Revitalising Canal Irrigation from Systemic Decay to Sustainable Governance

Dr NR Jagannath
Water Resources Management & Institutional Reforms Specialist

Abstract*—Canal irrigation management in Karnataka's Krishna Basin is shaped by a complex set of interconnected challenges that affect governance, system performance, and environmental sustainability. Field consultations with farmers, officials, and local stakeholders across the Tungabhadra Left Bank Canal (TLBC), Bhadra, Vijayanagar Channel, Gondi, and Narayanpur Right Bank Canal (UKP) systems indicate that these difficulties are not limited to a single level of administration, but rather emerge across state, district, canal, and outlet levels. As a result, issues of efficiency, equity, and reliability continue to influence both agricultural outcomes and the