotiating rights during project interventions, (b) the formalization of rights, (c) basin governance, and (d) intersectoral transfers.

The study emphasizes the importance of leveraging existing institutions' social capital in water resource management negotiations, rather than enforcing standardized approaches. This approach promotes self-governance tailored to specific challenges, enabling institutions to adapt and provide effective solutions. It could aid in developing water resources, strengthening allocation mechanisms, resolving basin management issues, and facilitating fair water transfers.

2.3.4. Five Principles for Sustainable Irrigation Management by Hamada & Samad

Hamada and Samad (2011) introduced a set of principles aimed at ensuring the functional sustainability of irrigation management. These principles include:

i. Clearly defining and assigning roles to Water User Associations (WUAs) and ensuring governance structures are adequate.
ii. Guaranteeing that farmers' water demands are met promptly through their participation in WUAs.
iii. Providing financial benefits to farmers from water use, enabling them to cover water costs and associated services.
iv. Ensuring equal treatment of all WUA members in terms of water allocation, cost-sharing, and decision-making.
v. Maintaining transparency by disclosing financial status and transactions to WUA members.

These principles, though simple, are applicable to all irrigation systems and are vital for ensuring their sustainable management.

2.3.5. Elinor Ostrom's Guiding Principles for Managing a Commons

Elinor Ostrom, Nobel laureate in Economics in 2009, dedicated her career to studying how communities manage CPRs like pasturelands, forests, and water for irrigation. Her research has been pivotal in understanding how communities can successfully govern shared resources, which remains central to current debates on resource use, public governance, and environmental sustainability. Ostrom's work demonstrates how communities worldwide have developed effective strategies to govern their commons, ensuring their sustainability for present and future generations. In her seminal work, Ostrom (1990) identified eight core design principles for the sustainable and equitable governance of CPRs within communities. These principles are:

i. Define clear boundaries for the group.
ii. Align rules for resource use with local needs and conditions.
iii. Ensure that those impacted by the rules can take part in changing them.
iv. Respect community members' rights in rule-making over outside authorities.
v. Create a system where the community monitors the behavior of its members.
vi. Implement graduated sanctions (progressive penalties) for those who break the rules.
vii. Provide accessible, low-cost mechanisms for resolving disputes.
viii. Set up a system where responsibility for governing the common resource is shared across different levels, from local to interconnected systems, fostering mutual accountability between Water User Associations (WUAs), government, third parties, and consumers.

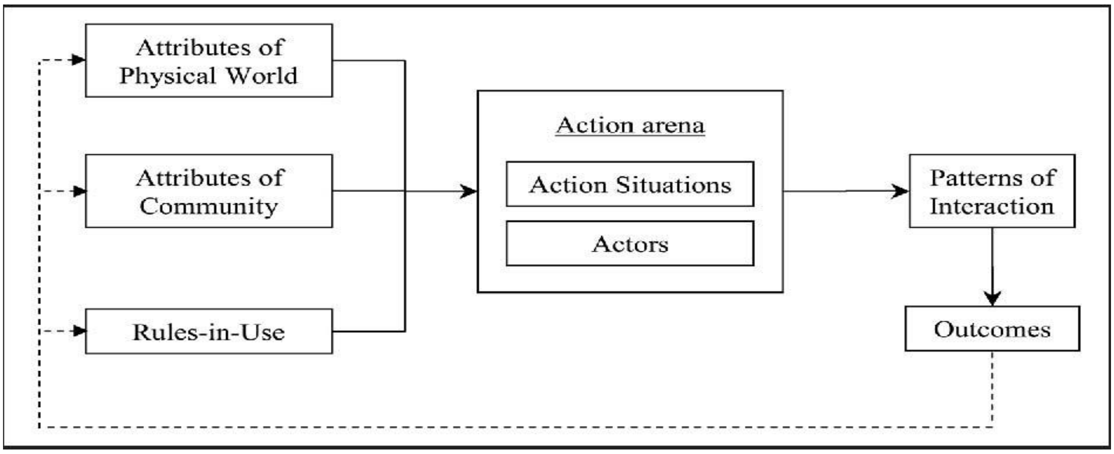
Ostrom (1990) and Uphoff (1986) suggest that there is no universally optimal method for organizing irrigation activities. The rules governing the supply and use of any physical system must be developed, tested, and refined over time. Therefore, significant time and resources must be invested in understanding how different institutional rules influence user behaviour. Well-designed institutions can significantly reduce opportunism, although the tendencies for taking advantage of others' efforts without contributing (free-riding), seeking economic gain through manipulation (rent-seeking), and dishonest behaviour (corruption), can never be completely eliminated. Nevertheless, institutions can be designed to effectively handle these concerns (Ostrom, 1992). While not all principles need to be present in every circumstance, the likelihood of sustainable governance increases when more of these principles are implemented (McGinnis, 2010). Agrawal summarized the conditions for successful local organizations based on Wade, Ostrom, Baland, and Platteau's work, supplemented by additional factors identified by Agrawal. He divided the enabling conditions into six sections, each enabling condition associated with specific authors and sources, providing a comprehensive framework for evaluating sustainability on the commons.as detailed in the table below:

Table 2.2 : Essential Conditions Enabling Commons Sustainability

S. No.		Enabling Condition
1	**Resource System Characteristics**	
	i.	Small Size
	ii.	Well-defined Boundaries
	iii.	Low Levels of Mobility
	iv.	Potential for Storing Benefits Derived from the Resource
2	**Group Characteristics**	
	i.	Small Size
	ii.	Clearly Defined Boundaries
	iii.	Shared Norms
	iv.	Past Successful Experiences- Social Capital
	v.	Appropriate Leadership - Youth, Adaptable to External Changes, Tied to Local Traditional Elite
	vi.	Mutual Dependence Among Group Members
	vii.	Diverse Endowments, Unified Identities, and Interests
	viii.	Low Levels of Poverty
3	**Relationship Between Resource System Characteristics and Group Characteristics (1 and 2)**	
	i.	Overlap of User Group and Resource Location
	ii.	Group Members' High Dependence on Resource System
	iii.	Ensuring Fair Allocation of Benefits from Common Resources
	iv.	Low Levels of User Demand
	v.	Gradual Change in Levels of Demand
4	**Institutional Arrangements**	
	i.	Rules are Simple and Easy to Understand
	ii.	Locally Devised Access and Management Rules
	iii.	Ease in Enforcement of Rules
	iv.	Graduated Sanctions
	v.	Availability of Low-Cost Adjudication
	vi.	Ensuring Monitors and Officials are Accountable to Users
5	**Relationship Between Resource System and Institutional Arrangements (1 & 3)**	
	Match Restrictions on Harvests to Regeneration of Resources	
6	**External Environment**	
	i.	Technology (Affordable Exclusion Technology, Time for New Technology Adoption)
	ii.	Limited Integration with External Markets
	iii.	Gradual shift in engagement with External Markets
	iv.	State: To respect local authority and support it with external institutions. Providing aid to compensate local users for conservation efforts. Establishing nested levels of management to ensure that rules are effectively implemented and enforced.

2.3.6. The Institutional Analysis and Development (IAD) Framework

The Institutional Analysis and Development (IAD) framework (Ostrom et al., 1994, Chap. 2) serves as a valuable research tool, outlining key elements to consider in studying Common-Pool Resources (CPRs) and their interrelationships. The concept revolves around the "action arena," where actors interact in a social space referred to as an action situation. This arena's characteristics are defined by the actors and the situation, and the outcomes of the institutional arrangement are shaped by interactions among individuals within it. External factors influencing the structure and functioning of action arenas can be categorized into three groups: the physical environment where actions occur, the rules governing interactions among participants, and the community structure within which participants operate.



Ostrom et al., 1994, 37.

Figure 2.4: The IAD Framework

Furthermore, Elinor Ostrom has brought forward the need to explore the role of community towards the outcomes, as described in (Ostrom, 2014). This study attempted to explore the impact of various attributes of WUAs towards canal efficiency (outcome). These attributes were taken from (Ghosh, et al, 2010).

2.3.7. Irrigation Systems as Common-Pool Resources

Irrigation systems exemplify CPRs, characterized by resources that are challenging to exclude and subject to competition among users. This competition often arises due to insufficient water supply, distribution issues, or timing conflicts in water delivery (Hamidov et al., 2016). Scholars suggest that specific forms of institutional design are crucial for enabling community-level institutions to effectively fulfill their legal mandates (Kazbekov et al., 2009).

In an irrigation system, two common resources—water and infrastructure (channels)—present collective action problems for users. Channels require regular maintenance, leading to a provision problem, while water use raises appropriation problems related to dividing water among users and monitoring compliance with water rights. Despite the complexity of managing these dual CPRs, many communities worldwide have successfully done so by establishing credible institutions tailored to local conditions. (Ostrom, 1992; Tang, 1992). Moreover, the effectiveness of the way institutions manage shared resources is influenced by both the physical nature of the resource and the social traits of the people who use it, such as shared values, worldviews, and existing social networks (Auer, 2006).

2.3.8. Definition of Success of WUAs

Participatory Irrigation Management (PIM) has been a focal point in India, evident from numerous expert groups' recommendations, legislative amendments, and program implementations at both central and state levels. However, the effectiveness of PIM policies should be measured by farmers' active involvement in improving irrigation system performance, not just by the number of programs. A crucial question is how farmers will respond to government initiatives aimed at increasing their involvement. While pilot projects have shown promise, expanding them to larger areas is still uncertain. (Raju et al., 2000).

The effectiveness of irrigation management transfer largely depends on farmers' perceptions. If farmers do not see it as beneficial, it is unlikely that the transfer will achieve the desired outcomes. Hence, impact assessments should focus on how users perceive the transfer. (G. Naik, A.H. Kalro, 2000).

According to Ostrom (1990), successful institutions are those that help people work together effectively, even when there's a temptation to avoid work or take advantage of other. Various studies, including those by R. Wade (1994), JM Baland and JP Platteau (1996), Ostrom (1990), and Agrawal (2001), discuss successful management using terms like "successful," "robust," and "sustainable," but often lack a clear definition of success. In this context, success is defined as improving the quality of functions (such as decision-making, payment mechanisms, and conflict resolution) from a deficient level to an improved one (where there is authority in entitlements and duties, financial stability, and awareness among members), and sustainably maintaining this improvement.

2.4. The Relevance of the Study in Jharkhand

Water is a crucial input for enhancing agricultural production and productivity. India has historically overlooked the catchment areas in remote drylands, home to tribal communities for centuries, in its irrigation and agriculture strategy. Harnath Jagawat, a key figure in India's rural development, emphasizes this, noting that a vast area in central India, approximately 1500 km long and 500 km wide, from Dumka in the east to Dungarpur in the west, offers significant agricultural potential with enhanced land and water management. This area contains 70% of India's tribal population, spread over 100 districts, and is one of the major concentrations of rural poverty in Asia (Agoramoorthy, 2008).

The tribal hinterland referred to above covers a large part of Jharkhand State, which is endowed with verdant greens, temperate plateaus, vibrant valleys, and rich reserves of minerals. Agriculture is a key part of Jharkhand's economy, supporting many people's livelihoods. However, the state faces a challenge in ensuring that development benefits all groups, including scheduled tribes, castes, and other underprivileged communities. In a State with more than three crores of population, the scheduled tribes and Schedule caste constitute 26.21% and 12.08%, respectively, of the entire state population (Census 2011). Agriculture is a significant sector in Jharkhand's rural economy, which leads to food security, income, price stability, and livelihoods for the majority. Of the total population of 329.88 lakh, rural population is 250.55 lakh (76%) and 63% of the workers are engaged in agriculture. Therefore, it is vital to prioritise this sector, which continues to be the largest employment-generating sector in the rural economy of the state. Since most agricultural and related activities are focused in rural areas, it is crucial to develop infrastructure for irrigation, transportation, storage, marketing, and communication. (State Focus Paper, Jharkhand, NABARD 2022).

2.4.1. Irrigation Sector in Jharkhand

Jharkhand urgently needs to develop its water resources because it is a water-deficient state. Managing and using the available water resources is crucial for the state's development. The total geographical area (TGA) of Jharkhand is 79.72 lakh hectares. The net sown area is 30.15 lakh hectares, which is 37.8% of the TGA. With Gross Cropped Area (GCA) of 38.00 lakh ha, the cropping intensity in Jharkhand was 126%. The net irrigated area in the state is 5.74 lakh hectares, which is about 19.0% of the net sown area. The gross irrigated area in the state is 7.00 lakh hectares, which is about 18.42% of GCA.

There are 30169 MCM of water available in the state, out of which surface water is 25877 MCM (86%) and ground water is 4292 MCM. The Ultimate Irrigation Potential (UIP) in Jharkhand was assessed as 24.25 lakh ha. The state has created irrigation potential of 10.00 lakh ha (41% achievement against ultimate potential). Of total Irrigation Potential Created, Minor Irrigation constitutes 6.19 lakh (62%), and the Major & Medium irrigation shares 3.81 lakh ha (38 %).

Table 2.3 : Comparing Irrigation Potential in Jharkhand and India

Particulars	Jharkhand (area in lakh ha)	India (area in million ha)
Total Geographic area	79.72	328.73
Total Cultivable area	38.00	159.70
Ultimate Irrigation potential	24.25	140.00
Irrigation potential created	10.00	112.00
Irrigation potential utilised	7.00	93.00
% Achievement against created potential	70%	83%
Irrigation coverage	26%	70%

(Source: WRD, Govt of Jharkhand; MoWRRD &GR, Govt of India).

The majority of the state's major and medium irrigation schemes have been in operation for over thirty years and require significant investment towards the Restoration, Extension, Re-strengthening and Modernization of completed irrigation projects. Since its establishment in 2000, Jharkhand has implemented the irrigation water rates that were in place in unified Bihar. The revision of these rates became operational on November 26, 2001. The state has also fixed two types of rates: one for perennial water sources, which are used for crops like wheat, paddy, and sugarcane, and another for non-perennial sources, used for paddy and wheat.

Table 2.4 : Irrigation Water Pricing in Jharkhand

(units in Rs/ha)

Flow Irrigation Range		Lift Irrigation Range		Date since applicable
Max	Min	Max	Min	
370.50	74.10	370.50	74.10	26-11-2001

Table 2.5 : Irrigation Water Rates for Crops in Jharkhand

(units in Rs/ha)

Paddy		Wheat		Sugarcane		Oilseeds		Pulses	
Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
217.36	108.68	185.25	138.32	370.50	370.50	98.80	74.10	98.80	74.10

The State Governments aim to recover the cost of water supply from irrigators through the assessment and collection of water charges. These rates are based on crop water requirements and the total irrigated area. In Jharkhand, the Water Resources Department is responsible for assessing and collecting irrigation charges. The Canal Officer assesses water charges based on the usage from an irrigation work. They then serve this assessment to the farmer. Analysis of the financial trends of Medium and Major Irrigation Projects in Jharkhand from 2000-01 to 2017-18, as shown in Table 2.6, reveals a consistent increase in capital spending from Rs. 56.15 crore to Rs. 1220.75 crore over the period. In comparison, annual operational costs have risen from Rs. 3.28 crore to Rs. 309.10 crore, while annual gross receipts have not shown a proportionate increase. A positive Gap in Annual Gross Receipts v/s Annual Working Expenses during 2000-01 at Rs. 2.38 crore became negative, and it has remained negative in each year from 2009-10 to 2017-18 (CWC, 2020).

Table 2.6 : Financial Trends in Medium and Major Irrigation Projects in Jharkhand (2000-01 to 2017-18)

Sl. No.	Year	Capital Expenditure		Working Expenses	Total Expenditure	Gross Receipts	% Recovery of WE through GR	Gap in GR v/s WE
		During the year	Up to the end of the year					
1	2	3	4	5	6=(3+5)	7	8 = (7/5) X 100	9=(7-6)
1	2000-01	56.15	56.15	3.28	59.43	5.66	172.64%	2.38
2	2001-02	155.45	211.61	16.72	172.17	26.74	159.89%	10.01
3	2002-03	202.92	414.53	16.31	219.23	16.53	101.37%	0.22
4	2003-04	280.91	695.44	15.56	296.47	23.31	149.80%	7.75
5	2004-05	228.59	924.03	12.85	241.44	15.53	120.89%	2.68
6	2005-06	296.27	1220.31	86.91	383.19	11.09	12.76%	-75.82
7	2006-07	171.54	1391.84	126.50	298.04	51.09	40.38%	-75.41
8	2007-08	595.03	1986.87	129.89	724.92	170.50	131.27%	40.61
9	2008-09	159.63	2146.50	171.97	331.60	48.13	27.99%	-123.83
10	2009-10	147.55	2294.05	204.01	351.56	52.86	25.91%	-151.14
11	2010-11	163.83	2457.88	203.19	367.02	36.60	18.01%	-166.59
12	2011-12	165.68	2623.56	219.90	385.58	40.53	18.43%	-179.37
13	2012.13	378.69	3002.25	220.39	599.08	43.29	19.64%	-177.10
14	2013-14	318.94	3321.20	240.36	559.31	86.89	36.15%	-153.48
15	2014-15	209.09	3530.20	254.07	463.16	215.20	84.70%	-38.87
16	2015-16	1058.56	4588.76	250.45	1309.02	61.28	24.47%	-189.18
17	2016-17	1105.60	5694.36	252.46	1358.06	78.79	31.21%	-173.67
18	2017-18	1220.75	6915.11	309.10	1529.85	274.14	88.69%	-34.96

Source: Financial Aspects of Irrigation Projects in India (Central Water Commission) December 2020.

In this context, Jharkhand has been lagging behind in enacting legislation for PIM in the state. The Jharkhand PIM Rules 2014 were notified as late as September 16, 2014. Thereafter, the progress of implementation was very slow. There are 460 WUAs covering 257.54 thousand ha of irrigated command area and 1709 User Committees have been formed. (WRD, Govt. of Jharkhand, 2019).

2.5. Research Gaps

Having identified the deficiency in managing irrigation systems in India as the cause of low irrigation efficiency and consequent low agricultural productivity and production, the exhaustive literature review focused on understanding what has been researched in the area of managing irrigation systems in India and elsewhere, with particular reference to PIM, IMT, and Decentralization of Water Resources. Second, a detailed study of literature on irrigation systems as Common Pool Resources (CPRs), its evolution, philosophy, components, tools, and methods, and how it has benefited the farmer, society, and ecology was also carried out.

The literature emphasizes the challenges of dealing with limited water resources and the increasing and changing demands for irrigation water. It also stresses the importance of a management approach that encourages efficiency and enables the voluntary transfer of water to meet evolving societal needs. Furthermore, it highlights the need to gauge the effectiveness of participatory approaches in the management of irrigation projects. The literature suggests investigating collaborative management involving both irrigation departments and water users to improve service delivery. It also reveals that successful collective action in public irrigation systems depends on specific conditions. Replicating these conditions elsewhere would be challenging and costly, if not impossible. Therefore, there is a need to study this phenomenon in different settings. Literature is either silent or there are limited studies with reference to the State of Jharkhand related to the research areas hinted at in the literature review.

On examining the conceptual and theoretical frameworks related to the study of irrigation management transfer to the water users' associations, in applying Leach's framework to actual cases, two limitations in the data are apparent. First, indicators may not be uniformly detailed across the six aspects of democracy. Second, there is potential for sample bias, as selection might limit the generality of the findings. However, Leach and Monor follow an instrumental approach that does not focus on the underlying processes. The four contexts for negotiating water rights by Bruns and Meinzen-Dick discuss how water rights can be negotiated in a legal pluralism environment. However, overlook important aspects of the resource system, group, rules, and the external environment. Similarly, the five principles for sustainable management by Hamada and Samad do not cover all aspects of an irrigation system, particularly the resource system's interrelation with the institutional arrangement and external environment. Ostrom (1990) has demonstrated the potential for successful internal management of CPRs by natives and explained this achievement theoretically. Irrigation systems exemplify common pool resources (CPRs). The IAD framework is a crucial research tool for understanding CPR studies and their relations.

From the review of above literature, primary gaps for further understanding are:

i. Despite the consistent rationale for IMT globally, the approaches, impacts, and progress vary across countries, indicating different levels of development. The contextual nature of the situation and problems suggests the need for a deeper understanding of the effects of institutions on behaviours and outcomes in diverse field settings. Few studies are available with reference to the State of Jharkhand.

ii. The literature suggests that as the situation and problems are contextual, more research is needed to determine if IMT results in the sustained performance of Irrigation Schemes. To date, few studies have been reported in the State of Jharkhand with reference to the users' perception, organizational, and procedural aspects of IMT and WUAs dynamics.

iii. The treatment of irrigation systems as a prime example of CPRs and application of the Frameworks and Conditions for Sustainable for Management of CPRs have not been reported in research studies with reference to PIM in the State of Jharkhand.

iv. Elinor Ostrom developed a set of core design principles that help communities manage common resources successfully. Her work in this area earned her the Nobel Prize in Economics in 2009. The literature on its application in the context of the State of Jharkhand is silent.

v. Over the years, the performance of the Indian irrigation sector has impeded its sustainability (Narayanmoorthy et al., 2018, Jain et al, 2019). The management of water for irrigation, maintenance of irrigation infrastructure, collection of water user charges, and implementation of PIM/IMT towards better effectiveness are some of the major issues in the sector. However, there are research gaps in the understanding of the factors affecting the sustainable and effective role of WUAs towards better canal or surface irrigation (Gupta et al., 2022). From most of the studies in the literature, many issues regarding irrigation were analysed on a standalone basis; therefore, a comprehensive study is needed that considers all the barriers and factors. Therefore, this study attempts to comprehensively identify all barriers and factors and prioritise them based on rankings using various MCDM techniques.

vi. There is a need to understand the economic, social, and environmental perspectives towards sustainable water management in irrigation (Sirimewan et al., 2021). Therefore, there is a need to understand various issues in irrigation management systems and the contributions of WUAs. Water investments by the government need to understand the objectives of land area irrigation and irrigation modernization (García-Mollá et al 2021). This study attempts to evaluate the investments and user charges collected by WUAs in Jharkhand state.

2.6. Research Problem Statement

Irrigation systems serve as a notable example of common pool resources (CPRs), with water and infrastructure being challenging to exclude and subject to competition among users (Hamidov et al., 2016). Given the complexity of managing irrigation systems as CPRs, understanding the effects of institutions on behaviours and outcomes in diverse field settings is crucial, as situations and problems are contextual. However, there is a lack of documentation on the factors that impact the success of local water management, particularly through WUAs and IMT in Jharkhand state.

CHAPTER 3

RESEARCH METHODOLOGY

Chapter 3
Research Methodology

3.1 Need and Scope of Study

The objective of this research is to understand and elucidate the status and repercussions of the transfer of irrigation management to WUAs in the State of Jharkhand in India. User satisfaction refers to the perception of users regarding their satisfaction with the performance and governance of WUAs. As such, this study sought to determine the impact of a variety of factors on user satisfaction within the decentralised water governance mechanism of WUAs, a phenomenon that has not been explored in the context and situation of the proposed study. The reasons for low irrigation efficiency were interrelated. There is a vicious circle. No previous studies have been conducted on the state of Jharkhand. This study explores the interplay between internal organizational structures and external factors that impact the success of local water management facilitated by WUAs and Irrigation Management Transfer.

3.2 Study Area

3.2.1 Irrigation in Jharkhand

The State of Jharkhand has a cultivable area of 3.8 million hectares, with only 12% of the crop area being under irrigation. Agriculture in various agro-ecologies of Jharkhand relies heavily on the monsoon for water, and its failure results in water scarcity and reduced crop yields. Despite adequate rainfall, the cropped area and intensity remained low. Although rice dominates most of the cropped area during the Kharif season, a significant portion remains uncultivated in subsequent seasons. Limited access to sustainable irrigation poses a significant obstacle to intensifying and diversifying farming systems, improving incomes for farmers, and providing resilience against climate change. Surface runoff storage is minimal, leading to dependence on groundwater irrigation even during dry spells within the monsoon. The state's surface and groundwater resources are estimated at 25.88 billion cubic meters (BCM) and 4.29 BCM, respectively. With Groundwater development at 15.0%, there is potential to increase its utilization in agriculture. However, challenges such as limited electrification and poor technology adoption have contributed to low groundwater development, particularly in rice-fallow areas.

Following the conclusion of the monsoon season, residual soil moisture is crucial in determining the prospects for subsequent crops during the succeeding seasons. The terrain of the region, characterised by undulating topography and a well-established network of streams, facilitates rapid runoff disposal from watersheds (Government of Jharkhand, 2020). The area comprises a series of hillocks with drainage lines and adjacent low-lying regions near streams, collectively termed lowlands, traditionally cultivated for paddy fields. In the study area, these lowlands extend horizontally for approximately 60-150 meters with local relief reaching 2-3 meters above the drainage line. These lowland areas experience prolonged waterlogging after the monsoon, with the soil becoming workable around January. The transitional zones between the lowlands and relatively flat uplands are known as midlands, featuring local topographic relief approximately 2-7 meters above the drainage line. Much of the original midland hill slope was terraced and bunded for paddy cultivation. The upper non-terraced and non-bunded flat areas generally have shallow, light-textured soil and lack local water resources for irrigation. Uplands situated at an elevation greater than 7 m above the drainage line primarily contribute to groundwater recharge, whereas lowlands serve as major discharge areas. Some fringe areas along stream banks are marginal uplands characterised by steep slopes, rocky terrains, and high runoff, making them unsuitable for agricultural production.

Several constraints encompassing technological, social, and policy aspects hinder the practice of multiple cropping in the state, with limited access to irrigation water as the primary obstacle. Many agro-ecologies in the state exhibit characteristics such as low investment, low productivity, monocropping, and marginal annual returns per unit of land. Poor adoption of technology further contributes to reduced productivity. The prevalent use of traditional water application methods among farming communities exacerbates the overuse of irrigation water, which leads to diminished water productivity. Addressing these challenges and enhancing future water use efficiency involves judicious utilization of available water resources through improved management practices and the using new and improved technologies at the farm level. This necessitates a revaluation of the existing policies regarding the development and management of irrigation infrastructure. Government subsidy schemes should align with the actual needs of farming communities and support the implementation of advanced irrigation technologies.

The study area for this research comprises the Tamar and Sonahatu blocks in the Ranchi district, as well as the Ichagarg block in the Seraikela-Kharsawan district, within the state of Jharkhand. These blocks were selected because the command area of the Kanchi River Canal Irrigation Project is concentrated in these blocks.

3.2.2 The Kanchi Canal Irrigation Project

The Kanchi Irrigation Scheme holds significant importance, providing irrigation to 14 villages in the Arki block of Khunti district, 44 villages in the Tamar block of Ranchi district, and 23 villages in the Sonahatu and Ichagarh blocks of Seraikela district, as illustrated in Figure 3.1. The GCA of the scheme covers 34,210 ha, with a Culturable Command Area (CCA) of 21,235 ha and a designed irrigation potential of 17,800 ha. The plan for constructing the Kanchi Irrigation Scheme was formulated during the Second Five-Year Plan (1956-61) of the Government of India, with the construction initiated in 1958 and completed in 1966. The primary structure of the Kanchi irrigation scheme is situated on the Kanchi River in the village of Churki, Panchayat – Aradih, Thana Adki block, Adki district – Khunti, at coordinates 25o07'30" S latitude and 85o09'30″ E. The main canal of the Kanchi Irrigation Scheme spans a length of 18.29 km, with the Tamar branch canal branching off from its right side, covering a length of 13.27 km and a discharge capacity of almost 150 cusec. Restoration work, including paving, has been undertaken in the Tamar branch canal under CADWM. Figures 3.2 and 3.3 depict the 18.29 km main canal network of the project. However, the bank of the Adradih branch canal is damaged and its structures deteriorate. Because the water discharge of the canal is significantly less than its total capacity, only partial irrigation is achieved. Restoration of this canal, necessitating essential earthwork for its channel section, has not been conducted for several decades.

Figure 3.1: Study Area Location

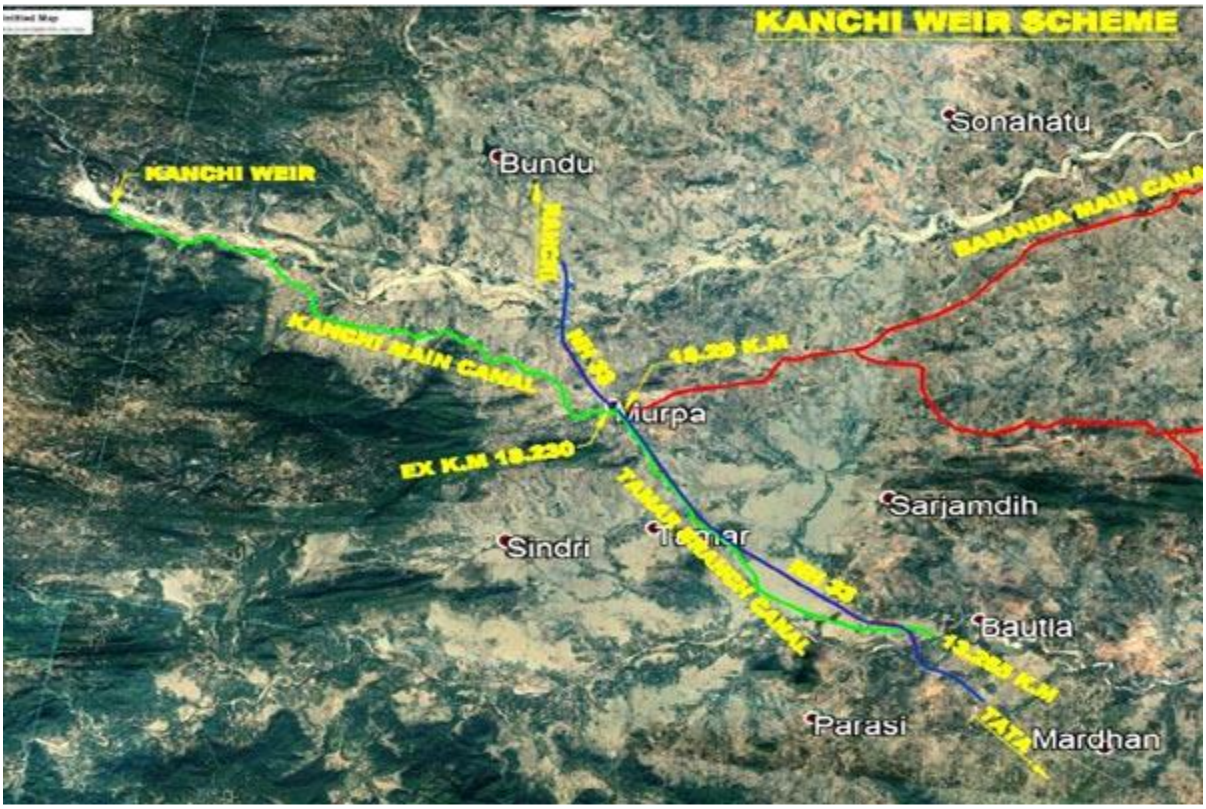


Figure 3.2: Kanchi Irrigation Project

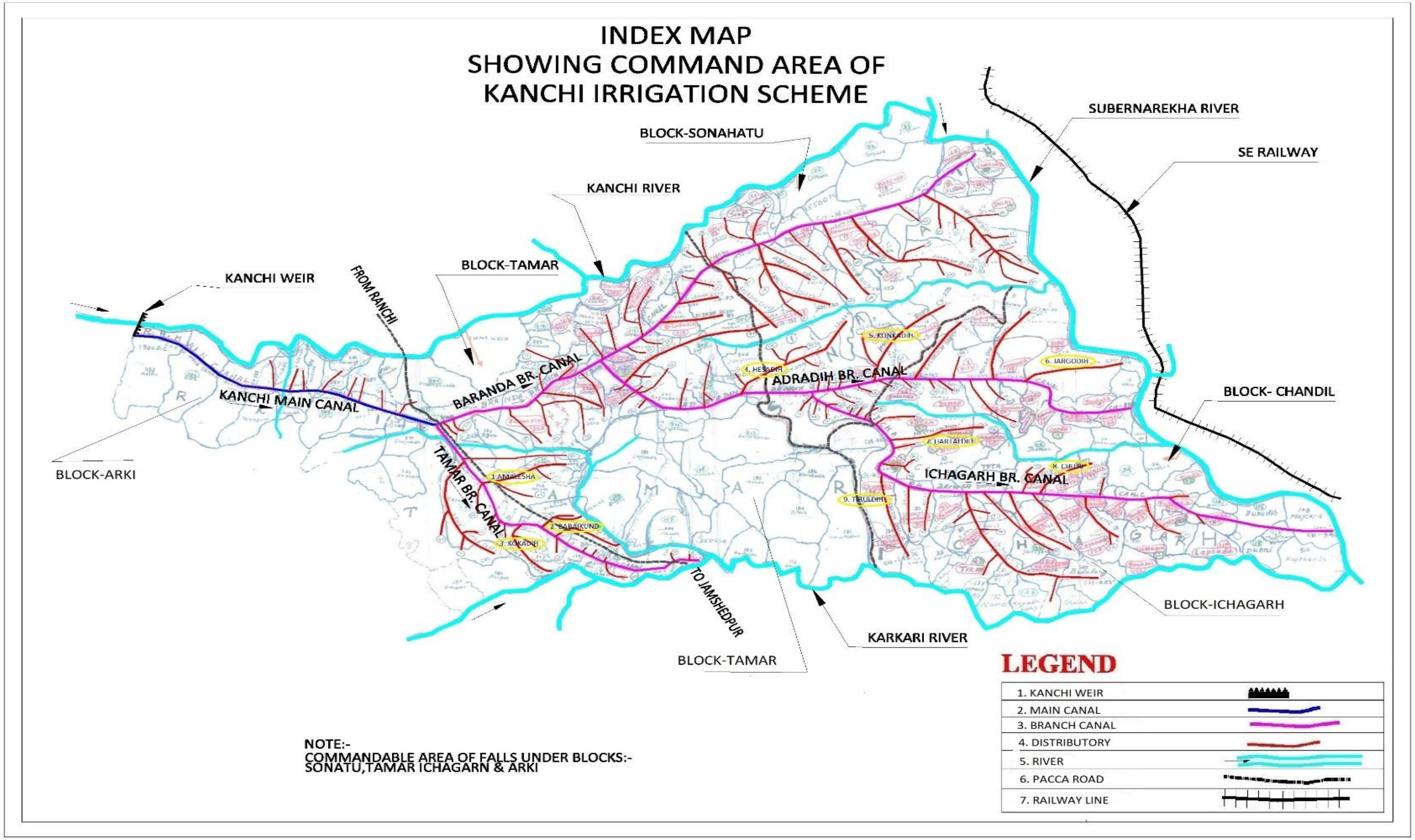


Figure 3.3: Kanchi Irrigation Project Index Map

3.3. Potential Significance

This research seeks to investigate the present state of affairs within the irrigation industry in the State of Jharkhand with regard to the alignment of the Irrigation Management Transfer aspect with the enabling legislation for Participatory Irrigation Management in the State with the overall strategy of increasing irrigation efficiency for increasing agricultural productivity and production. This work contributes to the academic field by enhancing our theoretical understanding and methodological approaches in interdisciplinary analysis of irrigation systems in Jharkhand State.

3.4. Conceptual Lens Based on Initial Conceptual Construct from Literature Review

In the research process, the researcher first defined the practical problem, followed by a systematic study to comprehensively grasp the nature of the problem (Maxwell, 1996). Research questions and designs were then formulated to methodically investigate this issue. Subsequently, existing theories relevant to the problem statement were examined and incorporated using theory development methodologies. A "conceptual lens" is constructed based on the identified theory to scrutinise the problem.

Furthermore, an empirical research design and data analysis approach were devised, drawing on the conceptual lens framework and research questions. The data collection phase was initiated according to a defined research methodology. The collected data were analysed using the conceptual lens framework, and the research findings emerged from this analysis. These findings may contribute to the extension of existing theories and offer insights into formulating recommendations to address the identified problem. To develop a holistic contextualised conceptual framework, the development of a conceptual lens integrating all the major perspectives is important. Hence, based on the literature review of the major perspectives on the phenomenon, the proposed study will use a conceptual lens to gain theoretical sensitivity, raise questions for initial interviews, confirm findings, and inform existing literature.

The focus of the proposed study revolves around the exploration of how and why certain decisions are made within the subject of research, reflecting a real-world situation that has not been studied previously in the context of Jharkhand. Simultaneously, it represents a common case for the situation and context given that all Water User Associations (WUAs) in the state are governed by shared rules.

The intended research aims to systematically comprehend and depict the current status and repercussions of IMT to WUAs in Jharkhand. Additionally, it seeks to gain insights into the interplay between internal organizational structures and external factors that contribute to the effectiveness of WUAs and IMT. The findings of this study were derived primarily from a significant irrigation system, acknowledging the diversity of irrigation systems across various regions. However, it's important to note that this research does not analyze how regional differences affect policy, as that is not part of the study. The analysis of regional variations and their impact on policy is beyond the scope of this study.

3.5 Research Questions

RQ1. What are the barriers to the effective use of canal irrigation by WUAs?

RQ2. How the canals may be prioritised for improving their performance?

RQ3. What attributes of WUAs influence the overall efficiency of canal irrigation efficiency?

These queries are exploratory in nature, aiming to foster comprehension regarding the interplay of internal organizational structures and external circumstances that shape the outcomes of local water management facilitated by Water User Associations (WUAs) and the process of Irrigation Management Transfer.

3.6 Research Objectives

The following research objectives were pursued to explore the answer to the research problem: What factors influence the success of local water management through WUAs and IMT?

RO1. To identify various barriers that Water User Associations face in the effective usage of canal irrigation and rank them.

RO2. To evaluate the relative efficiencies and performances of the nine selected canals managed by WUAs.

RO3. To examine the effects of various attributes of WUAs on canal irrigation efficiency.

Thus, the investigation into the status and impacts of Irrigation Management Transfer to Water User Associations is focused on discovering and ranking the diverse obstacles encountered by these associations in efficiently utilising canal irrigation, designated as RO1. RO2 involves the assessment of the relative efficiencies and performance of the nine chosen canals managed by

Water User Associations, achieved through the evaluation of investments and user charges collected by these associations in the state of Jharkhand. Finally, RO3 examined how various attributes of Water User Associations influence the efficiency of canal irrigation.

3.7 Data, Methods and Models

3.7.1 Data, Methods and Models for Objective 1

This study employed a methodology to evaluate the issues related to canal irrigation efficiency. The identification and finalization of canal irrigation issues were achieved through interviews and consultations with groups of experts, stakeholders, and academicians, supplemented by an extensive literature review. Pairwise comparison techniques were used to assess the identified issues. This study adopts an integrated approach to assessment utilising Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (FAHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) methods.

A thorough and comprehensive examination of the literature was conducted to identify prevalent issues in canal irrigation efficiency. The literature review encompassed a global perspective as well as a focus on the Indian context, specifically within the state of Jharkhand, to enhance the understanding of regional nuances.

The evaluation of barriers to canal irrigation efficiency as detailed in Table 3.1, involving the ranking of various barriers and sub-barriers based on their influence or importance, was conducted using the input of 19 experts. These experts, detailed in Table 3.2, were drawn from the Command Area of the Kanchi Irrigation Project in Jharkhand and represented various sectors, such as NGOs, the Water Resources Management Sector, Water Users Associations, and state government employees. During consultations, they were also asked about their preferences for weighting models when using AHP, Fuzzy AHP, and DEMATEL. Experts were chosen using convenience sampling based on their expertise and knowledge. They were tasked with assessing and ranking the five identified elements as primary issues in canal irrigation, gauging their influence and importance through the Questionnaire for Ranking of Barriers using Multiple Criteria Decision Making (MCDM) outlined in Appendix A.

Table 3.1 : List of Key Barriers and their Sub-Barriers

Resource System (RS)	Legal & Institutional (LI)	Financial Barriers (FB)	Capacity Building (CB)	External Environment (EE)
Canal infrastructure : (RSCI) Inadequate / Poor O&M / Repair of the irrigation system and consequent asset loss.	**Legal framework: (LILF)** Inadequate legal framework/policies on the nature and extent of irrigation management transfer	**Government funding (FBGF)** Lack of government support/ funding	**Training (CBTR):** Lack of training for staff/ WUA members in participatory irrigation management (PIM) and absence of leadership /willingness to take up management functions and dispute resolution	**Socio-economic inequality (EESE)**: Farmers less powerful deprived of irrigation water
Flow control structures: (RSFC) Lack of physical mechanisms to control the quantity and timeliness of water flow in the irrigation system.	**Control over water flow: (LICW)** Limited control over water flow.	**Water rate collection system: (FBWC)** Low collection of water charges /Non-payment of water charges makes WUAs financially unviable.	**Monitoring (CBMO):** Poor Monitoring of irrigation water flow deprives the tailenders of the canal and causes consequent dissatisfaction	**Groundwater depletion (EEGD):** The water table is receding fast, and high cost of electricity for running and repairing tube well/pump set
Climate Risk: (RSCR) Low flow water in the irrigation system, particularly during monsoon failure.	**Water distribution rules: (LIWR)** Lack of freedom in devising water distribution rules and water rates leads to in-equity in irrigation water distribution.	**Operation & Maintenance cost: (FBOM)** Inability to incur the high cost of maintenance resulting in a capital loss	**Coordination (CBCR):** Poor coordination with the irrigation department regarding water demand preparation and water charges collection.	**Extension services (EEES):** The lack of agricultural advisory services causes low farm productivity and reduced rural livelihood opportunities.

Resource System (RS)	Legal & Institutional (LI)	Financial Barriers (FB)	Capacity Building (CB)	External Environment (EE)
			Leadership (CBLD): Difficulty managing the activities of WUAs in the absence of leadership.	**Quality planting materials (EEQP):** Low productivity and production due to lack of quality seed/ planting materials
			Cooperation (CBCP): Disputes and inequity in the distribution of water due to poor cooperation among members	**Investment credit (EEIC):** Low capital formation due to lack of investment credit with farmers
			Dispute & Conflict (CBDC: Conflict among members about the quantity and timing of water	

Table 3.2 : Details of Experts Consulted.

S. No.	Details of Experts
1	Water resources management expert (Consultant)
2	Expert in water resources management involved in implementing irrigation projects.
3	NGO member dealing in the formation and training of WUAs
4	NGO member dealing in WUA program implementation
5	Representative of Irrigation Infrastructure Funding Institution
6	Executive Engineer serving as an Irrigation Bureaucrat in the Government of Jharkhand's Water Resources Department.
7	Engineering officer of the Water Resources Department of the Government of Jharkhand direct in charge of the project (Assistant Engineer)
8	Junior Engineer serving as an Engineering Officer in the Government of Jharkhand's Water Resources Department.
9	Canal head operator (Contract staff of Water resources department)

S. No.	Details of Experts
10	Supervisor of water distribution (Water resources department Staff)
11	WUA Office Bearer Farmer in Head Reach
12	WUA Office Bearer Farmer in Head Reach
13	WUA Office Bearer Farmer in Middle Reach
14	WUA Member Farmer in Head Reach
15	WUA Member Farmer in Head Reach
16	WUA Member Farmer in Head Reach
17	WUA Member Farmer in Middle Reach
18	WUA Member Farmer in Tail Reach
19	WUA Member Farmer in Tail Reach

Three techniques, namely AHP, FAHP, and DEMATEL, were employed to evaluate the influence and significance of issues in canal irrigation. AHP, a decision science method, was used to prioritise the issues. Both AHP and Fuzzy AHP are applied to analyse issue hierarchies, with Fuzzy AHP addressing the imprecisions associated with AHP. The results of AHP and FAHP were compared. Because the methods did not consider the cause-effect relationships among issues, DEMATEL was necessary to analyze these relationships, and thus, DEMATEL was introduced. This combination of MCDM techniques allows for a more accurate analysis, considering both cause-effect relationships and issue rankings, ensuring reliable results in the study. The evaluation of issues ranked in terms of influence or importance was conducted using the AHP, FAHP, and DEMATEL methods to ensure the attainment of reliable results. The DEMATEL approach was employed to emphasise the influence of one issue on the others. In the field of decision science, the AHP method is often used for problem solving because it helps simplify complex decisions by breaking them down into smaller, more manageable parts. AHP allows decision makers to compare different factors by giving them numerical values, which helps in prioritizing and making well-informed choices (Hossain and Thakur 2021). Both AHP and Fuzzy AHP were utilised in this study to investigate the hierarchy of issues in canal irrigation. Fuzzy AHP was specifically employed because the AHP method is known to have issues with unbalanced scales, uncertainty, biases, and resulting imprecision. To tackle this, Fuzzy AHP (FAHP) was used, and the rankings from both AHP and FAHP were compared. Since neither AHP nor FAHP accounts for cause-effect relationships among issues, the DEMATEL approach was introduced to analyze these relationships. Consequently, the combination of these three MCDM techniques allows for a comprehensive analysis of cause-effect relationships and rankings among issues, contributing to a more accurate assessment of the results.

The three methodologies employed in this study, notably AHP and FAHP, have found widespread application in various research areas. Moreover, the DEMATEL method, valued for its simplicity in discerning cause-and-effect relationships, has proven to be beneficial. So, these three methods are helpful tools for understanding the importance and impact of different factors. They make decision-making easier and can lead to improvements in various areas.

3.7.1.3 AHP Method

A scale is used for constructing the pairwise comparison matrix. The scale of relative importance is presented below in Table 3.3.

Table 3.3: Importance Scale for Comparison Matrix

Preference rating	Level of Relative Importance
Equal Importance	1
Moderate Importance	3
Strong Importance	5
Very Strong Importance	7
Extreme Importance	9

The approach involves the ensuing procedures (Saaty T.L. 1980):

Step 1: Collective input from the 19 experts (Appendix A) was utilised to compute the average of their responses, resulting in a conclusive pairwise comparison matrix.

Step 2 – The normalized pairwise comparison matrix is created using a scale of relative importance for a consistent and meaningful comparison between all pairs of items in the matrix.

Step 3: Determine the coefficient vector for criteria weights pertaining to criteria. This involved the finding the geometric means, summation, and then taking the reciprocal corresponding to each weight.

Step 4: The consistency index (CI) is calculated using the formula CI=(λ_{max}-n − n)/(n-1), where λ_{max} is the average of the coefficient vector and n is the number of categories.

Step 5 – The Consistency Ratio (CR) is estimated using the formula CR=CI/RI where RI is the Random Index.

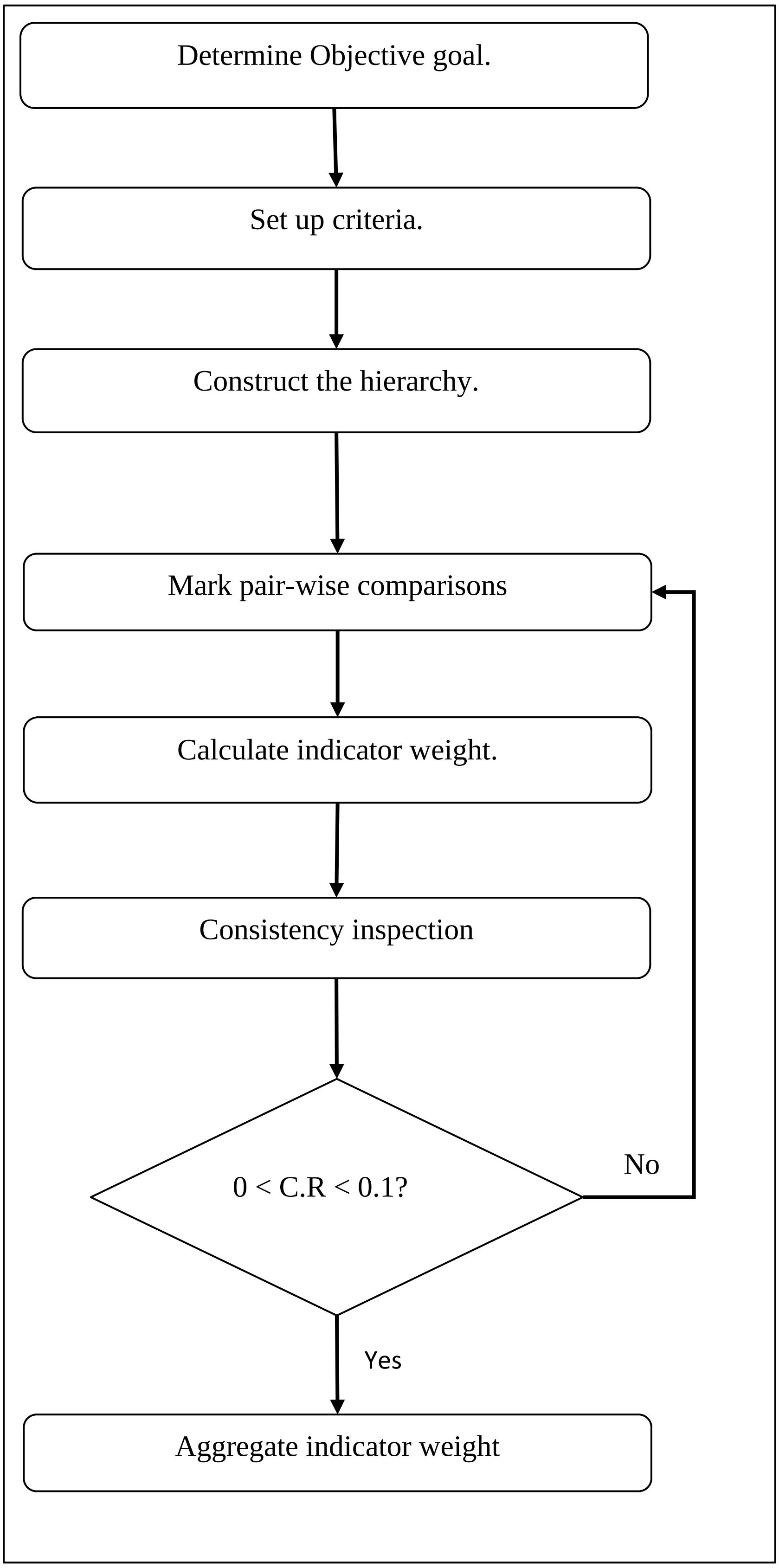


Figure 3.4: Flow Chart for AHP Method

3.7.1.4 Fuzzy AHP

The fuzzy AHP method is preferred over AHP because it provides a more accurate and logical representation of the performance of one criterion compared with another, addressing the imprecision inherent in AHP. As indicated by experts, the triangular fuzzy scale used to express the importance level is presented in Table 3.4.

Table 3.4: Intensity of Importance Scale for Pairwise Comparison Matrix Construction

Preference rating	TFNs
Equal Importance	(1,1,1)
Weak Importance	(1,3,5)
Fairly Strong Importance	(3,5,7)
Very Strong Importance	(5,7,9)
Absolute Importance	(7,9,9)

The steps involved in the FAHP method are outlined below:

- Utilization of Pairwise Comparison Matrix: The matrix obtained in Step 1 of the AHP method is employed.
- Replacement with Triangular Fuzzy Numbers (TFNs): The values in the matrix are substituted with the corresponding TFNs, as presented in tabular form.
- Estimation of Geometric Mean: The geometric mean of the fuzzy weights is then calculated, and the results are tabulated.
- Defuzzification: This step involves determining the relative nonfuzziness of each model (Mi). Subsequently, the normalised ranks of each criterion (Ni) were evaluated based on the values of Ni. Rankings are determined considering both Mi and Ni, involving the normalization of fuzzy numbers for Mi and utilising non-fuzzy Mis.

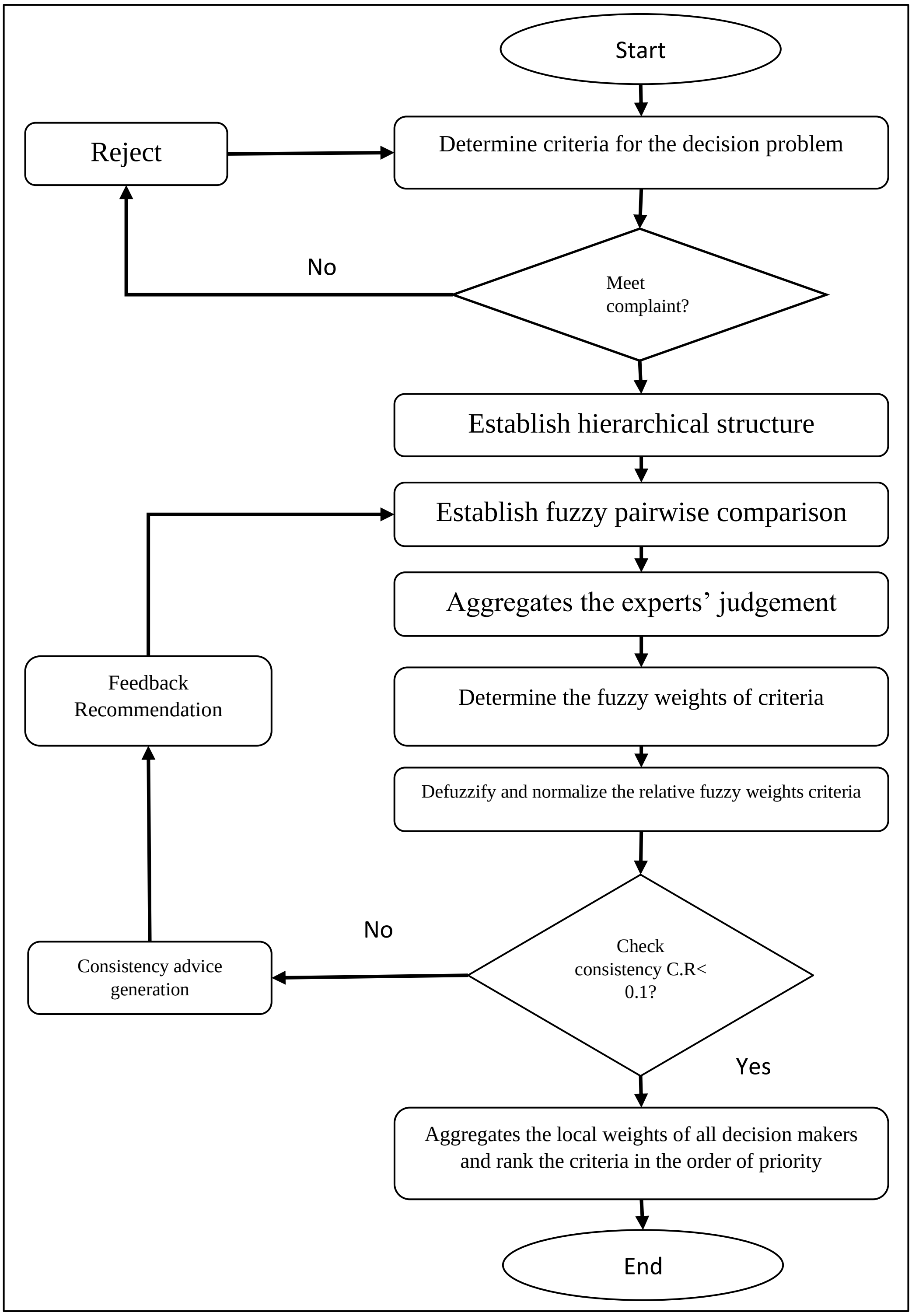


Figure 3.5: Flow Chart for Fuzzy AHP Method

3.7.1.2 DEMATEL

The DEMATEL approach was employed to evaluate cause-and-effect relationships among the issues. This comprehensive technique establishes causal connections among intricate factors using diagrams. The procedural steps of this method, as outlined by Bakir et al. (2018), are summarised below.

Step 1: The comparison scale, as illustrated in Table 3.5, is utilised to establish a direct relation matrix. Experts evaluated the direct impact of each pair of factors using this comparison scale. The notation x_{ij} denotes the influence of factor i on factor j, with a value of zero placed in the diagonal element when i equals j. For each expert, a nonnegative n × n matrix is derived as X_k= [x_{ij}^k], where k represents the number of experts ranging from 1 to N. Matrix X1, X2, ..., XN is obtained from N experts.

Table 3.5 : DEMATEL Method: Comparison Scale

Scale	0	1	2	3	4
Level of Influence	No influence	Low influence	Medium influence	High influence	Very High influence

Step 2: Using the values gathered from N respondents, the comprehensive direct-relation matrix, denoted as D, is formulated and depicted in a table. The average matrix X =[a_{ij}] can be obtained from the equation $a_{ij} = \sum_{k=1}^{N} x_{ij}^{k}$

Step 3 – Normalised initial direct-relation matrix, Y, is obtained using equations Y = A.S where $S=1/max_{1\leq i\leq n} \sum_{j=1}^{n} a_{ij}$. The value falling between 0 and 1 is put against each element in the matrix Y.

Step 4 – ‘T’ is calculated using the equation $T= Y(I-Y)^{-1}$ where I is the identity matrix, and T is the total relation matrix.

Step 5 – The underlying constraints are determined using calculations: $r_i = \sum_{i=1}^{n} t_{ij}\ \forall_j$ and c_j $\sum_{i=1}^{n} t_{ij}\ \forall_i$Where r_i represents the row sum and c_j indicates the column sum. The causes and effects are presented in a tabular form.

Step 6 – Use a dataset that includes the prominence (Pi) and the net effect (Ei), which are represented by the expressions Pi = Ri + Cj = i=j and Ei = Ri – Cj = i=j.

The effect of factor i on the overall system is indicated by the disparity between Ri and Cj (Ri – Cj). If this value is positive, factor i is identified as a net contributor, whereas if it is negative, factor i is recognised as a net recipient.

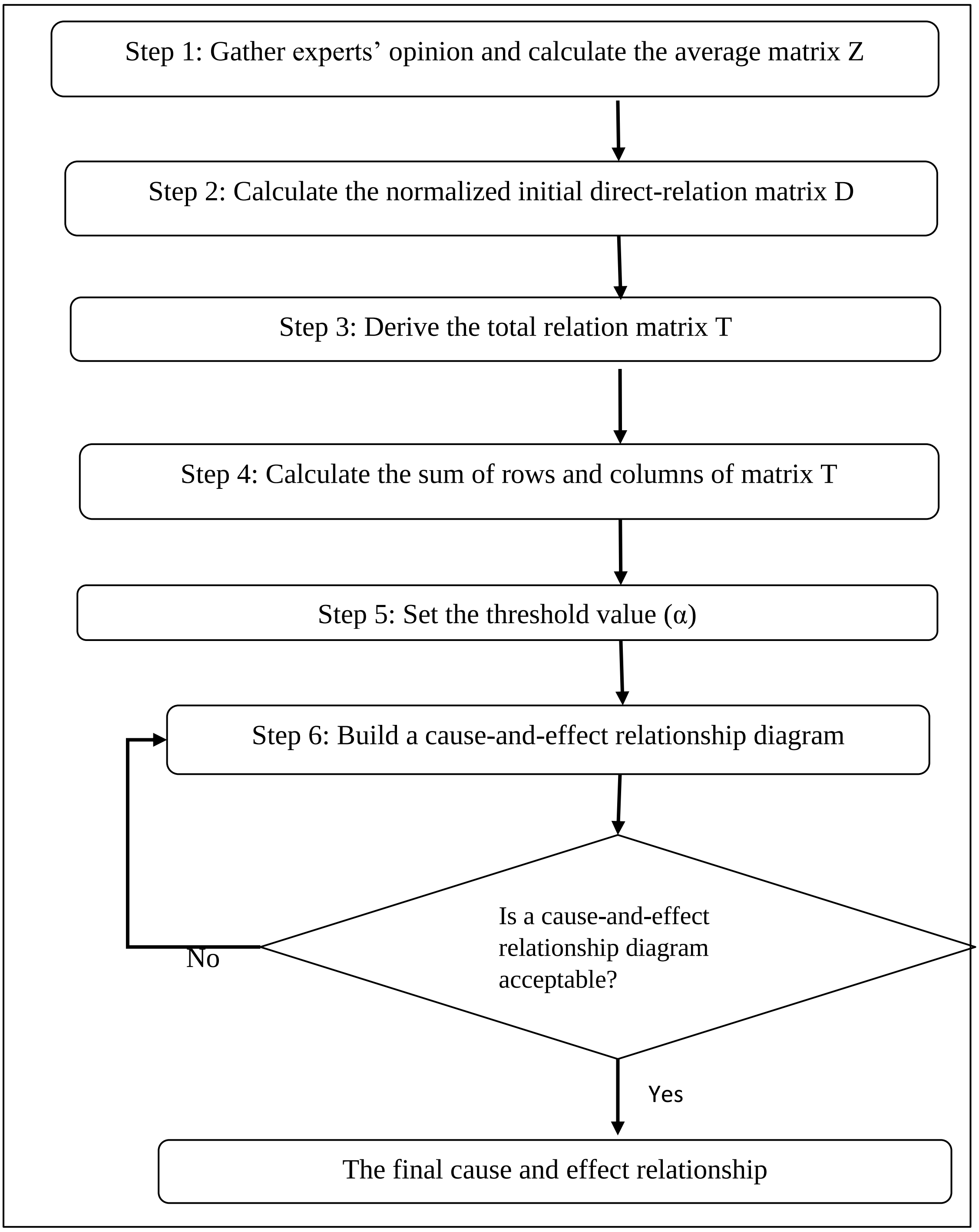


Figure 3.6: Flow Chart for DEMATEL Method

3.7.2 Data, Methods and Models for Objective 2

The objectives of irrigation system management policies are directed towards enhancing the productivity of irrigated land through effective utilization of water resources. These policies encompass the oversight of the water supply, drainage systems, and associated infrastructure to guarantee the equitable and efficient distribution of water to farmers. Additionally, these policies incorporate initiatives to encourage the adoption of contemporary irrigation technologies and farming methods that prioritise water conservation. Data Envelopment Analysis (DEA) is a technique used to evaluate how efficiently different decision-making units (DMUs) use their inputs to produce outputs. DEA method is employed to assess the comparative technical efficiency of diverse DMUs, such as farms or firms, by examining their input-output dynamics. This method involves the construction of an efficiency frontier, which represents the most efficient combination of inputs and outputs for each DMU. The efficiency frontier is built using the best practices of the most efficient DMUs, and other DMUs are assessed based on how close they are to this frontier.

This research endeavors to assess the investments and user charges gathered by Water User Associations (WUAs) in Jharkhand as outlined in Table 3.6.

Table 3.6 : Inputs and Outputs for the Study.

Input 1	The amount invested in WUA the Government of Jharkhand's Water Resources Department for meetings and additional training sessions.
Output 1	The amount collected by WUA.
Input 2	The funds allocated by both the Government of Jharkhand's Water Resources Department and the WUA for the O&M of the canals.
Output 2	Yield in crop production

Data were sourced from the Water Resources Department, Ranchi Division, and WUAs for insight into the Kanchi Irrigation Scheme. Additionally, field surveys were conducted with WUA members to gather information on the operational aspects of WUAs. In total, a sample of nine WUAs related to nine canals of the field study were chosen as Decision Making Units (DMUs), and a span of four years' worth of on-site data was compiled, encompassing various costs and outputs outlined in Table 3.6. The DMUs are Amlesha, Babaikund, Kokadih, Hesadih, Konkadih, Jargodih, Hartaldih, Chitri, and Tiruldih and the compiled data is presented in Appendix B.

The study was conducted in two phases. Initially, the performance of nine selected canals was assessed through Data Envelopment Analysis (DEA) methods, including Variable Returns to Scale (VRS) input and output-oriented approaches, along with a non-oriented Slack-Based Method (SBM). However, determining the ranks using the combined methods proved to be challenging. The second phase focused on ranking canals by integrating Shannon's entropy method with adopted DEA methods. This study aimed to provide a more precise approach for determining which blended methods should be used for ranking canals. The inclusion of a typical linear fit procedure and the coefficient of determination proved beneficial in making decisions regarding the ranks obtained through the adopted methods.

The concept of "technical efficiency" was introduced in the economic literature during the early 1950s when Koopmans (1951) defined it as an input-output vector that achieves technical efficiency if and only if increasing any output or decreasing any input is possible only by increasing any other input or decreasing any other output. This definition is recognised as the Pareto-Koopmans' condition of technical efficiency in economics. Building on Koopmans' work, Farrell (1957) made a significant contribution by creating a linear programming (LP) model using actual input-output data from a sample of businesses. Farrell's application of linear programming methods had a profound impact and eventually inspired Charnes et al. (1978) to develop Data Envelopment Analysis (DEA).

Due to its reduced reliance on assumptions regarding technology and the flexibility of mathematical programming techniques for obtaining pointwise estimates of the production function, Data Envelopment Analysis (DEA) is favoured over its counterpart, Suitability, Feasibility, and Acceptability (SFA), in the present context. DEA has inherent advantages, particularly in its capability to handle multiple inputs and outputs easily, which is a significant advantage given the common absence of such detailed information. Another distinguishing factor is that, unlike SFA, which seeks to correlate a Decision-Making Unit's (DMU) performance with statistical averages, DEA evaluates the inefficiency of a particular DMU by comparing it to similar DMUs that are considered efficient. Furthermore, DEA assists in identifying the causes of inefficiency, including factors such as scale or size inefficiency, and/or inefficiencies related to management practices (pure technical inefficiency).

3.7.2.1 Selection of the Model

Efficiency is measured by adjusting inputs or outputs in the models used for this purpose. The fundamental CCR model (Charnes et al., 1978) is based on constant returns to scale (CRS), while the BCC model (Banker, Charnes, and Cooper, 1984) is based on variable returns to scale (VRS). These models, namely the input-oriented model (IP) and output-oriented model (OP), determine efficiency either by achieving the intended outcome with minimal inputs or by maximising outputs while keeping input quantities constant. However, the BCC and radial CCR models are limited because they do not account for efficiency slack. To address this, the "slack-based model" (SBM) proposed by Tone (2001) is occasionally used to calculate the efficiency scores. The non-oriented SBM is applied when both inputs and outputs can be adjusted simultaneously, allowing the DMU to reduce inputs while increasing outputs. In their examination of the effectiveness of public hospitals in Uttarakhand, India, managers could utilize this approach to optimize efficiency concentrating on both inputs and outcomes, as demonstrated by Mogha et al. (2015) in their examination of the effectiveness of public hospitals in Uttarakhand, India. Several investigations have utilised output-and other input-oriented models, but selecting the orientation for efficiency evaluation can be challenging. Pannala et al. (2022) addressed this challenge by employing the orientation-independent CCR model, orientation-dependent BCC model, and non-oriented and non-radial SBM-DEA models in their study. They also explored the efficiency scores of hotels and restaurants in India using a combination of Data Envelopment Analysis and Shannon’s entropy.

In our current study, we adopted a similar approach to that of Pannala et al. (2022) to assess the efficiency and performance of the nine selected canals.

3.7.2.2 DEA with Shannon’s Entropy:

DEA methods, such as CCR, BCC, SBM, can categorise decision-making units (DMUs) into two distinct groups: efficient and inefficient. However, the process of ranking all DMUs or identifying the most effective among the efficient DMUs can be time consuming. Various approaches in the literature address this challenge, including super efficiency (Noura et al., 2011), cross-efficiency (Contreras, 2012), minimum and maximum efficiency scores

(Khodabakhshi and Aryavash, 2012), and the maximal balance index (Guo and Wu, 2013), among others.

When it comes to decision-making units (DMUs) using specific techniques, the selection of a particular model is typically performed in conjunction with the available dataset. However, determining the variables for this study is challenging. In such situations, it is recommended that all available DEA models (Soleimani-damaneh and Zarepisheh, 2009; Hosseinzadeh Lotfi et al., 2012; Qi and Guo, 2014; Xie et al., 2014). Subsequently, a total score was generated based on the combined data using Shannon's entropy. This combination of Shannon's entropy and DEA has found applications in engineering fields, such as in the formulation of drug gels (Kodavaty et al., 2022b) and the selection of experimental parameters (Kodavaty et al., 2022a). We followed the methodology proposed by Pannala et al. (2022) to rank DMUs using Comprehensive Efficiency Scores (CES). The chosen strategy is outlined below:

Steps for Combined Shannon's Entropy and DEA:

Step-1: Select datasets

Step-2: Create every feasible pairing of the initial data set's input and output subgroups using $L = (2^m - 1)(2^s - 1)$.

Step-3: Determine the relative efficiency scores of each DMU by evaluating the efficiency scores using DEA models (VRS-IP, VRS-OP, and SBM non oriented). As E_{jl}.

Variable returns to scale (VRS) models, that is, either the input-oriented model (IP) or output-oriented model (OP). slack-based method (SBM).

Step-4: Using the matrix $(E_{jl})_{nXL}$ determine the set $e_{jl} = \frac{E_{jl}}{\sum_{j=1}^{n} E_{jl}}$

Step-5: Determine the level of diversification set $d_l = 1 - f_l$ where $f_l = \frac{-1}{\ln(n)} \sum_{j=1}^{n} e_{jl} \ln(e_{jl})$.

Step-6: Determine the CES as $\theta_j = \sum_{l=1}^{L} w_l E_{jl}$ where $w_l = \frac{d_l}{\sum_{l=1}^{L} d_l}$ such that $\sum_{l=1}^{L} w_l = 1$.

Using MATLAB, the findings of the DEA with Shannon's entropy model are provided.

3.7.3 Data, Methods and Models for Objective 3

Purposely Selected: Jharkhand: No exhaustive study has so far been reported on Irrigation Management Transfer (IMT) in the state of Jharkhand, with special reference to the organizational and procedural aspects of IMT and Water Users' Associations (WUAs) dynamics. Therefore, Jharkhand State was chosen for this study.

Purposely Selected: Kanchi Irrigation Project: This study was planned to be conducted in a completed major/medium irrigation scheme in Jharkhand. Based on the list of 105 completed Medium and Major Irrigation projects obtained from WRD, Government of Jharkhand, four with the highest irrigation potential created were identified. In these schemes, WUAs were formed, and all three tiers were working.

Sample Size: The sample size, denoted as 'n,' was determined using Slovin's formula. Slovin's formula is given by:

$$n = N / (1 + Ne^2)$$

where, N is the population size and e is the margin of error.

The sample size of the present study was fixed based on Solvin's formula with 90% confidence level, error value of 0.10, and size of the population (Punzalan, 2012). Sample calculations for the irrigation project are described below.

N	=	Potential created/Average size of landholdings in the State of Jharkhand		
	=	18800 / 1.11	=	16937.
n	=	$16937 / (1 + 16937 \times (0.10)^2)$	=	99.

In this study, the chosen samples are individuals who are "representative and capable of providing information from various perspectives" (Ritchie & Lewis, 2003). The sampling approach encompasses both probability and non-probability designs. This investigation uses a large number of samples and depends on referral sampling (Lewis & Ritchie 2003).

Stratified Random Sampling: WUAs were selected such that they represented WUAs functioning in the head reach, middle region, and the tail end of the canal command of the selected project.

Stratified Random sampling: Approximately 99 member farmers from Water User Associations (WUAs) were selected as participants for the current study. The command area under each WUA ranged from 10 ha to 40 ha. The average landholding size in Jharkhand is

1.11 hectares, and the number of members of each WUA was expected to range from 9 to 36, with an average of 23. Thus, to arrive at a total sample size of 99 at the project level, a sample of 11 or 1/3rd of the total users, whichever is less from each of the nine selected WUAs gave a fair representation of the WUAs at the project level. It was guaranteed that in the case of a specific WUA, the chosen sample of farmers was evenly distributed, including representatives from all outlets falling within the jurisdiction of that WUA. Furthermore, at least one farmer, who was both a member of the outlet committee and owned land covered by the outlet's service area, was included in the selection.

Building on prior research, it can be asserted that, in situations where overseeing and managing a resource cannot anticipate all the consequences of their actions, learning over time becomes crucial. This entails adjusting to a variety of biophysical systems, encompassing factors like rainfall patterns, soil composition, and geological characteristics, while also navigating the cultural and economic frameworks within which they operate. The IAD framework is employed to scrutinise action situations within specific focal arenas, predicting likely interactions and outcomes. This allows for focused inquiry and effective addressing of pertinent questions in a specific area. While game-theoretical analyses often use a simplified model of human behavior to predict competitive scenarios, understanding human behavior in social dilemma situations requires a broader theory. This theory should consider the idea that individuals may be only partially rational and may also base their decisions on social norms.

In this study, we selected community attributes (Fig. Ref Section 2.4.6, under LR) and treated the Kanchi Irrigation Project System as a common pool resource (CPR). A model was developed to analyze the human-interaction situation and the participating individuals as an analytical whole. This model does not delve into the underlying exogenous variables. This study focuses on the efficiency of irrigation as the dependent variable (DV), defined in terms of timely water availability in adequate quantity, an increase in irrigated area, and reduced maintenance costs (see Section 2.2.3).

Multiple variables can be employed to analyse the likely actions of participants and the resulting outcomes. Independent variables (IVs) were identified, concentrating on the biophysical world, community attributes, and rule configurations. The internal dynamics of the group, encompassing formation, structure, processes, and their impact on individual members/farmers, other groups, and the broader organization, were considered. Ghosh et al. outlined various indicators. (2010), was used to assess the effect of the identified indicators (IVs), with each of the nine indicators evaluated based on the defined criteria.

1. Participation: Participation refers to a farmer's engagement in various Water User Association (WUA) activities. This aspect is evaluated through five statements gauging an individual farmer:
    a. Attendance in meetings,
    b. Involvement in discussions,
    c. Participation in different WUA functions (e.g., Collecting water taxes, Scheduling water delivery, Planning crops, Repairing and maintaining watercourses)
    d. Collaboration in group activities with fellow farmers,
    e. Perceptions regarding the participation of other farmers.
2. Decision making: Decision-making involves executing various WUA activities. Five statements reflecting the perspectives of individual farmers formed the basis for responses to this parameter:
    a. Ability to make decisions independently without consulting the WUA,
    b. Support for other members' suggestions leading to consensus,
    c. Preference for majority decisions through voting,
    d. Efforts to gain acceptance for the WUA's decisions from all members,
    e. Consideration of individual views before finalising decisions related to WUA activities.
3. Operation, Maintenance, and Management Functions: These tasks encompass the operation of the control system, maintenance of watercourses, and management of the irrigation system. The assessment was conducted using five statements related to these functions:
    a. Consensus among all farmers regarding the allocation of water within the group.
    b. Following a procedure for sharing water for crop irrigation.
    c. All farmers in an outlet command selecting specific crop patterns.
    d. Farmers' groups maintaining and repairing watercourses, field channels, and field drainage.
    e. Using the WUA's own funds for the maintenance of the irrigation system.
4. Group Atmosphere: Group atmosphere is evaluated through five statements reflecting;
    a. The friendliness of the atmosphere within the WUA.
    b. Efforts to suppress conflicts,
    c. Avoidance of unpleasant feelings,
    d. Balancing the diverse interests of farmers.
    e. Members' satisfaction and harmony within the group.

5. Membership Feeling: This aspect is assessed based on statements concerning:
    a. The presence of sub-groups within the WUA.,
    b. The cohesion and mutual support among members.
    c. The level of bond or loyalty to the WUA.
    d. Preferences of some members to remain passive or be outside,
    e. The occurrence of members joining and leaving the WUA based on their interests.
6. Norm: Norms refer to the rules and regulations governing the WUA, evaluated through statements related to:
    a. Each member's adherence to the rules of the WUA.
    b. Members' collaboration in upholding rules,
    c. Standards for membership disqualification,
    d. Regulation of behavior and activities,
    e. Handling of non-compliant members.
7. Empathy is the perception one farmer has of another, assessed through five statements:
    a. Being sensitive to the needs of others.
    b. Understanding others' problems,
    c. Paying attention during discussions,
    d. Dealing with irritation or anger due to others' inability to follow WUA decisions,
    e. Avoiding to discuss the interests of others..
8. Interpersonal Trust: Assessed through statements referring to:
    a. Members interacting and providing suggestions to each other.
    b. Trust in a member's competence in WUA activities,
    c. Accepting the decisions reached.
    d. Trusting the opinions of others.
    e. Keeping one's ideas to oneself and not sharing them with others.
9. Social Support: 'Social support' assesses how stable the WUA is within its area of operation, through the following five statements:
    a. Support from officials in the irrigation department on technical matters.
    b. Assistance in carrying out WUA functions.
    c. Help and inputs from other line departments,
    d. The interconnection of one WUA with others.
    e. Strengthening the skills of WUA members through training in various areas.

Individual farmers responded to various statements under each indicator, and these responses were assessed based on five statements. The farmers used a 5-point Likert scale, ranging from 1 to 5, to express their agreement or disagreement. The data collection instrument can be found in the Appendix. An analysis of farmers' responses regarding irrigation efficiency will be conducted by evaluating their agreement or disagreement with different statements. The cumulative responses of the farmers were analysed using advanced statistical techniques.

The research model was examined using structural equation modeling (SEM), with a specific focus on the direct impact of Independent Variables (IVs) on efficiency (EFFCNCY). Additionally, the study's hypotheses will be further tested through multiple regression analyses. This analysis will be conducted using SmartPLS to statistically assess the hypotheses outlined in the study.

H1: Decision making (TDCNMKNG) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H2: Empathy (TEMPTHY) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H3: Group atmosphere (TGRPATMPHR) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H4: Interpersonal trust (TINPRSTRST) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H5: Membership feeling (TMEMBFLNG) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H6: Norms/rules & regulations of the WUA (TNRMRLSREG) have a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H7: Operation, maintenance, and management (TOPRMGT) have a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H8: Participation (TPARTCPN) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

H9: Social support (TSOCSPRT) has a significantly positive impact on Canal Irrigation Efficiency (EFFCNCY).

CHAPTER 4

RESULTS AND ANALYSIS

Chapter 4

Results and Analysis

This chapter focuses on the results and analysis for exploring the answer to the research problem based on data, methods and models applied for each of the research objectives.

4.1 Analysis for Objective 1

Three methods, namely AHP, FAHP, and DEMATEL, were used to evaluate the influence and importance of issues in canal irrigation. AHP, a decision science method, was used to prioritise the issues. Both AHP and Fuzzy AHP are applied to analyze issue hierarchies, with Fuzzy AHP addressing the imprecisions associated with AHP. The results of AHP and FAHP were compared. As these methods do not account for the cause-effect relationships among issues, DEMATEL was introduced to analyze these relationships. This combination of MCDM techniques allows for a more accurate analysis, considering both cause-effect relationships and issue rankings, ensuring reliable results in the study. The abbreviations for barriers and their sub-barriers in the following discussion are as outlined in Table 3.1.

4.1.1 Utilising the AHP Approach.

The normalised weights for the primary criteria were computed and are listed in Table 4.1. The table also displays the ranking assigned to each criterion. The key criteria yielded a λmax of 5.393. This was further supported by a Consistency Index (CI) of 0.098, and a calculated Consistency Ratio (CR) of 0.0807. Because the CR value was below 0.10, it signified the adequacy of the data. The corresponding values were then substituted with the corresponding TFNs, which are detailed below in tabular format in Table 4.1.

Table 4.1: Normalised Weights of the Key Criteria (AHP)

	RS	LI	FB	CB	EE
RS	0.0612	0.0345	0.0761	0.0423	0.1765
LI	0.1837	0.1034	0.1066	0.0704	0.1765
FB	0.4286	0.5172	0.5330	0.6338	0.2941
CB	0.3061	0.3103	0.1777	0.2113	0.2941
EE	0.0204	0.0345	0.1066	0.0423	0.0588

Source: AHP analysis

The study calculated the geometric mean of the fuzzy weights, and the findings are subsequently given in tabular format in Table 4.2.

Table 4.2: Criteria Weights and Rankings

Main Criteria	Criteria Weight	Rank
RS	5.1092	5
LI	5.4862	3
FB	5.6322	1
CB	5.6092	2
EE	5.1322	4

Source: AHP analysis

As above, the Financial Barriers emerged as the most important criteria, followed by Capacity Building, Legal and Institutional Framework, External Environment and Resource System; in that order.

4.1.2 Using FAHP Method

The fuzzy AHP method tackles the inherent imprecision of the AHP method. The fuzzy AHP method provides a more accurate and logical representation of the importance levels of criteria. It offers valuable insights into the relative importance of each criterion and sub-criterion in the decision-making process. This helps in making more informed decisions. The fuzzy weights of geometric means. Table 4.3 gives the fuzzy weights of lower, middle, and upper values of geometric means along with the normalised weights. Based on the FAHP analysis (Table 4.3), the primary criteria were ultimately ranked as FB>CB>LI>RS>EE.

Table 4.3: Fuzzy Weights for the Geometric Means (wl, wm, and wu) of Both Key Criteria and Sub-Criteria.

Criteria	w_l	w_m	w_u	M_i	N_i	Rank
RS	**0.0297**	**0.0688**	**0.1860**	**0.0949**	**0.0735**	**4**
RSCI	0.1031	0.2583	0.7330	0.3648	0.2847	**2**
RSFC	0.2542	0.6370	1.4022	0.7645	0.5967	**1**
RSCR	0.0539	0.1047	0.2972	0.1519	0.1186	**3**
LI	**0.0461**	**0.1265**	**0.3542**	**0.1756**	**0.1361**	**3**
LILF	0.0539	0.1047	0.2972	0.1519	0.1186	3
LICW	0.1031	0.2583	0.7330	0.3648	0.2847	2
LIWR	0.2542	0.6370	1.4022	0.7645	0.5967	1
FB	**0.2012**	**0.4904**	**1.0808**	**0.5908**	**0.4577**	**1**
FBGF	0.1031	0.2583	0.7330	0.3648	0.2847	2
FBWC	0.0539	0.1047	0.2972	0.1519	0.1186	3
FBOM	0.2542	0.6370	1.4022	0.7645	0.5967	1
CB	**0.1057**	**0.2668**	**0.6964**	**0.3563**	**0.2760**	**2**

Criteria	w_l	w_m	w_u	M_i	N_i	Rank
CBTR	0.0531	0.1682	0.6019	0.2744	0.1766	3
CBLD	0.0160	0.0377	0.1349	0.0629	0.0405	6
CBCP	0.0259	0.0743	0.3328	0.1443	0.0929	5
CBCR	0.0989	0.3701	1.0732	0.5141	0.3308	1
CBMO	0.0695	0.2426	0.7870	0.3664	0.2357	2
CBDC	0.0338	0.1071	0.4352	0.1920	0.1236	4
EE	**0.0227**	**0.0474**	**0.1493**	**0.0731**	**0.0567**	**5**
EESE	0.0607	0.1851	0.5294	0.2584	0.1864	3
EEGD	0.1594	0.3827	1.1334	0.5585	0.4028	1
EEES	0.0199	0.0477	0.1214	0.0630	0.0455	5
EEQP	0.0838	0.2872	0.7304	0.3671	0.2648	2
EEIC	0.0330	0.0972	0.2879	0.1394	0.1005	4

Source: FAHP analysis

We have obtained the rankings of the key criteria using both the AHP and FAHP methods. Table 4.4 below compares the rankings derived from both approaches.

Table 4.4: Comparison of Criteria Weight Ranks from AHP and FAHP

Criteria	For AHP Method	For FAHP Method
RS	5	**4**
LI	3	**3**
FB	1	**1**
CB	2	**2**
EE	4	**5**

Source: AHP and FAHP analysis

The Potential Criteria in Sequence were identified through a comparison of the AHP and FAHP criteria weight ranks. This comparison is illustrated in Table 4.4 and summarized in Table 4.5.

Table 4.5 : The Potential Criteria in Sequence

RANKS	CRITERIA
4,5	RS
3	LI
1	FB
2	CB
5,4	EE

Source: AHP and Fuzzy AHP analysis.

Of the five major factors listed in this study, the "Financial Barriers" (FB) category had the highest priority.

The calculated rank correlation factor of 0.900, with a significance level (α) of 0.037 and $p < 0.01$ as shown in Table 4.6, indicates a significant relationship between the rankings obtained from the AHP and FAHP methods. This suggests that the rankings from both methods align closely and reinforce each other. The complementary nature of the AHP and FAHP applications underscores their consistency and reliability in providing accurate results, enhancing the overall robustness of the analysis. Along these lines, the ranking of the five components RS, LI, FB, CB, and EE considered in this investigation utilising both AHP and FAHP methods are shown. A slight change in the weight provided to the category with the highest ranking may have an impact on the other categories (see Table 4.6).

Table 4.6: *P*-value for Rank Correlation

Sample 1	Sample 2	*N*	Correlation	*P*-value
RANK 1(AHP)	RANK 2 (FAHP)	5	0.900	.037

The AHP method is pivotal in evaluating the importance of criteria in decision-making, offering a ranking of key criteria based on their significance. This ranking aids in making well-informed decisions. In contrast, the Fuzzy AHP method is tailored to address the inherent imprecisions present in the traditional AHP approach, offering a more accurate and logical representation of the importance levels of the criteria. This method offers valuable insights into the importance of each criterion and sub-criterion in decision-making. The results can help develop an effective decision-making model that considers the importance of each criterion and sub-criterion. When comparing the rankings derived from the AHP and FAHP analyses, the order of importance for the key criteria is as follows: Financial Barriers (FB) is the most critical criterion, followed by CB, LI, RS, and EE.

4.1.3 Sensitivity Analysis

Sensitivity analysis is a technique that evaluates how changes in the weights assigned to criteria impact the overall ranking. It helps assess the ranking's stability and robustness by examining how sensitive it is to variations in these weights. By systematically adjusting the weights and observing the resulting changes in the ranking, decision-makers can understand the ranking's reliability and the potential effects of uncertainties in the weight assignments. In this study, sensitivity analysis was employed to address the variances among the variables. Table 4.7 depicts the effect of a small shift in the weight given to the highest ranked category, ‘Financial barriers’ (FB) on rest of the categories.

Table 4.7: Sensitivity Analysis of the Primary Criteria with Variations in the "FB" Criteria Weight from (0.4577*0.9... 0.4577*0.1)

Barriers	Normalised FB=.4577	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FB	1	1	1	1	1	1	1	1	1	1
CB	2	2	2	2	2	2	2	2	2	2
LI	3	3	3	3	3	3	3	3	3	3
RS	4	4	4	4	4	4	4	4	4	5
EE	5	5	5	5	5	5	5	5	5	4

Source: Sensitivity Analysis

As a result, instead of using 0.4577(FB), the weight assigned to the extensively prioritised category could be altered to 0.4577*0.9 or 0.4577 × 0.8. Using four decimal places, the formula is 0.4577 × 0.1. Refer to Figure 4.1 for illustration of the awareness examination.

.

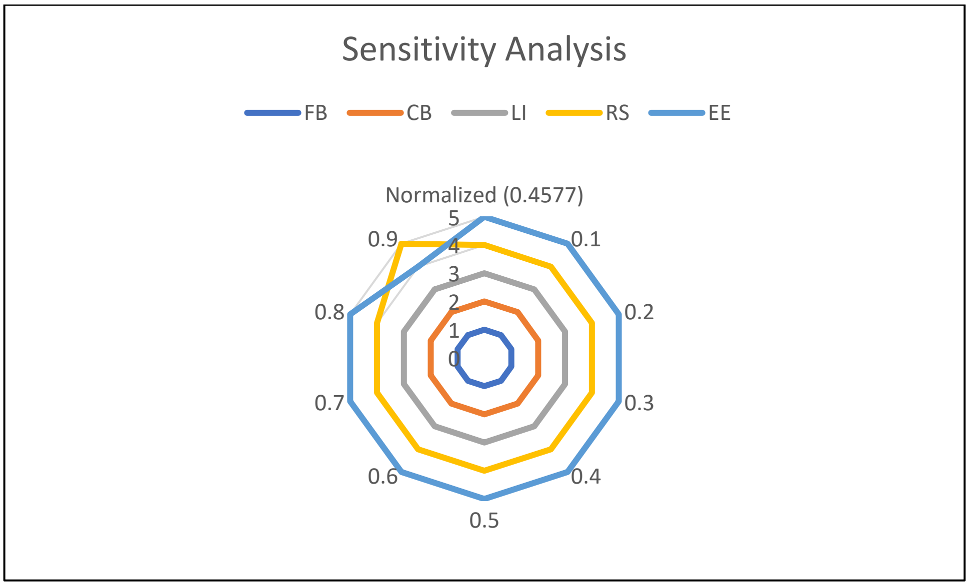


Figure 4.1: Results of Sensitivity Analysis for Criteria

4.1.4 Applying the DEMATEL Method

The DEMATEL method was applied to explore the cause-and-effect relationships among the five primary criteria, revealing how they are interconnected. This method helps analyze the influence each criterion has on the others, providing insights into their interdependencies. The comparison scale used to create a direct relation matrix for DEMATEL is specified below in Table 4.8, aiding in the assessment of these relationships.

Table 4.8: Scale of Comparison for the DEMATEL Technique

Scale	0	1	2	3	4
Level of Influence	No influence	Low influence	Medium influence	High influence	Very High influence

In Table 4.9 below, the matrix represents the total relation with the sum of each row denoted as Ri and the sum of each column denoted as Ci. These sums offer insights into the overall relationships and dependencies among the criteria analyzed using the DEMATEL method.

Table 4.9: Total Relation Matrix

	RS	LI	FB	CB	EE
RS	0.3965	0.3696	0.5376	0.4431	0.5395
LI	0.4756	0.2439	0.4339	0.3351	0.4788
FB	0.7786	0.5802	0.4576	0.5421	0.7264
CB	0.5893	0.4235	0.4269	0.3050	0.6018
EE	0.3840	0.3017	0.3950	0.3727	0.3062

Table 4.10 illustrates the cause-and-effect relationships among the five main criteria, the same is depicted in Figure 4.2.

Table 4.10: Cause and Effect of Criteria

code	Ri	Ci	Ri+Ci	Ri-Ci	Identity	Rank
RS	2.2862	2.6240	4.9102	-0.3378	Effect	2
LI	1.9673	1.9188	3.8861	0.0485	Cause	5
FB	3.0849	2.2511	5.3360	0.8338	Cause	1
CB	2.3464	1.9979	4.3443	0.3486	Cause	4
EE	1.7597	2.6527	4.4124	-0.8930	Effect	3

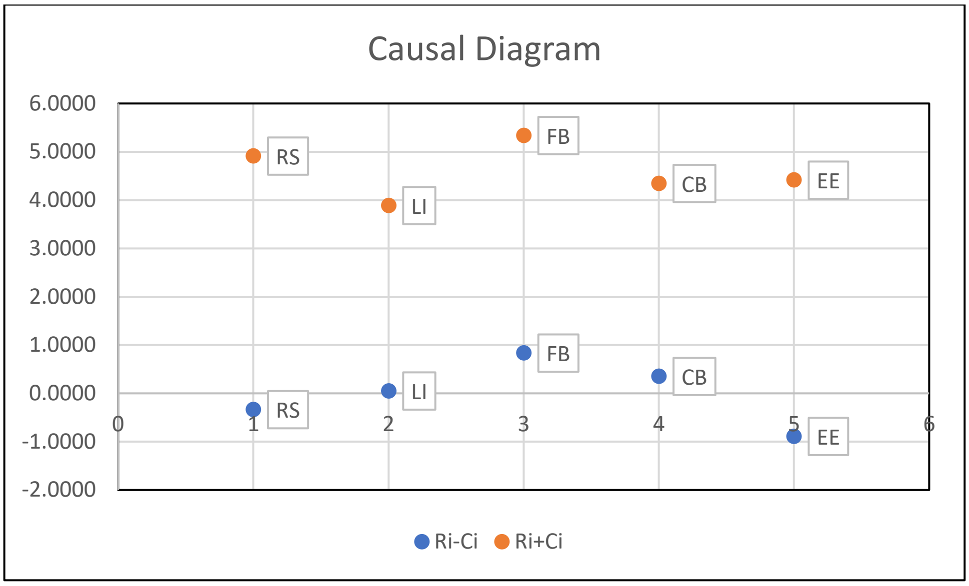


Figure 4.2: Cause and effect analysis with DEMATEL

The findings indicate that Financial Barriers (FB) exerted the most significant influence on the other criteria, establishing it as a causal criterion directly affecting the rest. Likewise, Capacity Building (CB) and the External Environment (EE) are also categorised as causal criteria. In contrast, Resource Availability (RS) and Legal Implications (LI) are recognised as consequential criteria, indicating that they are directly influenced by other criteria, as depicted in Figure 4.2.

4.2 Analysis for Objective 2

This study comprised two distinct phases. In the initial phase, we assessed the performance of nine chosen canals in India using DEA techniques, including VRS input and output-oriented methods, as well as the non-oriented slack-based method (SBM). The second phase involved ranking these canals using Shannon's entropy method in conjunction with the adopted DEA methods. The outcomes are presented in Tables 4.11, 4.12 and 4.13 and Figure 4.3 to 4.6, based on the datasets of the nine selected canals for the years 2018 to 2021.

Table 4.11 presents the efficiency scores for all canals from 2018 to 2021, calculated using VRSIP, VRSOP, and SBM.

Table 4.11: Efficiency of Canals Implementing VRSIP, VRSOP, and SBM from 2018 to 2021

	Efficiencies using VRSIP				Efficiencies using VRSOP				Efficiencies using SBM			
DMU	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**
Canal1	0.9487	0.8392	1	0.8778	0.9678	0.969	1	0.9472	0.9364	0.6679	1	0.8243
Canal2	1	0.7177	0.8403	1	1	0.9002	0.9495	1	1	0.7142	0.6148	0.8746
Canal3	1	0.9365	0.9955	0.9512	1	0.9589	0.9989	0.9653	1	0.8635	0.8925	0.7964
Canal4	0.9217	1	1	0.9384	0.9367	1	1	0.9554	0.8603	1	1	0.6941
Canal5	1	1	0.9024	1	1	1	0.9094	1	1	1	0.7539	1
Canal6	0.9901	1	0.9795	1	0.9901	1	0.9795	1	0.986	1	0.7841	1
Canal7	0.7863	0.7346	0.8187	0.879	0.7863	0.7836	0.8238	0.8939	0.7665	0.5833	0.6112	0.6984
Canal8	1	0.9188	0.9998	0.6626	1	0.9188	0.9998	0.6626	1	0.6749	0.9079	0.6074
Canal9	1	0.8545	0.99	1	1	0.8545	0.99	1	1	0.6003	0.876	1

Table 4.11 illustrates that the count of efficient canals and Decision-Making Units (DMUs) remains consistent across the applied methodologies for the corresponding years. Canal 7 consistently exhibits inefficiency across all years, whereas Canal 5 demonstrates efficiency for three years. Notably, no canal maintained its efficiency for all four years. In 2018, five canals were efficient: four in 2021, three in 2019, and only two in 2020. The fluctuating number of efficient canals each year poses challenges in categorising canals as either consistently efficient or inefficient. To address this issue, a novel methodology was introduced to segregate and rank the canals. The adopted methods were integrated with Shannon's entropy to compute comprehensive efficiency scores (CES). These scores are presented in Table 4.12.

Table 4.12: Comprehensive Efficiency Scores for all Canals from 2018 to 2021

	CES using VRSIP				CES using VRSOP				CES using SBM			
DMU	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**
Canal1	0.8051	0.6381	0.7877	0.7608	0.8918	0.8029	0.9855	0.8331	0.7897	0.6265	0.7026	0.7066
Canal2	0.8398	0.6828	0.6343	0.892	0.9244	0.8798	0.8026	0.9702	0.8061	0.6838	0.5854	0.8218
Canal3	0.8662	0.8043	0.8996	0.7315	0.9038	0.8826	0.9008	0.8103	0.8684	0.8183	0.8874	0.6754
Canal4	0.7464	0.7772	0.9988	0.6305	0.8661	0.8202	0.9984	0.7343	0.7358	0.7535	0.9991	0.5858
Canal5	0.9667	0.9604	0.7245	0.9325	0.9875	0.9936	0.8804	0.948	0.8493	0.9702	0.7062	0.8668
Canal6	0.8414	0.8482	0.6761	0.964	0.9126	0.797	0.8351	0.9895	0.835	0.6667	0.6524	0.8823
Canal7	0.6508	0.5281	0.5946	0.6573	0.6858	0.556	0.6469	0.6701	0.6499	0.546	0.5726	0.6033
Canal8	0.8429	0.6167	0.7395	0.5249	0.8919	0.5314	0.7563	0.5516	0.8621	0.6088	0.733	0.5216
Canal9	0.8145	0.5368	0.9156	0.9299	0.8212	0.5359	0.8959	0.9116	0.8137	0.5485	0.8955	0.9235

Canal 7 consistently recorded the lowest Comprehensive Efficiency Score (CES) among all canals for each year, based on their respective adopted methods. Notably, each canal exhibited a unique CES in each corresponding year, facilitating a straightforward ranking, as illustrated in Table 4.13.

Table 4.13: Rankings for all Canals Utilising VRSIP, VRSOP, and SBM CES

	Ranks using VRSIP-CES				Ranks using VRSOP-CES				Ranks using SBM-CES			
DMU	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**
Canal1	7	6	4	5	6	5	2	5	7	6	6	5
Canal2	5	5	8	4	2	3	7	2	6	4	8	4
Canal3	2	3	3	6	4	2	3	6	1	2	3	6
Canal4	8	4	1	8	7	4	1	7	8	3	1	8
Canal5	1	1	6	2	1	1	5	3	3	1	5	3
Canal6	4	2	7	1	3	6	6	1	4	5	7	2
Canal7	9	9	9	7	9	7	9	8	9	9	9	7
Canal8	3	7	5	9	5	9	8	9	2	7	4	9
Canal9	6	8	2	3	8	8	4	4	5	8	2	1

Table 4.13 shows that canal rankings change from year to year, illustrating that the blended methodology effectively facilitates canal ranking.

However, determining ranks using blended methods is challenging. As a solution, a more precise approach is recommended to select one of the blended methods for ranking canals. This involves employing a standard linear fitting procedure and assessing the R-squared value to determine the ranks derived from the adopted methods.

Figures 17–20 depict the linear relationships between the ranks derived from CES values obtained through the adopted methods and the corresponding R-squared values.

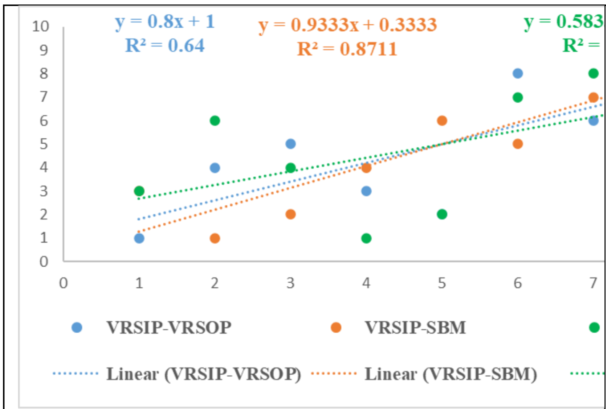


Figure 4.3: Linear fit and R-squared values between ranks based on CES values assessed using chosen techniques for the year 2018.

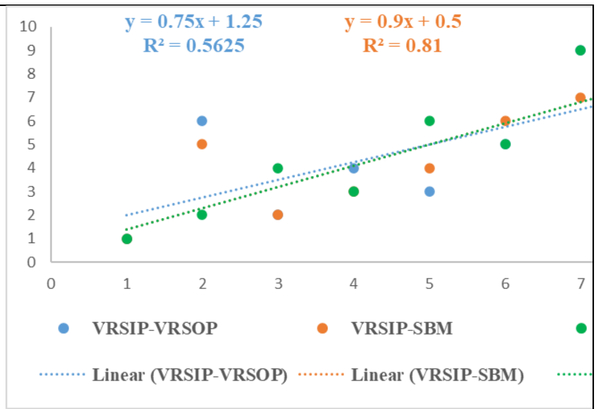


Figure 4.4: Linear fit and R-squared values between ranks based on CES values assessed using chosen techniques for the year 2019.

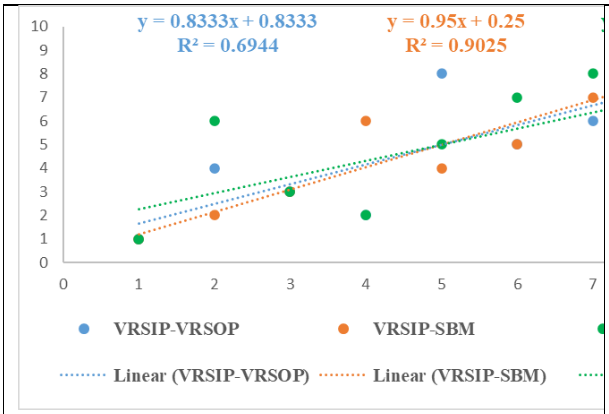


Figure 4.5: Linear fit and R-squared values between ranks based on CES values assessed using chosen techniques for the year 2020.

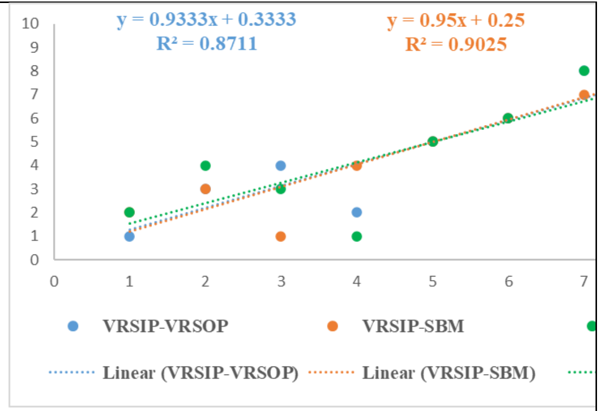


Figure 4.6: Linear fit and R-squared values between ranks based on CES values assessed using chosen techniques for the year 2021.

Specifically, Figures 4.3 and 4.5 reveal a notably low R-squared value when comparing the ranks derived from the (CES) values obtained through the VRSOP and SBM. Moreover, Figures 4.3, 4.4, and 4.5 indicate moderate R-squared values for the ranks derived from CES values of VRSIP and VRSOP. Additionally, the relationship between the ranks obtained through CES values of VRSIP and SBM methods appears strong, as shown in Figures 4.3–4.6. The results presented in these figures highlight that there is either a moderate or strong relationship that can be considered when selecting one of the adopted methods for ranking canals. Notably, ranks derived from CES values of VRSIP consistently demonstrated moderate to strong relationships with ranks obtained using CES values from VRSOP and SBM methods, emphasising the appropriateness of ranks derived from VRSIP for further exploration in canal rankings.

4.3 Analysis for Objective 3

For RO3, the study introduces the Kanchi Irrigation Project System as a CPR and develops a model to analyze human interactions within it, focusing on the Efficiency of Irrigation as the Dependent Variable (DV). The IAD framework is employed to center on action situations within a specific focal arena, considering probable interactions and outcomes. This approach enables concentration of efforts to predict events within a focused area by deliberately narrowing the scope of inquiry, allowing for a more effective exploration of specific questions. Multiple Independent Variables were identified to study likely participant actions and outcomes, multiple Independent Variables (IVs) are identified, including biophysical factors, community attributes, and rule configurations. The internal nature of groups and their formation, structures, processes, and impact on individuals and organizations have been chosen based on prior research. In this research, indicators developed by Ghosh et al. (2010) were utilised to evaluate the impact of independent variables (IVs), focusing on nine specific indicators related to group dynamics. These indicators encompass a wide range of aspects including participation, styles of influence, decision making processes, task functions, maintenance functions, group atmosphere, membership feelings, norms, empathy, interpersonal trust, and group achievements. The SEM model (Figure 4.7) examines the direct effect of IVs on efficiency (EFFCNCY). The research model underwent further exploration using structural equation modeling (SEM), with the study's hypotheses further tested using multiple regression analysis. Multiple regression analysis was conducted using SmartPLS to statistically examine the hypotheses.

4.3.1 Confirmatory Factor Analysis

Convergent and discriminant validity evaluations, along with a review of construct composite reliability, were conducted to assess the measurement model's goodness of fit. (Hsu and Lin, 2008; Lim, 2015). The dependability of the constructions was assessed using composite reliability, a measure of construct reliability (Fornell and Larcker, 1981). A threshold value exceeding 0.70 is considered suitable for composite dependability, according to Liu and Wang (2016). In our analysis, all components showed reliability values between 0.797 and 0.914, surpassing the threshold value (Table 4.14). Moreover, the Cronbach's alpha coefficient for each construct was above 0.70. (Hair et al., 2014). Factor loadings and average variance extracted (AVE) were utilized to assess convergent validity (Fornell and Larcker, 1981). Hair, Ringle, and Sarstedt (2011) predicted an AVE of over 0.50 and factor loadings above 0.60. In our study, all constructions showed AVEs above the 0.50 threshold, ranging from 0.551 to 0.697, and item loadings that exceeded the threshold of 0.60, ranging from 0.707 to 0.880. Consequently, there were no issues with the convergent validity of this instrument. Moreover, the rho_A values surpassed the threshold of 0.70, ranging from 0.853 to 0.950. Furthermore, the variance inflation factors (VIF) indicated no concerns regarding high correlations among the items, ensuring that there were no occurrences of cross-high correlation.

Table 4.14: Factor Loadings, CR, AVE and Sqr. AVE

variables	Items	Factor Loadings	VIF	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Efficiency	EFFCNCY	0.834	2.51	0.913	0.914	0.932	0.697
Decision making is the procedure of carrying out different	TDCNMKNG1	0.825	1.89	0.888	0.902	0.917	0.688
	TDCNMKNG2	0.832	2.17				
	TDCNMKNG3	0.830	2.46				
	TDCNMKNG4	0.837	2.21				
	TDCNMKNG5	0.824	2.45				
Empathy is defined as one farmer' s perceptions	TEMPTHY1	0.851	2.22	0.869	0.873	0.905	0.656
	TEMPTHY2	0.811	1.99				
	TEMPTHY3	0.754	1.73				
	TEMPTHY4	0.805	1.96				
	TEMPTHY5	0.825	2.16				
Group atmosphere	TGRPATMPHR1	0.810	2.04	0.851	0.856	0.893	0.625
	TGRPATMPHR2	0.779	1.71				
	TGRPATMPHR3	0.766	1.82				
	TGRPATMPHR4	0.796	1.85				
	TGRPATMPHR5	0.803	1.73				
Interpersonal trust	TINPRSTRST1	0.806	1.98	0.868	0.872	0.904	0.654
	TINPRSTRST2	0.775	1.71				
	TINPRSTRST3	0.858	2.29				
	TINPRSTRST4	0.808	2.02				
	TINPRSTRST5	0.794	1.93				
Membership feeling	TMEMBFLNG1	0.765	1.79	0.844	0.870	0.888	0.614
	TMEMBFLNG2	0.833	1.79				
	TMEMBFLNG3	0.799	1.88				
	TMEMBFLNG4	0.807	1.92				
	TMEMBFLNG5	0.707	1.49				
Norm refers to the rules and regulations of the WUA.	TNRMRLSREG1	0.744	1.59	0.796	0.797	0.860	0.551
	TNRMRLSREG2	0.749	1.59				
	TNRMRLSREG3	0.739	1.52				
	TNRMRLSREG4	0.730	1.45				
	TNRMRLSREG5	0.749	1.56				
Operation, maintenance and management functions of	TOPRMGT1	0.880	2.66	0.862	0.875	0.901	0.645
	TOPRMGT2	0.789	1.98				
	TOPRMGT3	0.831	2.14				
	TOPRMGT4	0.758	1.83				
	TOPRMGT5	0.750	1.89				
Participation is referred to as involvement of a farmer in	TPARTCPN1	0.797	2.01	0.877	0.882	0.910	0.670
	TPARTCPN2	0.815	2.01				
	TPARTCPN3	0.843	2.26				
	TPARTCPN4	0.809	2.18				
	TPARTCPN5	0.829	2.18				
Social support is the stability of the WUA in its area of	TSOCSPRT1	0.822	1.98	0.847	0.851	0.891	0.620
	TSOCSPRT2	0.818	1.97				
	TSOCSPRT3	0.771	1.64				
	TSOCSPRT4	0.761	1.74				
	TSOCSPRT5	0.764	1.73				

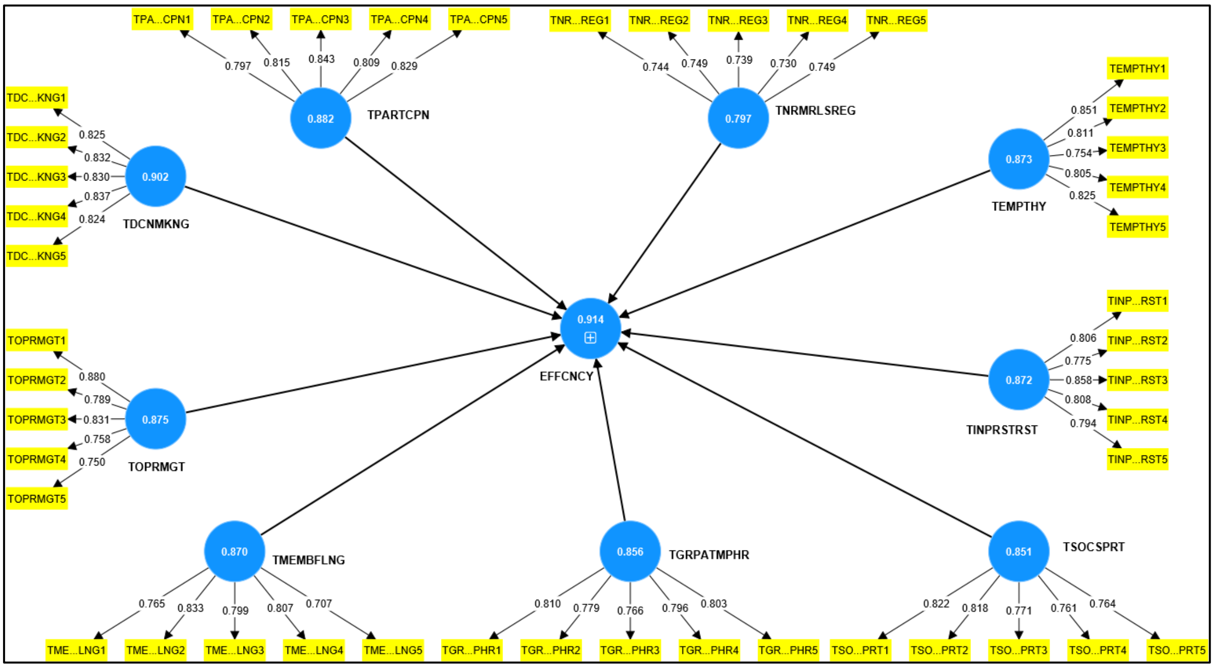


Figure 4.7: Measurement Model

Traditionally, the instrument's discriminant validity was assessed by comparing the square root of the average variance extracted (AVE) with the correlation between constructs, a method introduced by Fornell and Larcker (1981). However, this approach has been criticized by several researchers. (Benitez, Henseler, Castillo, and Schuberth, 2019; Fornell and Larcker, 1981). To address these issues, Henseler, Ringle, and Sarstedt (2015) proposed using Heterotrait-Monotrait (HTMT) ratios to assess the discriminant validity of constructs. According to this approach, the HTMT ratio should be less than 0.85 (Henseler et al., 2015; Benitez et al., 2019; Ogbeibu, Senadjki, & Gaskin, 2018). In our study, the HTMT ratios for all constructs ranged from 0.167 to 0.718, falling below the 0.85 threshold (see Table 4.15), thus confirming discriminant validity.

Table 4.15: Heterotrait-Monotrait (HTMT) Ratio

	EFFCNCY	TDCNMKNG	TEMPTHY	TGRPATMPHR	TINPRSTRST	TMEMBFLNG	TNRMRLSREG	TOPRMGT	TPARTCPN	TSOCSPRT
EFFCNCY										
TDCNMKNG	0.558									
TEMPTHY	0.712	0.275								
TGRPATMPHR	0.632	0.297	0.542							
TINPRSTRST	0.661	0.210	0.539	0.626						
TMEMBFLNG	0.506	0.258	0.579	0.483	0.291					
TNRMRLSREG	0.686	0.336	0.424	0.449	0.521	0.291				
TOPRMGT	0.474	0.167	0.432	0.190	0.253	0.308	0.265			
TPARTCPN	0.718	0.356	0.647	0.527	0.589	0.348	0.530	0.269		
TSOCSPRT	0.617	0.306	0.413	0.328	0.415	0.221	0.362	0.324	0.499	

Before testing the model, we assessed its fit using the Standardised Root Mean Square Residual (SRMR). We also considered the Normed Fit Index (NFI) and conducted a detailed assessment based on bootstrapped statistical inference. Values below 0.08 (per Hu & Bentler, 1998) indicate a satisfactory match. SRMR evaluates the degree of congruence between the observed correlations and the correlations predicted by the model. SRMR is a PLS-SEM-specific fitting metric developed by Henseler et al. (2014) to help identify and avoid model misspecification. The chi-square value for the proposed model is benchmarked for comparison in the second measure of fit, called NFI (Bentler & Bonett, 1980). NFI values greater than 0.9 are often suggestive of a good match.

The third criterion for assessing fit examines how well the empirical covariance matrix matches the covariance matrix implied by the composite factor model, using statistical inference with bootstrapping. This helps determine the precise fit of the model. Dijkstra and Henseler (2015a, 2015b) presented two distinct methods, d_LS (squared Euclidean distance) and d_G (geodesic distance), to quantify this discrepancy. A well-fitted model should have a minimal difference between the correlation matrices implied by the model and the empirical correlation matrix. This indicates that any difference is likely due to sampling error. Therefore, the difference between the correlation matrices of the model and empirical data should not be statistically significant ($p > 0.05$). Henseler et al. (2016) suggested that both dULS and dG should be smaller than the 95% bootstrapped quantile (HI 95% for dULS and HI 95% for dG).

The fit indices for both the saturated model (measurement) and the estimated model (structural model) are nearly identical. This is because our model is saturated, meaning it has no free parameters. Both the saturated and estimated models' SRMR values are 0.069, which is below the generally recognised threshold point of 0.08 and suggests a satisfactory match. The NFI score, however, was 0.598, which is below the ideal threshold point of 0.90, but still within a tolerable range. Further evidence that the data are getting close to a good fit with the model comes from the fact that the d_ULS value is lower than the bootstrapped HI 95% of d_ULS, and the d_G value is lower than the bootstrapped HI 95% of d_G. Nonetheless, the whole approach fell short of achieving the necessary degree of satisfaction. The study's large number of variables, along with its relatively small sample size of 99 respondents, may be a contributing factor. The degrees of freedom are constrained by this restriction, which makes it difficult to obtain an optimal model fit (Table 4.16).

Table 4.16 : Model Fit Indices

	Saturated model	Estimated model
SRMR	0.069	0.069
d_ULS	6.395	6.395
d_G	3.647	3.647
Chi-square	1634.468	1634.468
NFI	0.598	0.598

4.3.2 Correlation and Descriptive Statistics

Tables 4.17 and 4.18 present the findings of the descriptive statistics and correlation analyses. According to the descriptive data, the average response score for effectiveness (EFFCNCY) was 3.51 (Standard Deviation = 1.007). Additionally, TDCNMKNG had an average score of 2.81 (standard deviation: 0.995). The average value for TEMPTHY was 3.26, with a standard deviation of 1.054. The average TGRPATMPHR response score was 3.77 (Std Dev = 0.822). The TINPRSTRST average value was 3.31 with a standard deviation of 1.003. TMEMBFLNG had an average score of 3.62 (Std Dev = 0.912). The other constructs such as TNRMRLSREG, TOPRMGT and TPARTCPN average responses are 3.31 (Std Dev = 0.856), 3.02 (Std Dev = 0.975) and 3.32 (Std Dev = 1.019) respectively. The TSOCSPRT had a mean responses of 3.31 (Std Dev = 0.997).

Kurtosis and skewness were employed to assess whether the indicators conform to the assumptions of a normal distribution (Kline, 2005). Kurtosis measurements were used to determine the degree of normality or abnormality of the distribution curve. A leptokurtic curve, which deviates from normality, is characterised by a pronounced peak and shorter tail. Conversely, platykurtic curves are flatter than standard curves, with a smaller peak and longer tails. Skewness is linked to asymmetry, where positive skewness indicates scores clustered below the mean, and negative skewness indicates the opposite. Both skewness and kurtosis contribute to deviations from the symmetrical shape of the normal curve. Descriptive statistics allowed for the assessment of skewness and kurtosis. According to Brown (2006), the acceptable skewness and kurtosis ranges for structural equation modelling (SEM) are generally between -3 and +3. SEM is often resilient; therefore, small departures from these bounds may not signify serious adherence to assumptions.

The Skewness and kurtosis of the data are listed in Table 4.17. The permissible range for the skewness values was between -0.669 and 0.183. Kurtosis readings, which were within the usual range of -1.112 to 0.876, were similar. These results support a normal distribution of the data. In this study, Pearson correlation coefficients were calculated to examine the associations between variables. The results of these computations are detailed in Table 4.18, which provides insights into the relationships among the variables under investigation.

Table 4.17: Descriptive Statistics

	Mean	Std. Deviation	Skewness	Kurtosis
TPARTCPN	3.32	1.019	-0.490	-0.905
TDCNMKNG	2.81	0.995	0.183	-0.962
TOPRMGT	3.02	0.975	-0.137	-0.888
TFUNDGENR	3.27	1.064	-0.259	-1.112
TGRPATMPHR	3.77	0.822	-1.029	0.876
TMEMBFLNG	3.62	0.912	-0.881	0.195
TNRMRLSREG	3.31	0.856	-0.449	-0.524
TEMPTHY	3.26	1.054	-0.363	-1.073
TINPRSTRST	3.31	1.003	-0.407	-0.799
TSOCSPRT	3.31	0.997	-0.435	-0.796
EFFCNCY	3.51	1.007	-0.669	-0.753
Valid N (listwise) 99				

Table 4.18: Correlation Analysis

	EFFCNCY	TDCNMKNG	TEMPTHY	TGRPATMPHR	TINPRSTRST	TMEMBFLNG	TNRMRLSREG	TOPRMGT	TPARTCPN	TSOCSPRT
EFFCNCY	**0.835**									
TDCNMKNG	0.518	**0.829**								
TEMPTHY	0.637	0.246	**0.810**							
TGRPATMPHR	0.564	0.276	0.469	**0.791**						
TINPRSTRST	0.592	0.175	0.470	0.541	**0.809**					
TMEMBFLNG	0.459	0.240	0.501	0.418	0.252	**0.783**				
TNRMRLSREG	0.588	0.293	0.360	0.373	0.439	0.234	**0.742**			
TOPRMGT	0.425	0.153	0.375	0.150	0.212	0.264	0.224	**0.803**		
TPARTCPN	0.648	0.325	0.566	0.461	0.519	0.305	0.448	0.237	**0.819**	
TSOCSPRT	0.547	0.274	0.365	0.284	0.359	0.175	0.301	0.275	0.440	**0.787**

Table 4.18 presents the outcomes of examining the relationships between the variables by obtaining Pearson correlation coefficients.

- TDCNMKNG (r = 0.518), TEMPTHY (r = 0.637), TGRPATMPHR (r = 0.564), TINPRSTRST (r = 0.592), and TMEMBFLNG (r = 0.459) were positively correlated with EFFCNCY.
- TDCNMKNG was positively correlated with TEMPTHY (r = 0.246), TGRPATMPHR (r = 0.276), TINPRSTRST (r = 0.175), and TMEMBFLNG (r = 0.240).
- TDCNMKNG relationships between TDCNMKNG and TNRMRLSREG (r = 0.293), TOPRMGT (r = 0.153), TPARTCPN (r = 0.325), and TSOCSPRT (r=0.274) were positive.
- EFFCNCY association was positive for TNRMRLSREG (r = 0.588), TOPRMGT (r = 0.425), TPARTCPN (r = 0.648), and TSOCSPRT (r=0.547).
- TEMPTHY association was positive for TGRPATMPHR (r = 0.469), TINPRSTRST (r = 0.470), and TMEMBFLNG (r = 0.501).
- TEMPTHY was positively correlated with TNRMRLSREG (r = 0.360), TOPRMGT (r = 0.375), TPARTCPN (r = 0.566), and TSOCSPRT (r=0.365).
- TGRPATMPHR correlations between TGRPATMPHR and TINPRSTRST (r = 0.541) and TMEMBFLNG (r = 0.418) were positive.
- TGRPATMPHR was positively correlated with TNRMRLSREG (r = 0.373), TOPRMGT (r = 0.150), TPARTCPN (r = 0.461), and TSOCSPRT (r=0.284).
- TINPRSTRST and TMEMBFLNG showed a positive relationship (r = 0.252).
- TINPRSTRST was positively related to TNRMRLSREG (r = 0.439), TOPRMGT (r = 0.212), TPARTCPN (r = 0.519), and TSOCSPRT (r=0.359).
- TMEMBFLNG was positively correlated with TNRMRLSREG (r = 0.234), TOPRMGT (r = 0.264), TPARTCPN (r = 0.305), and TSOCSPRT (r=0.175).
- TNRMRLSREG relationships with TOPRMGT (r = 0.224), TPARTCPN (r = 0.448), and TSOCSPRT (r=0.301) were positive.
- TOPRMGT assessment was positive for TPARTCPN (r=0.237) and TSOCSPRT (r=0.275).
- TPARTCPN and TSOCSPRT were positively correlated (r = 0.440).

The explanatory factors, especially those among the independent variables, showed weak-to-moderate correlations. This indicates that the independent variables did not exhibit any multicollinearity issues. In addition, the diagonal numbers show the average extracted variance square root (AVE). The AVE values' square roots of the AVE values were greater than the correlations between the variables, proving the discriminant validity of the instruments.

4.3.3 Multivariate Analysis

Through structural equation modelling, the research model was further examined. The study's hypotheses were further investigated through multiple regression analysis. To statistically assess the study's hypothesis, multiple regression analysis was carried out using Smart PLS. The results are as follows.

The direct impact of IVs on EFFCNCY was investigated using the SEM model (Figure 4.8). Table 4.19 presents the study outcomes.

H1 evaluates whether Decision making (TDCNMKNG) referred to as involvement of a farmer in different WUA activities significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). TDCNMKNG had a positive and significant ($\beta = 0.235$, $p < 0.001$, $f^2 = 0.191$) effect on EFFCNCY. Hence, H1 was supported.

H2 evaluates whether Empathy (TEMPTHY) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TEMPTHY was positively and significantly associated with EFFCNCY ($\beta = 0.153$, $p < 0.05$, $f^2 = 0.049$) associated with EFFCNCY. Hence, H2 was supported.

H3 evaluates whether Group atmosphere (TGRPATMPHR) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TGRPATMPHR impact of TGRPATMPHR on EFFCNCY was positive and insignificant ($\beta = 0.100$, $p > 0.05$, $f^2 = 0.025$). Hence, H3 was not supported.

H4 evaluates whether Interpersonal trust (TINPRSTRST) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TINPRSTRST ($\beta = 0.155$, $p > 0.05$, $f^2 = 0.057$) has positive and significant impact on EFFCNCY. Hence, H4 was supported.

H5 evaluates whether Membership feeling (TMEMBFLNG) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TMEMBFLNG ($\beta = 0.092$, $p > 0.05$, $f^2 = 0.024$) has insignificant impact on EFFCNCY Hence, H5 was not supported.

H6 evaluates whether Norms/rules & regulations of the WUA (TNRMRLSREG) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TNRMRLSREG was positively and significantly associated with EFFCNCY ($\beta = 0.193$, $p < 0.01$, $f^2 = 0.111$) associated with EFFCNCY. Hence, H6 was supported.

H7 evaluates whether Operation, maintenance and management (TOPRMGT) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TOPRMGT had a significant ($\beta = 0.137$, $p < 0.05$, $f^2 = 0.065$) and positive association with EFFCNCY. Hence, H7 was supported.

H8 evaluates whether Participation (TPARTCPN) significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TPARTCPN was positive and insignificant ($\beta = 0.137$, $p > 0.05$, $f^2 = 0.041$) impact on EFFCNY. Hence, H8 was not supported.

H9 evaluates whether social support (TSOCSPRT)significantly and positively affects the Canal Irrigation Efficiency (EFFCNCY). The results revealed that TSOCSPRT had a positive and significant ($\beta = 0.171$, $p < 0.01$, $f^2 = 0.090$) effect on EFFCNCY. Hence, H9 was supported.

The R-square of this model was 0.763. This demonstrates that these IVs account for 76.3% of the efficiency variance.

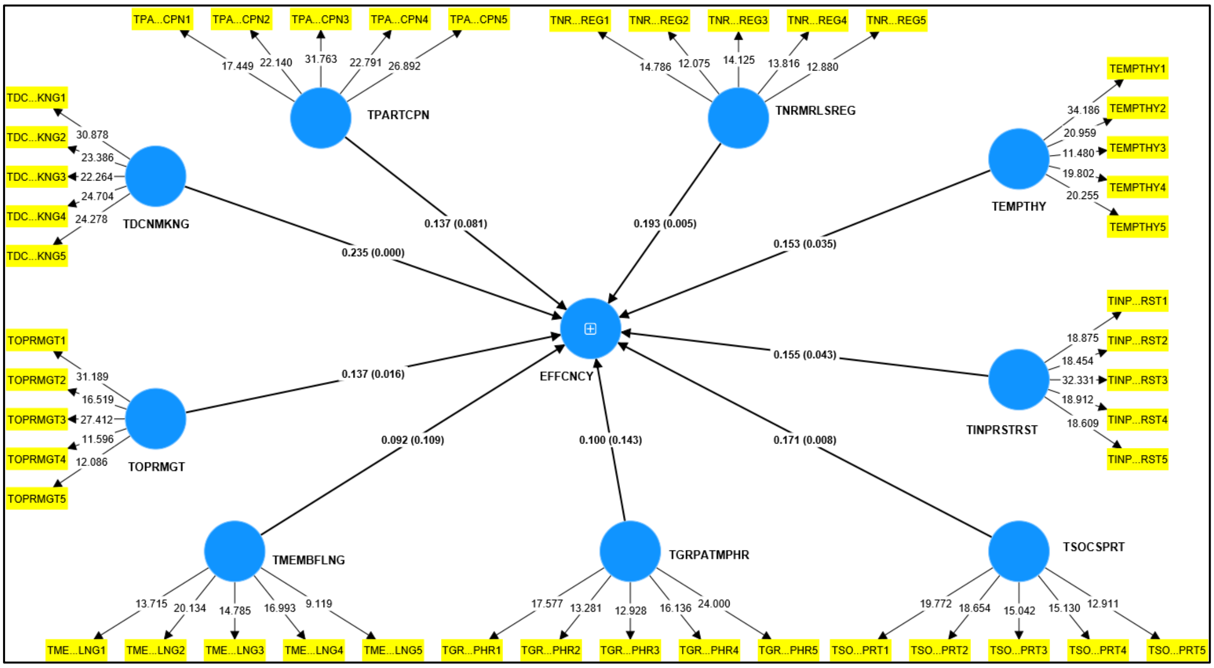


Figure 4.8: Direct Effect of IVs on Efficiency

After analyzing the measurement model, the next stage involves evaluating the structural path. This step focuses on assessing the path coefficients, which indicate the relationships between the constructs in the study, and determining their statistical significance.

Table 4.19: Composite Effect of IVs on EFFCNCY

Hypothesis	**β**	**(STDEV)**	**T statistics**	**P values**	**VIF**	**f-square**	**Results**
H1: TDCNMKNG -> EFFCNCY	0.235	0.059	4.011	0.000	1.218	**0.191**	Supported*
H2: TEMPTHY -> EFFCNCY	0.153	0.073	2.109	0.035	2.016	**0.049**	Supported*
H3: TGRPATMPHR -> EFFCNCY	0.100	0.069	1.464	0.143	1.734	**0.025**	Not supported*
H4: TINPRSTRST -> EFFCNCY	0.155	0.077	2.026	0.043	1.787	**0.057**	Supported*
H5: TMEMBFLNG -> EFFCNCY	0.092	0.057	1.601	0.109	1.464	**0.024**	Not supported*
H6: TNRMRLSREG -> EFFCNCY	0.193	0.069	2.787	0.005	1.423	**0.111**	Supported*
H7: TOPRMGT -> EFFCNCY	0.137	0.057	2.406	0.016	1.225	**0.065**	Supported*
H8: TPARTCPN -> EFFCNCY	0.137	0.078	1.748	0.081	1.922	**0.041**	Not supported*
H9: TSOCSPRT -> EFFCNCY	0.171	0.065	2.638	0.008	1.361	**0.090**	Supported*

Note. *Relationships are significant at $P < 0.05$

Composite effect of IVs on EFFCNCY is accounted for by the predictor variable, taking into consideration other predictors in the model. PLS-SEM model is predictive of the given endogenous variable under scrutiny. SEM allows us to study the relationships among latent and not directly observable variables.

As outlined by Henseler et al. (2015), the f^2 can be understood in the following manner:

- Small effect size: $f^2 < 0.02$
- Medium effect size: $0.02 \leq f^2 < 0.15$
- Large effect size: $f^2 \geq 0.15$

A higher f-square value indicates a more pronounced influence of the predictor variable on the response variable, whereas a smaller f-square value indicates a weaker effect. Therefore, the f-squared measure offers insights into the practical significance of a predictor variable in explaining the variability observed in the response variable.

The f-square statistic has a dual role. Firstly, it allows for a comparative assessment of the relative significance of different predictor variables in explaining the variance of the response variable. Secondly, it communicates the strength of the relationship between predictor and response variables. This statistic helps to determine which predictor factors contribute more significantly to the fluctuations in the response variable than only displaying the intensity of the association. Essentially, it provides a useful tool for evaluating the relative strength of predictor variables in the context of explaining variance in the response variable. This feature is particularly valuable when dealing with models that involve multiple predictor variables. By considering the f-squared values, the relative contributions and importance of each predictor variable can be assessed. In summary, the f-square statistic is a helpful tool in PLS analysis. It helps us understand how important the relationships are between the predictor and response variables in real-world situations. The findings of the impact size f-square (f^2) analysis in this study are shown in Table 4.19. The effect sizes, which varied from 0.024 to 0.191, were medium to substantial, respectively.

Table 4.19 includes the Variance Inflation Factor (VIF) values for the inner structural equation model (SEM). The VIF values were all below five, indicating the absence of multicollinearity issues among the variables. Overall, there were no signs of model mis-specification.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter 5
Conclusions and Recommendations

5.1. Evaluation of Barriers to Efficient Canal Irrigation

5.1.1 Many researchers, both in India and internationally, have made concerted efforts to evaluate the effectiveness of different facets of WUAs, as discussed in the earlier sections. Given the multitude of variables at play, including geographical location and extent of user involvement, arriving at sweeping conclusions about the impact of WUAs is a formidable task. This study identified five primary obstacles to achieving irrigation efficiency, along with the subsidiary challenges faced by Water User Associations in effectively utilising canal irrigation. A systematic approach has also been proposed for prioritising these barriers in the context of the multifaceted problem of suboptimal irrigation efficiency to enhance the management of the infrastructure in place. Addressing these identified barriers simultaneously is not a simple task but it represents an extensive undertaking that demands substantial allocation of human and financial resources. It is important to recognise that the resource system in question encompasses not only the canal infrastructure itself, but also the imperative need for its proper operation and maintenance. Different farming techniques have resulted in different water needs from shared sluices, necessitating customised irrigation schedules, control systems at canal outlet heads, and measurement mechanisms at field outlets. This necessitates a shift toward farmers actively monitoring and adjusting the amount of water they use in their fields. Agricultural advisory services are crucial for boosting farm productivity, especially given factors like limited access to high-quality seeds or planting materials and decreasing rural livelihood opportunities.

It is crucial to recognise that financial solutions alone cannot resolve challenges faced by Water User Associations (WUAs). The absence of government funding and low water charge collection, often coupled with non-payment, contribute to the financial unsustainability of WUAs. Consequently, they struggle to cover the high maintenance costs, leading to capital losses. The primary obstacle lies in identifying and prioritising barriers for resolution under limited resources. This study identifies Financial Barriers, Capacity Building, and the Legal and Institutional framework as root causes, while Resource Availability (RS) and the External Environment (EE) are presented as outcome criteria influenced by other factors. A sensitivity analysis demonstrates how adjusting the weight assigned to the Financial Barriers (FB) criterion affects the ranking of other criteria. The relative importance of different criteria is directly affected by how much weight is allocated to the Financial Barriers (FB) criterion. Within the context of irrigation projects in Jharkhand, it is evident that addressing and mitigating financial obstacles should be a priority to enhance overall project performance. This involves securing sufficient government funding and improving the collection of water fees. Without robust government support and financial backing, coupled with the challenge of low water charge collection, WUAs face significant financial difficulties, leading to their financial unsustainability. To reinforce this, addressing financial challenges should be complemented by strengthening the Capacity Building criterion. This can be achieved by providing training and education to WUA members and other stakeholders in participatory irrigation management (PIM). Training should cover various aspects, including monitoring, coordination, leadership, cooperation, and dispute resolution.

Establishing a well-defined Legal and Institutional (LI) framework that clearly outlines the scope and nature of Integrated Management of Irrigation is of paramount importance. Therefore, government policies should be geared towards creating an environment that not only ensures sufficient financial resources but also empowers Water User Associations (WUAs) to effectively administer project-related matters and facilitate the collection of water charges. The methodology presented in this study offers a valuable template that can be adapted and applied to diverse contexts. This provides policymakers and researchers with a framework to discern and tackle the challenges associated with sustainable canal irrigation efficiency. By implementing this methodology in various scenarios, valuable insights can be gained, aiding the development of more effective policies and strategies to enhance irrigation management and promote sustainable practices. This not only benefits the immediate context of Jharkhand, but can also be a useful model for addressing similar issues in other regions, ultimately contributing to more efficient and sustainable canal irrigation.

5.2. Irrigation Canal Performance Evaluation with Data Envelopment Analysis

5.2.1. Data Envelopment Analysis (DEA) is a method used to assess how efficiently different Decision-Making Units (DMUs) can produce specific outputs using a given set of inputs. This study employed various DEA methods, including VRSIP, VRSOP, and SBM, each serving distinct analytical purposes. VRSIP, as an input-oriented approach, compares the actual input-to-output ratios of a DMU with the optimal ratios of other DMUs in the dataset. Conversely, VRSOP, an output-oriented method, primarily assesses technical efficiency from an output perspective. SBM focuses on gauging the extent of slack or unused resources in each DMU. This study analysed the technical efficiency of various DMUs over four years using DEA methods. Notably, efficiency scores from VRSOP generally exceeded those from VRSIP, whereas SBM scores tended to be lower than both VRSIP and VRSOP. Rankings based on Constant Elasticity of Substitution (CES) values using VRSIP showed a significant correlation with rankings obtained using CES values from the VRSOP and SBM methods. This suggests that rankings derived from CES values using VRSIP can serve as a suitable basis for further investigations of canal efficiency.

5.2.2. This study evaluated the effectiveness of nine Decision-Making Units (DMUs) from 2018 to 2021 using the Variable Returns to Scale-input-oriented (VRSIP) method within the framework of DEA. Efficiency scores, ranging from 0 to 1, indicated higher efficiency with higher scores and demonstrated variations across years. Notably, Canal 5 consistently emerged as the most efficient DMU, with comprehensive efficiency scores of 0.9667, 0.9604, 0.7245, and 0.9325 in 2018, 2019, 2020, and 2021, respectively. Canal 5 consistently achieved a high efficiency score, often reaching one. Conversely, Canal 7 was identified as the least efficient DMU, with efficiency fluctuating between 0.7346 and 0.879 over the four-year period. The Comprehensive Efficiency Scores (CES) offered a comprehensive view of DMU efficiency over four years, considering all relevant inputs and outputs. In the realm of irrigation system management, DEA is a valuable tool for evaluating the technical efficiencies of various DMUs. This analysis not only identifies the most efficient DMUs but also highlights areas where others may need improvement, providing valuable insights for refining policies and practices related to irrigation system management. To summarise, DEA, by revealing efficiency disparities among DMUs, serves as a potent tool for guiding enhancements in irrigation system management.

5.2.3. In 2014, Jharkhand introduced a policy to transfer the administration of irrigation systems to farmer groups, aligning with the implementation of the Jharkhand PIM Rules. This policy framework, along with the associated rules, is formulated to supervise the management of the irrigation water supply and related infrastructure. The primary goals include ensuring fair and effective water distribution among farmers, and promoting the adoption of modern irrigation technologies and farming practices that emphasise water conservation. As part of a research initiative, nine WUAs were chosen from the Kanchi canal command areas based on available data and discussions with irrigation department officials. Data for the study were gathered from two main sources: information collected from a sample of farmers, and records maintained by the nine selected water users' associations within the study area. Regarding the establishment and recognition of WUAs in Jharkhand, in line with the government's policy of transferring irrigation system management to farmer groups, the study observed that formation and registration fees for the WUAs were shared between the WUA members and the Ministry of Water Resources (MoWR) of the Jharkhand government. This shared financial commitment underscores collective interest in establishing and endorsing WUAs. Additionally, WUAs collect fees from their members, which are then utilised to cover the expenses associated with the O&M of the irrigation system. These costs encompass various components such as venue rental, transportation, refreshments, and materials for conducting regular meetings.

5.2.4. The study's findings indicate that, specifically in the case of Canal 5, particularly the Konkadih distributory, WUAs effectively utilized the government's investments in meetings and training. This success manifested in their ability to generate comparatively higher user charges from their members, as demonstrated by the active engagement of these members in meetings. Moreover, the financial support provided by the government for O&M costs was effectively used to increase the value and impact of projects carried out by the WUA. Consequently, with improved water availability, the cultivated area expanded, and crop diversification became a reality. The increase in food grain cultivation and non-food grain crops was notable and driven by the enhanced profitability of the latter. The establishment of WUAs has promoted greater accountability in the management of irrigation water, leading to the expansion of irrigated areas. The expansion was notably substantial, witnessing a 35% rise during the summer season and approximately 23% and 16% increases in the Kharif and Rabi seasons, respectively.

In contrast, on-site assessments of Canal 7 (Hartaldih) revealed that the canal delivered incomplete irrigation services because of extensive damage and inadequate maintenance. In summary, the examination of technical efficiency through the application of Data Envelopment Analysis (DEA) methods offers valuable perspectives on the efficacy of WUAs in Jharkhand. These insights can be utilised to pinpoint effective approaches and areas in need of enhancement, guiding the formulation of policies and strategies to promote sustainable management of irrigation systems.

5.3. Group Member Attributes and Efficiency of Canal Irrigation

5.3.1. This study took place in Jharkhand, where a policy has been implemented since 2014 to hand over the management of the entire irrigation system to user groups, particularly farmers. The state has also established rules, known as the 'Jharkhand Participatory Irrigation Management Rules' (2014), to legally recognise Water Users Associations (WUAs). Recognising that the performance of WUAs may vary across locations owing to differences in water sources and physical characteristics, a sample of nine WUAs was selected from a significant canal irrigation project in Jharkhand State based on available data and consultations with irrigation officials. This study aimed to evaluate the effectiveness of these reforms by analyzing their overall impact on the management and performance of the irrigation system. Hence, field-level data were collected from sample farmers and WUAs to assess the on-the-ground impact of WUAs on various parameters.

5.3.2. By examining the responses from the sampled farmers, the study aimed to investigate how different stakeholders and various socioeconomic categories contribute to the functioning of WUAs. The study introduces the Kanchi Irrigation Project System as a CPR and develops a model to analyze human interactions within it, focusing on the Efficiency of Irrigation as the Dependent Variable (DV). Using the IAD framework, the study centers on action situations within a specific focal arena to predict events within a focused area. Multiple Independent Variables (IVs) are identified, including biophysical factors, community attributes, and rule configurations, to study likely participant actions and outcomes and to evaluate the impact of IVs on group dynamics, focusing on nine specific indicators. The SEM model examines the direct effect of IVs on efficiency, and hypotheses are tested through structural equation modeling and multiple regression analysis using SmartPLS. The findings revealed that the participation of diverse stakeholders in WUA-related activities is relatively limited. Specifically, about one sixth of respondents considered the Chairman's role to be highly active, while nearly one third reported that head reach farmers were extremely active participants in various WUA activities. Farmers in canal command areas noticed a significant transformation in the distribution of authority. Before the establishment of WUAs, almost all matters related to irrigation water were controlled by the State Agency, which was the irrigation department. This situation has undergone substantial changes since the inception of WUAs. Before WUAs came into existence, almost all farmers emphasised the critical role of state control in various aspects of water management. However, after the formation of WUAs, approximately one fourth of farmers still perceived that state control persisted. Most farmers observed shifts in the devolution of authority, particularly in matters such as water charge collection, operations, and maintenance.

5.3.3. The impact of water user associations has resulted in favourable changes in cropping patterns and the amount of irrigated land, positively affecting the agricultural economy. In particular, the area allocated for the kharif season has witnessed an increase, and there has been a slight rise in the rabi season area since the formation of WUAs. On average, more than 90% of farmers have reported an increase in crop productivity, particularly for major crops like paddy, maize, tomatoes, and various vegetable crops, following the establishment of water user associations (WUAs). While farmers' responses regarding productivity improvements vary depending on the specific crops, the general trend indicates that, overall, farmers have experienced increased crop yields after the formation of WUAs. Moreover, the study identified that the establishment of WUAs has had a positive impact on the local economy in the selected area. WUAs have notably benefited a wide range of groups, including farmers of all types, wage earners, livestock owners, and head and middle reach farmers, with over 80% to 95% of farmers indicating substantial or favourable gains for these categories. However, it is noteworthy that for some groups, such as tribals, individuals from lower castes or scheduled castes, youth, women's groups, economically disadvantaged farmers, and last-mile farmers, the impact of WUAs is perceived differently. Between one third and two thirds of farmers expressed that WUAs had either had "no influence" or, in some cases, a "negative impact" on these groups.

In conclusion, the formation of WUAs has been linked to enhanced productivity for major crops, a trend that has been widely reported by the majority of farmers. Moreover, WUAs have made a substantial contribution to the growth of the local economy and yielded distinctly positive outcomes for numerous groups. However, it is essential to acknowledge that opinions regarding the impact of WUAs differ across demographic segments, with some groups feeling less influenced or even adversely affected by their presence.

REFERENCES

Abdel-Aziz, Y. (2003). Decentralization and Participatory Irrigation Management in Egypt. Paper presented at the Water Demand Management Forum on Decentralization and Participatory Irrigation Management, 2-4 February 2003, Cairo, Egypt.

Adelodun, B., Mohammed, A. A., Adeniran, K. A., Akanbi, S.-U. O., Abdulkadir, T. S., & Choi, K. S. (2021). Comparative assessment of technical efficiencies of irrigated crop production farms: A case study of the large-scale Kampe-Omi irrigation scheme, Nigeria. African Journal of Science, Technology, Innovation and Development, 13, 293–302. https://doi.org/10.1080/20421338.2020.1755111.

Ahmad, B., Pham, H. D., Ashfaq, M., Memon, J. A., Bano, R., Dahri, Z. H., Mustafa, R. N., Baig, I. A., & Naseer, M. A. u. R. (2020). Impact of institutional features on the overall performance assessment of participatory irrigation management: Farmers' response from Pakistan. Water, 12, 497. https://doi.org/10.3390/w12020497

Ali, M. K., & Klein, K. K. (2014). Water use efficiency and productivity of the irrigation districts in southern Alberta. Water Resources Management, 28, 2751–2766. https://doi.org/10.1007/s11269-014-0634-y

Asian Development Bank (ADB). (2014). India: Support for the Implementation of the National Water Mission by State Governments in India: Scoping Study for a National Water Use Efficiency Improvement Support Program.

Asian Development Bank (ADB). (2008). Irrigation management transfer. Sage Publication, India Pvt. Ltd., New Delhi.

Asian Development Bank. (2007). Irrigation management transfer. Asian Development Bank, Mandaluyong, Philippines.

Auer, M. (2006). Contexts, multiple methods, and values in the study of common-pool resources. Journal of Policy Analysis and Management, 25(1), 215-227.

Azemzi, H., & Erraoui, E. H. (2021). Irrigation water management and collective action: Understanding the shift from community management to participatory management in

Souss-Massa (Morocco). Euro Mediterranean Journal of Environmental Integration, 6, 1-12. https://doi.org/10.1007/s41207-020-00207-6

Bakir, S., Khan, S., Ahsan, K., & Rahman, S. (2018). Exploring the critical determinants of environmentally oriented public procurement using the DEMATEL method. Journal of Environmental Management, 225, 325–335. https://doi.org/10.1016/j.jenvman.2018.07.081

Balasubramanya, S., Price, J. P. G., & Horbulyk, T. M. (2018). Impacts assessments without true baselines: Assessing the relative effects of training on the performance of water user associations in southern Tajikistan. Water Economics and Policy, 4, 1850007. https://doi.org/10.1142/S2382624X18500078

Banker, R. D., & Morey, R. C. (1986). Efficiency analysis for exogenously fixed inputs and outputs. Operations Research, 34, 513–521.

Benitez, J., Henseler, J., Castillo, A., & Schuberth, F. (2019). How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory IS research. Information & Management. https://doi.org/10.1016/j.im.2019.05.003

Bhatia, R. (2006). Water and economic growth. In Handbook of Water Resources in India. The World Bank.

Bhatia, R. (1989). Financing irrigation services in India: A case study of Bihar and Haryana states. In L. E. Small et al. (Eds.), Financing Irrigation Services: A Literature Review and Selected Case Studies from Asia (pp. xxx-xxx). Colombo, Sri Lanka: HMI.

Bhatt, S. (2012). Performance of participatory irrigation management: A study of two water users associations in Anand district of Gujarat. IWMI-Tata Water Policy Program. Retrieved from www.iwmi.org/iwmi-tata/apm2012

Bhogle, S. G. (2005). Report of the mid-term performance assessment of participatory restoration and management of irrigation systems by water users in Madhya Pradesh.

Bravo, G., & Marelli, B. (2008). Irrigation systems as common-pool resources. Revue de Géographie Alpine, (96–3), 15–26. https://doi.org/10.4000/rga.536

Brewer, J., Kolavalli, S., Kalro, A. H., Naik, G., Ramnarayan, S., Raju, K. V., & Sakthivadivel, R. (1999). Irrigation management transfer in India—Policies, processes and performance. New Delhi and Calcutta: Oxford and IBH.

Bruns, R. B., Ringler, C., & Meinzen-Dick, R. (Eds.). (2005). Water rights reform—Lessons for institutional design. Washington, DC: International Food Policy Research Institute.

Central Water Commission (CWC), Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWRRD&GD), Government of India. (2013). Water and related statistics.

Central Water Commission, Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWRRD&GD), Government of India. (2019). Annual Report 2017-18.

Chand, R. Doubling of farmers' income rationale, strategy prospects and action plan. Retrieved from http://www.indiaenvironmentportal.org.in/node/441902/

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. European Journal of Operational Research, 2, 429–444. https://doi.org/10.1016/0377-2217(78)90138-8

Choi, S.-M., Yoon, K.-S., & Kim, J.-S. (2016). Irrigation management transfer between public organizations and the role of participatory irrigation management under public irrigation management in Korea. Irrigation and Drainage, 65, 69–75. https://doi.org/10.1002/ird.2026

Contreras, I. (2012). Optimizing the rank position of the DMU as secondary goal in DEA cross-evaluation. Applied Mathematics and Computation, 36, 2642–2648. https://doi.org/10.1016/j.apm.2011.09.046

Culas, R. J., & Baig, I. A. (2020). Impacts of irrigation water user allocations on water quality and crop productivity: The LCC irrigation system. Irrigation and Drainage, 69, 38–51. https://doi.org/10.1002/ird.2402

Department of Agriculture, Cooperation & Farmers Welfare. (2022-23). Annual Report 2022-23. Retrieved from https://agriwelfare.gov.in/Documents/annual_report_english_2022_23.pdf

Dwivedi, P., & Dwivedi, A. (2012). Public community participation model for renewable energy projects in India. WREF.

FAO. (2017). Water for sustainable food and agriculture. United Nations, Rome.

Farrell, M. J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society. Series A (General), 120, 253. https://doi.org/10.2307/2343100

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with observable variables and measurement error. Journal of Marketing Research, 18(1), 39–50. https://doi.org/10.1177/002224378101800104

Frija, A., Speelman, S., Chebil, A., Buysse, J., & van Huylenbroeck, G. (2009). Assessing the efficiency of irrigation water users' associations and its determinants: Evidence from Tunisia. Irrigation and Drainage, 58, 538–550. https://doi.org/10.1002/ird.446

Frija, A., Wossink, A., Buysse, J., Speelman, S., & van Huylenbroeck, G. (2011). Irrigation pricing policies and its impact on agricultural inputs demand in Tunisia: A DEA-based methodology. Journal of Environmental Management, 92, 2109–2118. https://doi.org/10.1016/j.jenvman.2011.03.013

Ganapathy, K. D. (2008). Operationalisation of participatory irrigation management in Upper Krishna Project Command Area – An economic perspective (Master's thesis). University of Agricultural Sciences, Dharwad.

Gandhi, & Namboodhri. (n.d.). Participatory Irrigation Management in India: An Evaluation of the Performance in Andhra Pradesh, Gujarat and Maharashtra. Indian Institute of Management Publication, Ahmedabad.

Gandhi, V. P., Johnson, N., Neog, K., & Jain, D. (2020). Institutional structure, participation, and devolution in water institutions of eastern India. Water, 12, 476. https://doi.org/10.3390/w12020476

Garces-Restrepo, C., et al. (2007). Irrigation management transfer worldwide efforts and results. Food and Agriculture Organization Publication, United Nations.

García-Mollá, M., Puertas, R., & Sanchis-Ibor, C. (2021). Application of data envelopment analysis to evaluate investments in the modernization of collective management irrigation systems in Valencia (Spain). Water Resources Management, 35, 5011–5027. https://doi.org/10.1007/s11269-021-02986-1

Geng, Q., Ren, Q., Nolan, R. H., Wu, P., & Yu, Q. (2019). Assessing China's agricultural water use efficiency in a green-blue water perspective: A study based on data envelopment analysis. Ecological Indicators, 96, 329–335. https://doi.org/10.1016/j.ecolind.2018.09.011

Ghosh, S., Kumar, A., Nanda, P., & Anand, P. S. B. (2010). Group dynamics effectiveness of water user associations under different irrigation systems in an eastern Indian state. Irrigation and Drainage, 59(5), 559-574.

Goutham, T. (2008). An economic analysis of participatory irrigation management in Tungabhadra Left Bank Canal Command Area (Master's thesis). University of Agricultural Sciences, Dharwad.

Government of Bihar. (1994). The report of the Second Irrigation Commission, 1994. Patna: Government of Bihar.

Groenfeldt, D., & Svendsen, M. (2000). Case studies in participatory irrigation management. Washington, DC: World Bank.

Gulati, A., et al. (2017). Making rapid strides agriculture in Madhya Pradesh: Sources, drivers, and policy lessons (Working Paper 339). Indian Council for Research on International Economic Relations.

Gulati, A., Meinzen-Dick, R., & Raju, K. V. (2005). Institutional reforms in Indian irrigation. New Delhi: Sage Publications.

Guo, D., & Wu, J. (2013). A complete ranking of DMUs with undesirable outputs using restrictions in DEA models. Mathematical and Computer Modelling, 58, 1102–1109. https://doi.org/10.1016/j.mcm.2011.12.044

Gupta, A., Singh, R. K., Kumar, M., Sawant, C. P., & Gaikwad, B. B. (2022). On-farm irrigation water management in India: Challenges and research gaps. Irrigation and Drainage, 71, 3–22. https://doi.org/10.1002/ird.2637

Hair, J. F. J., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. European Business Review, 26(2), 106–121. https://doi.org/10.1108/EBR-10-2013-0128

Hamada, H., & Samad, M. (2011). Basic principles for sustainable participatory irrigation management. JARQ, 45, 371–376. https://doi.org/10.6090/jarq.45.371

Hamidov, A., Helming, K., & Ball, D. (2016). Impact of agricultural land use in Central Asia: A review. Agronomy for Sustainable Development.

Han, S., Xin, P., Li, H., & Yang, Y. (2022). Evolution of agricultural development and land-water-food nexus in Central Asia. Agricultural Water Management, 273, 107874. https://doi.org/10.1016/j.agwat.2022.107874

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hooja, R., & Joshi, L. K. (2000). Introduction. In L. K. Joshi & R. Hooja (Eds.), Participatory Irrigation Management - Paradigm for the 21st Century, Vol. 1. Jaipur: Rawat Publications.

Hossain, M. K., & Thakur, V. (2021). Benchmarking health-care supply chain by implementing Industry 4.0: A fuzzy-AHP-DEMATEL approach. Benchmarking: An International Journal, 28, 556–581. https://doi.org/10.1108/BIJ-05-2020-0268

Hsu, C. L., & Lin, J. C. C. (2008). Acceptance of blog usage: The roles of technology acceptance, social influence, and knowledge sharing motivation. Information & Management, 45(1), 65–74. https://doi.org/10.1016/j.im.2007.11.001

IMTI. (2005). National Seminar on PIM, 21-22 October 2005, Organised by CAD and IMTI Kota (Rajasthan).

Inocencio, A., Tiongco, M., Yoshinaga, K., & Siriban-Manalang, A. B. (2018). Exploring the potential of PPP in Philippine irrigation. DLSU Business and Economics Review, 28(Special issue).

IWMI. (2019). Innovative Water Solutions for Sustainable Development. International Water Management Institute (IWMI), Colombo.

Jain, R., Kishore, P., & Singh, D. K. (2019). Irrigation in India: Status, challenges, and options. Journal of Soil and Water Conservation, 18, 354. https://doi.org/10.5958/2455-7145.2019.00050.X

Johnson, S. H. (1997). Irrigation Management Transfer: Decentralizing Public Irrigation in Mexico. Water International, 22, 159–167. https://doi.org/10.1080/02508069708686695

Joshi, L. K., & Hooja, R. (Eds.). (2000). Participatory Irrigation Management - Paradigm of the 21st Century. Jaipur and New Delhi: Rawat Publications.

Kadirbeyoglu, Z., & Özertan, G. (2015). Power in the Governance of Common-Pool Resources: A comparative analysis of irrigation management decentralization in Turkey. Environmental Policy and Governance, 25(3), 157–171. https://doi.org/10.1002/eet.1673

Kazbekov, J., Abdullaev, I., Manthrithilake, H., Qureshi, A., & Jumaboev, K. (2009). Evaluating planning and delivery performance of water user associations (WUAs) in Osh province, Kyrgyzstan. Agricultural Water Management, 96(8), 1259–1267. doi:10.1016/j.agwat.2009.04.002

Khadra, I. R., et al. (2017). Participatory Irrigation Management and Transfer: Setting the guiding principles for a sustaining Monitoring & Evaluation system – A focus on the Mediterranean. Water Resources Management.

Khodabakhshi, M., & Aryavash, K. (2012). Ranking all units in data envelopment analysis. Applied Mathematics Letters, 25, 2066–2070. https://doi.org/10.1016/j.aml.2012.04.019

Kodavaty, J., Pannala, R. P. K., Wasson, S., Mittal, M., & Irshad, A. (2022). A Novel Method to Choose the Experimental Parameters in Large Amplitude Oscillatory Shear Rheology. Materials Science Forum, 1048, 54–64. https://doi.org/10.4028/www.scientific.net/MSF.1048.54

Kodavaty, J., Pavan Kumar Pannala, R. K., Singh, M., Bharti, A., & Fahar Ahmad, Q. (2022). Optimizing composition of a drug gel using release kinetics—A new way of approach. Materials Today Proceedings, 66, 1611–1616. https://doi.org/10.1016/j.matpr.2022.05.249

Koopmans, T. C. (Ed.). (1951). An Analysis of Production as an Efficient Combination of Activities. In Activity Analysis of Production and Allocation. John Wiley and Sons Inc.: London, UK.

Lilienfeld, A., & Asmild, M. (2007). Estimation of excess water use in irrigated agriculture: A Data Envelopment Analysis approach. Agricultural Water Management, 94, 73–82. https://doi.org/10.1016/j.agwat.2007.08.005

Lim, W. M. (2015). Antecedents and consequences of e-shopping: An integrated model. Internet Research, 25(2), 184–217. https://doi.org/10.1108/IntR-11-2013-0247

Liu, S., & Wang, L. (2016). Influence of managerial control on performance in medical information system projects: The moderating role of organizational environment and team risks. International Journal of Project Management, 34(1), 102–116. https://doi.org/10.1016/j.ijproman.2015.10.003

Lotfi, F. H., Eshlaghy, A. T., & Shafiee, M. (2012). Providers Ranking Using Data Envelopment Analysis Model, Cross Efficiency and Shannon Entropy. Applied Mathematics Sciences, 6, 153–161.

Malik, R. P. S. (2006). Water and Poverty. Handbook of Water Resources in India. The World Bank.

Mamata Swain, & Deepak Kumar Das. (2008). Participatory Irrigation Management in India. Journal of Development and Sustainable Agriculture, 3, 28–39. https://doi.org/10.11178/jdsa.3.28

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework. Policy Studies Journal, 39(1), 169–183. https://doi.org/10.1111/j.1541-0072.2010.00401.x

Meinzen-Dick, R., Raju, K., & Gulati, A. (2002). What Affects Organization and Collective Action for Managing Resources? Evidence from Canal Irrigation Systems in India. World Development, 30, 649–666. https://doi.org/10.1016/S0305-750X(01)00130-9

Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi. (2016). State of Indian Agriculture, 2015-16.

Ministry of Agriculture, Cooperation & Farmers Welfare, Government of India, New Delhi. (2017). Operational Guidelines of Micro Irrigation Component of PMKSY.

Ministry of Agriculture, Cooperation & Farmers Welfare, Government of India, New Delhi. (2019). Annual Report- 2018-19.

Ministry of Water Resources. (2006). 10th Five-Year Plan Document, Command Area Development. New Delhi: Ministry of Water Resources, GOI.

Mitra, A. K. (1996). Irrigation sector reforms: Issues and approaches. Economic and Political Weekly, 31, A31–A37.

Mogha, S. K., Yadav, S. P., & Singh, S. P. (2015). Slack-based measure of efficiencies of public sector hospitals in Uttarakhand (India). Benchmarking: An International Journal, 22, 1229–1246. https://doi.org/10.1108/BIJ-12-2013-0122

Mukherji, A., Das, B., Majumdar, N., Nayak, N. C., Sethi, R. R., & Sharma, B. R. (2009). Metering of agricultural power supply in West Bengal, India: Who gains and who loses? Energy Policy, 37, 5530–5539. doi:10.1016/j.enpol.2009.08.051

NABARD. (2019). Annual Report. National Bank for Agriculture and Rural Development (NABARD), Mumbai.

NABARD, ICRIER. (2018). Water Productivity mapping of Major Indian Crops.

Naik, G., & Kalro, A. H. (2000). A methodology for assessing impact of irrigation management transfer from farmers' perspective. Water Policy, 2, 445–460. https://doi.org/10.1016/S1366-7017(00)00019-2

Narayanamoorthy, A. (2018). Financial performance of India's irrigation sector: A historical analysis. International Journal of Water Resources Development, 34, 116–131. https://doi.org/10.1080/07900627.2017.1298998

National Institution for Transforming India (NITI), Government of India New Delhi. (2017). Doubling farmers' income rationale, strategy, prospects and action plan, policy paper no.1/2017

Niti Ayog. (2015). Raising Agricultural Productivity and Making Farming Remunerative for Farmers—An Occasional Paper. Niti Ayog, New Delhi, India.

Nitin Bassi, & Kumar, M. D. (2011). Can Sector Reforms Improve Efficiency? Insight from Irrigation Management Transfer in Central India. International Journal of Water Resources Development, 27, 709–721.

Noura, A. A., Hosseinzadeh Lotfi, F., Jahanshahloo, G. R., & Fanati Rashidi, S. (2011). Super-efficiency in DEA by effectiveness of each unit in society. Applied Mathematics Letters, 24, 623–626. https://doi.org/10.1016/j.aml.2010.11.025

OECD. (2006). Water and Agriculture: Sustainability, Markets and Policies. OECD, Paris.

Ogbeibu, S., Senadjki, A., & Gaskin, J. (2018). The moderating effect of benevolence on the impact of organizational culture on employee creativity. Journal of Business Research, 90, 334–346. https://doi.org/10.1016/j.jbusres.2018.05.032

Ostrom, E. (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, UK: Cambridge University Press.

Ostrom, E. (2014). Do institutions for collective action evolve?. Journal of Bioeconomics, 16, 3-30.

Ozlii, H., E. Doker, F. Cenap, E. Do an, & E. Emino lu. (2003). 'Decentralization and Participatory Irrigation Management in Turkey. Paper presented at the 'Water Demand

Management Forum on Decentralization and Participatory Irrigation Management', 2-4 February 2003, Cairo, Egypt.

Pannala, R. P. K., Mogha, S. K., Sharma, N., & Garg, V. (2022). Combined Shannon's entropy and DEA: Case of Indian hotel and restaurant sector. International Journal of Data Analysis Techniques and Strategies, 14, 203. https://doi.org/10.1504/ijdats.2022.128281

Pant, N. (1999). Impact of Irrigation Management Transfer in Maharashtra: An Assessment. Economic and Political Weekly, 34, A17–A26.

Parra, L., Botella-Campos, M., Puerto, H., Roig-Merino, B., & Lloret, J. (2020). Evaluating Irrigation Efficiency with Performance Indicators: A Case Study of Citrus in the East of Spain. Agronomy, 10, 1359. https://doi.org/10.3390/agronomy10091359

Parthasarathy, R. (2002). Poverty Dimensions of Irrigation Management Transfer in Large-Scale Canal Irrigation in Andra Pradesh and Gujarat, India. Research Report, International Water Management Institute, Sri Lanka.

Parthasarathy, R. (2000). Participatory Irrigation Management Programme in Gujarat: Institutional and Financial Issues. Economic and Political Weekly, 35, 3147–3154.

Qi, X.-G., & Guo, B. (2014). Determining Common Weights in Data Envelopment Analysis with Shannon's Entropy. Entropy, 16, 6394–6414. https://doi.org/10.3390/e16126394

Raju, K. S., & Kumar, D. N. (2006). Ranking Irrigation Planning Alternatives Using Data Envelopment Analysis. Water Resources Management, 20, 553–566. https://doi.org/10.1007/s11269-006-3090-5

Rap, E. (2006). The success of a policy model: Irrigation management transfer in Mexico. Journal of Development Studies, 42, 1301–1324. https://doi.org/10.1080/00220380600930606

Razzaq, A., Liu, H., Zhou, Y., Xiao, M., & Qing, P. (2022). The Competitiveness, Bargaining Power, and Contract Choice in Agricultural Water Markets in Pakistan: Implications for Price Discrimination and Environmental Sustainability. Frontiers in Environmental Science, 10, 917984. https://doi.org/10.3389/fenvs.2022.917984

Razzaq, A., Qing, P., Naseer, M. A. u. R., Abid, M., Anwar, M., & Javed, I. (2019). Can the informal groundwater markets improve water use efficiency and equity? Evidence from a semi-arid region of Pakistan. Science of the Total Environment, 666, 849–857. https://doi.org/10.1016/j.scitotenv.2019.02.266

Reddy, V. R., & Reddy, P. P. (2005). How Participatory Is Participatory Irrigation Management? Water Users' Associations in Andhra Pradesh. Economic and Political Weekly, 40, 5587–5595.

Ros, B. (2010). Participatory Irrigation Management and the Factors that Influence the Success of Farmer Water User Communities: A Case Study in Cambodia. Master Thesis, Massey University, New Zealand.

Saaty, T. L. (1980). The Analytic Hierarchy Process. McGraw-Hill: New York, NY, USA.

Sekhar, A. (2006). Development and Management Policies: Perspective of the Planning Commission. Handbook of Water Resources in India, The World Bank.

Senanayake, N., Mukherji, A., & Giordano, M. (2015). Re-visiting what we know about Irrigation Management Transfer: A review of the evidence. Agricultural Water Management, 149, 175–186. https://doi.org/10.1016/j.agwat.2014.11.004

Shindo, S., & Yamamoto, K. (2017). Strengthening Water Users' Organization Targeting for Participatory Irrigation Management in Egypt. Paddy Water Environment, 15, 773–785. https://doi.org/10.1007/s10333-017-0590-2

Shukla, U., & Butt, V. (2013). Is Quality in Capacity Building and Training Institution Development Matters the Most? Setting Benchmarking Process and Benchmark Standards for Training Institutions WALMI Bhopal a Case in Point. International Journal of Advances in Agricultural Science and Technology, 5(10), 1-9.

Siebert, S. (2002). Global modelling of irrigation water requirements. Water Resources Research, 38(4). https://doi.org/10.1029/2001WR000355

Sinha, Mukesh Kumar. (2015). Policy Initiatives for Reform in Irrigation Management. NDCWWC Journal, New Delhi.

Sinha, Phanish. (2014). Status of Participatory Irrigation Management (PIM) In India. National Convention of Presidents of Water User Associations organised by MoWR RD & GR.

Sirimewan, D. C., Mendis, A., Rajini, D., Samaraweera, A., & Manjula, N. H. C. (2021). Analysis of issues in sustainable water management of irrigation systems: Case of a developing country. Built Environment Project and Asset Management, 11, 529–543. https://doi.org/10.1108/BEPAM-02-2020-0038

Sitaram Phadnis, S., & Kulshrestha, M. (2012). Evaluation of irrigation efficiencies for water users' associations in a major irrigation project in India by DEA. Benchmarking: An International Journal, 19, 193–218. https://doi.org/10.1108/14635771211224536

Soleimani-damaneh, M., & Zarepisheh, M. (2009). Shannon's entropy for combining the efficiency results of different DEA models: Method and application. Expert Systems with Applications, 36, 5146–5150. https://doi.org/10.1016/j.eswa.2008.06.031

Speelman, S., D'Haese, M., Buysse, J., & D'Haese, L. (2008). A measure for the efficiency of water use and its determinants, a case study of small-scale irrigation schemes in North-West Province, South Africa. Agricultural Systems, 98, 31–39. https://doi.org/10.1016/j.agsy.2008.03.006

Srinivasa Raju, K., & Nagesh Kumar, D. (2013). Fuzzy Data envelopment analysis for performance evaluation of an irrigation system. Irrigation and Drainage, 62, 170–180. https://doi.org/10.1002/ird.1721

Subramanian, A. (1996). After the Transfer: WUAs and Water Management in Colombia. Systems Network held at Chiang Mai, Thailand, 12-15 December 1989, Colombo, International Irrigation Management Institute.

Swain, M., & Das, D. K. (2008). Participatory Irrigation Management in India: Implementations and Gaps. Journal of Developments in Sustainable Agriculture, 3, 28-39.

Tang, S. Y. (1992). Institutions and Collective Action: Self-Governance in Irrigation. San Francisco, CA: ICS Press.

Tang, S. Y. (1994). Institutions and performance in irrigation systems. In Rules, Games, and Common-Pool Resources, ed. E. Ostrom, R. Gardner, J. M. Walker, 225-45. Ann Arbor: Univ. of Michigan Press.

Tang, J., Folmer, H., van der Vlist, A. J., & Xue, J. (2014). The impacts of management reform on irrigation water use efficiency in the Guanzhong plain, China. Papers in Regional Science, 93, 455–475. https://doi.org/10.1111/pirs.12064.

The report on the State of Indian Agriculture placed by the Government to the Rajya Sabha in March 2012. http://pib.nic.in/newsite/erelease.aspx?relid=80852

Tone, K. (2001). A slacks-based measure of efficiency in data envelopment analysis. European Journal of Operational Research, 130, 498–509. https://doi.org/10.1016/S0377-2217(99)00407-5.

Tucker, Satya Prakash, & Gupta, Sanjay. (2010). Improving Irrigation Performance Management: Navigating through Andhra Pradesh experience, Irrigation & Command Area Development, Andhra Pradesh.

Uphoff, Norman. (1992). Learning from Gal Oya: Possibilities for participatory development and post-Newtonian social science. Ithaca, New York: Cornell University Press.

Vaidyanathan, A., & Oudshoorn, H. M. (Eds.). (2004). Managing Water Scarcity—Experiences and Prospects. New Delhi: IDPAD, Manohar.

Vaidyanathan, A. (1994). Transferring irrigation management to farmers. Econ. Political Wkly., 29, 2965–2967.

Varughese, G. C. (2006). Water and Environmental Sustainability. In Handbook of Water Resources in India. The World Bank.

Vermillion, D. (1997). Management Devolution and the Sustainability of Irrigation: Results of Comprehensive versus Partial Strategies. Paper presented at the FAO/World Bank Technical Consultation on Decentralisation and Rural Development, 16-18 December 1997, Rome.

Vermillion, D. L. (1995). Irrigation Management Transfer: Towards an Integrated Management Revolution. In Johnson, et al.

Vermillion, D. L., Parhusip, U., & Susetiawan. (2002). Financing the Irrigation Sector in Indonesia: A Guide to Restructuring. Report prepared for the World Bank and the Government of Indonesia, Jakarta.

Vohra, K., & Saxena, P. K. (2014). Irrigation Growth in India- Prospects, Initiatives and Challenges. Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India.

Von Korff, Y., Daniell, K. A., Moellenkamp, S., Bots, P., & Bijlsma, R. M. (2012). Implementing Participatory Water Management: Recent Advances in Theory, Practice, and Evaluation. E&S, 17(1). https://doi.org/10.5751/ES–04733–170130.

Wang, F., Yu, C., Xiong, L., & Chang, Y. (2019). How can agricultural water use efficiency be promoted in China? A spatial-temporal analysis. Resources, Conservation and Recycling, 145, 411–418. https://doi.org/10.1016/j.resconrec.2019.03.017

Wang, G., Chen, J., Wu, F., & Li, Z. (2015). An integrated analysis of agricultural water-use efficiency: A case study in the Heihe River Basin in Northwest China. Physics and Chemistry of the Earth, Parts A/B/C, 89–90, 3–9. https://doi.org/10.1016/j.pce.2015.10.009

Wang, J., Xu, Z., Huang, J., & Rozelle, S. (2006). Incentives to managers or participation of farmers in China's irrigation systems: Which matters most for water savings, farmer income, and poverty? Agricultural Economics, 34, 315–330. https://doi.org/10.1111/j.1574-0864.2006.00128.x

Wang, X. (2010). Irrigation Water Use Efficiency of Farmers and Its Determinants: Evidence from a Survey in Northwestern China. Agricultural Sciences in China, 9, 1326–1337. https://doi.org/10.1016/S1671-2927(09)60223-6

Watkins, K. B., Henry, C. G., Hardke, J. T., Mane, R. U., Mazzanti, R., & Baker, R. (2021). Non-radial technical efficiency measurement of irrigation water relative to other inputs used in Arkansas rice production. Agricultural Water Management, 244, 106441. https://doi.org/10.1016/j.agwat.2020.106441

Xie, Q., Dai, Q., Li, Y., & Jiang, A. (2014). Increasing the Discriminatory Power of DEA Using Shannon’s Entropy. Entropy, 16, 1571–1585. https://doi.org/10.3390/e16031571

Yakubov, M. (2012). Assessing irrigation performance from the farmers' perspective: A qualitative study. Irrigation and Drainage, 61, 316–329. https://doi.org/10.1002/ird.649

Yang, L., Ren, Y., Tang, Z., & Zhu, Y. (2021). Impact of institutional constraints on participatory irrigation management: The regulating role of moral obligation. Irrigation and Drainage, 70, 1287–1297. https://doi.org/10.1002/ird.2602

Yohannes, D. F., Ritsema, C. J., Solomon, H., Froebrich, J., & van Dam, J. C. (2017). Irrigation water management: Farmers' practices, perceptions and adaptations at Gumselassa irrigation scheme, North Ethiopia. Agricultural Water Management, 191, 16–28. https://doi.org/10.1016/j.agwat.2017.05.009

Zema, D. A., Nicotra, A., Mateos, L., & Zimbone, S. M. (2018). Improvement of the irrigation performance in Water Users Associations integrating data envelopment analysis and multi-regression models. Agricultural Water Management, 205, 38–49. https://doi.org/10.1016/j.agwat.2018.04.032

Zhang, W., Du, X., Huang, A., & Yin, H. (2019). Analysis and Comprehensive Evaluation of Water Use Efficiency in China. Water, 11, 2620. https://doi.org/10.3390/w11122620

Zhou, Q., Deng, X., Wu, F., Li, Z., & Song, W. (2017). Participatory Irrigation Management and Irrigation Water Use Efficiency in Maize Production: Evidence from Zhangye City, Northwestern China. Water, 9, 822. https://doi.org/10.3390/w9110822

Zinzani, A. (2015). Irrigation Management Transfer and WUAs' dynamics: Evidence from the South-Kazakhstan Province. Environmental Earth Sciences, 73, 765–777. https://doi.org/10.1007/s12665-014-3209-6

LIST OF PUBLICATIONS

LIST OF PUBLICATIONS

1. Publication in Water Journal

Title: **Assessment of Barriers to Canal Irrigation Efficiency for Sustainable Harnessing of Irrigation Potential.**

Published in Water Journal under Section: Water Resources Management, Policy, and Governance.

Water is a peer-reviewed, open-access journal on water science and technology, including the ecology and management of water resources, and is published online by the MDPI.

Impact Factor: 3.53, CITESCORE:4.8, Journal Rank: CiteScore - Q1 (Water Science & Tech.).

2. Publication in Energies Journal

Title: **Performance Evaluation of Irrigation Canals Using Data Envelopment Analysis for Efficient and Sustainable Irrigation Management in the Jharkhand State of India.**

Published in Energies Journal under section: Data-Driven Approaches for Environmental Sustainability 2023.

Energies is a peer-reviewed, open-access journal of related scientific research, technology development, engineering, and studies in policy and management, and is published online by the MDPI.

Impact Factor: 3.2; CITESCORE:5.5; Journal Rank: CiteScore - Q1 (Engineering (miscellaneous).

APPENDICES

Appendix A : Questionnaire for Ranking of Barriers using MCDM

Hello

In the attachment to the e-mail, six tables depict various barriers to irrigation efficiency through the canals.

Kindly fill (only tick mark) in all tables (it takes only five minutes). While filling in your responses, you must rate the importance of one factor over another in that row.

Thank you for being so cooperative.

Regards

Jay Nigam
94256 48274

To fill the Excel Form please read the example shown below, on likeness of Ice-cream vs Chocolate.

Here I like Chocolate fairly more than Ice-cream, thus I tick ***Fairly Strong*** towards Chocolate.

Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Ice cream	☐	☐	☐	☐	☐	☐	☑	☐	☐	Chocolate

If you like Only Chocolate Tick on ***Absolute*** column towards Chocolate.

Or, if you like both Chocolate and Ice-cream Equally, Tick on the middle column ***Equal***.

Thus, accordingly please fill all 6 Tables, rating a factor's importance over one another in that row.

Thank you very much for your Cooperation.

Table 1: Pair wise comparison of categories w.r.t. overall objective

O	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Resource System	☐	☐	☐	☐	☐	☐	☐	☐	☐	Legal & Institutional
Resource System	☐	☐	☐	☐	☐	☐	☐	☐	☐	Financial Barriers
Resource System	☐	☐	☐	☐	☐	☐	☐	☐	☐	Capacity Building
Resource System	☐	☐	☐	☐	☐	☐	☐	☐	☐	External Environment
Legal & Institutional	☐	☐	☐	☐	☐	☐	☐	☐	☐	Financial Barriers
Legal & Institutional	☐	☐	☐	☐	☐	☐	☐	☐	☐	Capacity Building
Legal & Institutional	☐	☐	☐	☐	☐	☐	☐	☐	☐	External Environment
Financial Barriers	☐	☐	☐	☐	☐	☐	☐	☐	☐	Capacity Building
Financial Barriers	☐	☐	☐	☐	☐	☐	☐	☐	☐	External Environment
Capacity Building	☐	☐	☐	☐	☐	☐	☐	☐	☐	External Environment

Table 2: Pair wise comparison of Specifics w.r.t. category C1 (Resource System**)**

C1	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Canal Infrastructure	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flow Control Structures
Canal Infrastructure	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate Risk
Flow Control Structures	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate Risk

Table 3: Pair wise comparison of Specifics w.r.t. category C2 (Legal & Institutional**)**

C2	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Legal Framework	☐	☐	☐	☐	☐	☐	☐	☐	☐	Control over water flow
Legal Framework	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water distribution Rules
Control over water flow	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water distribution Rules

Table 4 : Pair wise comparison of Specifics w.r.t. category C3 (Financial Barriers)

C3	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Government Funding	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water rate collection System
Water rate collection System	☐	☐	☐	☐	☐	☐	☐	☐	☐	Operation and Maintenance cost
Water rate collection System	☐	☐	☐	☐	☐	☐	☐	☐	☐	Operation and Maintenance cost

Table 5: Pair wise comparison of Specifics w.r.t. category C4 (Capacity Building)

C4	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	Leadership
Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation
Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	Coordination
Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	Monitoring
Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dispute and Conflict
Leadership	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation
Leadership	☐	☐	☐	☐	☐	☐	☐	☐	☐	Coordination
Leadership	☐	☐	☐	☐	☐	☐	☐	☐	☐	Monitoring
Leadership	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dispute and Conflict
Cooperation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Coordination
Cooperation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Monitoring
Cooperation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dispute and Conflict

Coordination	☐	☐	☐	☐	☐	☐	☐	☐	☐	Monitoring
Coordination	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dispute and Conflict
Monitoring	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dispute and Conflict

Table 6 : Pair wise comparison of Specifics w.r.t. category C5 (External Environment)

C 5	Importance of one category over the other									
Criterion	Absolute	Very strong	Fairly Strong	Weak	Equal	Weak	Fairly Strong	Very strong	Absolute	Criterion
Socio-economic inequality	☐	☐	☐	☐	☐	☐	☐	☐	☐	Groundwater depletion
Socio-economic inequality	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extension serviced
Socio-economic inequality	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality planting materials
Socio-economic inequality	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment credit
Groundwater depletion	☐	☐	☐	☐	☐	☐	☐	☐	☐	Extension serviced
Groundwater depletion	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality planting materials
Groundwater depletion	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment credit
Extension serviced	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality planting materials
Extension serviced	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment credit
Quality planting materials	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment credit

Appendix B : Data for DEA Analysis

Data were collected to rank the irrigation canals based on their efficiencies and inefficiencies for nine irrigation canals based on financial inputs, such as investments in training and development of WUAs, maintenance and repair of canals, and outputs, such as users' charge collection and yield in crop production. All units are in Lakhs' INR.

	Year 2018			
DMUs Canal Names	**Input 1**	**Input 2**	**Output 1**	**Output 2**
Amlesha Distribution	0.17	7.77	10.28	12.23
Babaikund Distribution	0.13	9.10	11.56	9.35
Kokadih Distribution	0.16	7.18	9.66	13.22
Hesadih Distribution	0.21	6.60	9.89	11.25
Konkadih Distribution	0.20	7.21	12.45	12.67
Jargodih Distribution	0.17	6.23	10.48	10.56
Hartaldih Distribution	0.14	6.93	7.56	8.65
Chitri Distribution	0.15	4.72	8.56	9.15
Tiruldih Distribution	0.13	5.86	6.85	10.97
	Year 2019			
	Input 1	**Input 2**	**Output 1**	**Output 2**
DMUs Canal Names	0.07	6.74	6.57	15.89
Amlesha Distribution	0.04	7.90	7.55	13.25
Babaikund Distribution	0.04	6.23	7.42	14.68
Kokadih Distribution	0.06	5.73	6.31	16.89
Hesadih Distribution	0.04	6.26	8.54	14.56
Konkadih Distribution	0.03	5.41	5.34	14.55
Jargodih Distribution	0.04	6.01	4.25	12.35
Hartaldih Distribution	0.02	4.10	2.58	10.23
Chitri Distribution	0.04	5.08	3.54	12.38
Tiruldih Distribution				
	Year 2020			
	Input 1	**Input 2**	**Output 1**	**Output 2**
Amlesha Distribution	0.15	3.69	8.35	18.95
Babaikund Distribution	0.11	4.32	6.39	16.54
Kokadih Distribution	0.08	3.41	7.45	15.64
Hesadih Distribution	0.08	3.13	8.53	15.64
Konkadih Distribution	0.11	3.42	7.42	15.64
Jargodih Distribution	0.12	2.96	6.58	14.88
Hartaldih Distribution	0.09	3.29	4.87	13.54
Chitri Distribution	0.07	2.24	4.67	11.34
Tiruldih Distribution	0.06	2.78	5.82	11.35
	Year 2021			
	Input 1	**Input 2**	**Output 1**	**Output 2**
Amlesha Distribution	0.21	5.13	5.63	19.56
Babaikund Distribution	0.19	6.01	7.21	18.56
Kokadih Distribution	0.23	4.75	5.34	19.88
Hesadih Distribution	0.25	4.36	4.58	18.54
Konkadih Distribution	0.19	4.76	6.58	20.65
Jargodih Distribution	0.23	4.12	7.55	18.65
Hartaldih Distribution	0.16	4.58	3.49	16.54
Chitri Distribution	0.17	3.12	3.19	9.35
Tiruldih Distribution	0.11	3.87	4.51	14.65

Appendix C : Questionnaire for Attributes of WUAs

A. District : Block : Village :

B. WUA name /Description :

Command Area under WUA (ha) :

C. Farmer name : M / F Age (years) :

D. Type of Farmer : Small/Medium/Large

(On the basis of landholding: small: < 2 ha/medium: 2 to 10 ha/large: > 10 ha).

E. Occupational status in Farming : Primary /Secondary

F. Farming experience (No. of years):

Below 5 years	5 -1 0 years	Above 10 years

G. Educational Status:

Graduate degree or above	Secondary	Primary	No schooling but literate	Illiterate
5	4	3	2	1

H. **Attributes of WUAs**

Scale of relative importance/preference:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

1. Participation is referred to as involvement of a farmer in different WUA activities.

1.1 An individual farmer participates in meetings:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

1.2 An individual farmer participates in discussions:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

1.3 An individual farmer participates in different WUA functions (water tax collection, water delivery scheduling, crop planning, repair, and maintenance of water courses):

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

1.4 An individual farmer participates in group activity with other farmers:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

1.5 An individual farmer feels that other farmers also participate:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

2. Decision making is the procedure of carrying out different WUA activities.

2.1 An individual farmer is making a decision and carrying it out without checking with the WUA:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

2.2 An individual farmer is supporting other members' suggestions and decisions resulting in consensus:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

2.3 An individual farmer is having the majority's decision prevail through voting:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

2.4 An individual farmer is attempting to get all members to accept the WUA's decision:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

2.5 An individual farmer is recognising the views of each individual before finalising any decision regarding WUA activities:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

3. Operation, maintenance and management functions include operation of the control system, repair and maintenance of watercourses and management of the irrigation system.

3.1 The consent of all farmers in fixing internal water distribution:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

3.2 Following a water sharing process for irrigating crops:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

3.3 Selection of specific crop patterns by all farmers in an outlet command:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

3.4 Maintenance and repair of the watercourses, field channels, and field drainage by the farmers' group:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

3.5 Maintenance of the irrigation system through the WUA's own fund:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

4. Group atmosphere:

4.1 The congeniality of the atmosphere in the WUA:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

4.2 Suppressing conflict:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

4.3 Avoiding unpleasant feelings:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

4.4 The different interests of farmers:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

4.5 Satisfaction and harmony of members:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

5. Membership feeling:

5.1 The prevalence of any sub-grouping in the WUA:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

5.2 Cohesiveness and support among members:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

5.3 Feeling of attachment to the WUA:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

5.4 Preference of some members to be outside or be passive:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

5.5 The presence of some members who move in and out of the WUA as per their interests and wishes:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

6. Norm refers to the rules and regulations of the WUA.

6.1 Each member's adherence to WUA rules:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

6.2 Cooperation of members in maintaining rules and regulations:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

6.3 Criteria for disqualification of membership:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

6.4 Control of behaviour:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

6.5 Activities of WUA members, and avoidance of defaulters:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

7. Empathy is defined as one farmer's perceptions about another.

7.1 Having a feeling for others' needs:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

7.2 Understanding others' problems:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

7.3 Listening carefully when others are speaking:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

7.4 Irritation or anger due to others' inability to follow any of the WUA's decisions without knowing the reasons for such inability:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

7.5 Avoiding any discussion of others' interests:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8. Interpersonal trust

8.1 Interactions and suggestions between members:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8.2 Faith of others in capability of a member in WUA activity:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8.3 Acceptance of decisions made:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8.4 Belief in others' opinions:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8.5 Non-disclosure of one's own ideas to others:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

8. Social support is the stability of the WUA in its area of jurisdiction.

9.1 Irrigation department officials support on technical aspects of irrigation system management:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

9.2 Irrigation department officials facilitate in performing the WUA's functions:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

9.3 Irrigation department officials help and give inputs from other line departments:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

9.4 Irrigation department officials facilitate linkage of one WUA with others:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

9.5 Irrigation department officials do capacity building of WUA members on different aspects through training:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

10. Efficiency Related: Timely and Adequate Water Availability:

Fully agree	Agree	Partially agree	Do not quite agree	disagree
5	4	3	2	1

SHORT BIOGRAPHY OF AUTHOR

SHORT BIOGRAPHY OF AUTHOR

Jay Nigam
https://orcid.org/0000-0002-1842-3234

Jay Nigam works in Mumbai as DGM at NABARD, an apex development finance institution. He has served NABARD since March 1996 and was posted in various capacities in UP, North-East, MP, and Jharkhand. He has also worked at CPWD and in the private sector. He has experience in the Appraisal, Monitoring, and Evaluation of Infrastructure Projects, viz., Irrigation Projects, Drinking water supply, Roads, Bridges, Storage, market yards, etc. He has implemented projects in Natural Resources Management (NRM), Climate Change, Rural Development Banking, Financial Inclusion and Banking Technology, SHGs, JLGs, FPOs and OFPOs. He holds a bachelor's degree in Civil Engineering, a PG Diploma in Computer Science, and an MBA. He is a Certified Associate of the Indian Institute of Bankers (CAIIB), a Fellow of the Institution of Engineers-India (FIE), a Member of the International Association of Hydrological Sciences: Wallingford, GB and a Life Member of the Indian Water Resources Society (LM-IWRS). He has contributed seven articles/posters in research journals and conferences. His detailed bio-data is as follows:

Employment:

1. **National Bank for Agriculture and Rural Development: Mumbai, Maharashtra, IN**
   1996-03-06 to present | DGM (Risk Management Department, NABARD, Head Office, Mumbai)
2. **Central Public Works Department: Dewas, Madhya Pradesh, IN**
   1993-10-28 to 1996-02-28 | Engineer (CPWD, Govt of India)
3. **Private Sector: Bhopal, Madhya Pradesh, IN**
   1991-07-01 to 1992-12-01 | Site Engineer (Construction of New Vidhan Sabha, Bhopal)
4. **Private Sector: Bhopal, Madhya Pradesh, IN**
   1991-02-01 to 1991-05-31 | Design Engineer (Micro Irrigation Network Planning for Sardar Sarovar Narmada Nigam, Gujarat)

Education and qualifications:

1. **Indian Institute of Banking and Finance: Mumbai, Maharashtra, IN**
   CAIIB (Certified Associate of the Indian Institute of Bankers)
2. **Barkatullah Vishwavidyalaya: Bhopal, Madhya Pradesh, IN**
   MBA (C Rajagopalachari Institute of Management (CRIM))
3. **Resources Development Institute, Bhopal: Bhopal, Madhya Pradesh, IN**
   Post Graduate Diploma (Computer Science)
4. **Rani Durgavati Vishwavidyalaya: Jabalpur, Madhya Pradesh, IN**
   BE (Civil Engineering)

Membership:

1. **Institution of Engineers India: Kolkata, West Bengal, IN**
   FIE (Civil Engineering)
2. **International Association of Hydrological Sciences: Wallingford, GB**
   Member (Hydrological Sciences)
3. **Indian Water Resources Society (IWRS): Roorkee, Uttarakhand, IN**
   Life Member (Water Resources Development and Management)

Works:

1. **Sustainable Pesticides Use in Jharkhand**
   Social Science Research Colloquium 2023-24 | 2023-12-01 | conference-paper
2. **Assessment of Barriers to Canal Irrigation Efficiency for Sustainable Harnessing of Irrigation Potential**
   Water | 2023-07-12 | journal-article | DOI: 10.3390/w15142558 |
   Part of ISSN:2073-4441
3. **Performance Evaluation of Irrigation Canals Using Data Envelopment Analysis for Efficient and Sustainable Irrigation Management in Jharkhand State, India**
   Energies | 2023-07 | journal-article | DOI: 10.3390/en16145490
4. **Sustainable Pesticides Use in Jharkhand**
   International Symposium on Sustainable Urban Environment (Issue 2022) |
   2022-10-11 | conference-poster
5. **A Study of the Status and Prospects of Financial Inclusion in Madhya Pradesh**
   11th International Conference on Frontier Global Issues and Challenges in the New Millennium on Emerging Economy, Accounting, Finance, Information and Communication Technology, Business and Management | 2012-01-05 |
   conference-paper
6. **Integrating the Environment in Financing Water Resources Projects**
   Technical Digest, NABARD | 2009-12-31 | magazine-article
7. **Development of Rural Infrastructure in North Eastern Region (NER) of India Through Rural Infrastructure Development Fund (RIDF)**
   3rd General Conference of Joint Council of KJR Bank Employees Association and
   KA Bank Officers' Association, Shillong, Meghalaya | 2004-07-05 | conference-paper.

PLAGIARISM REPORT

PLAGIARISM REPORT

phd thesis v9

ORIGINALITY REPORT

9%	6%	5%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dr.ddn.upes.ac.in:8080 Internet Source	1%
2	Submitted to Higher Education Commission Pakistan Student Paper	1%
3	journals.openedition.org Internet Source	<1%
4	Souvik Ghosh, Ashwani Kumar, Prabhakar Nanda, P.S.B. Anand. "Group dynamics effectiveness of water user associations under different irrigation systems in an eastern Indian state", Irrigation and Drainage, 2010 Publication	<1%
5	environmentportal.in Internet Source	<1%
6	Sonal Gupta, Rupesh Kumar, Amit Kumar. "Green hydrogen in India: Prioritization of its potential and viable renewable source",	<1%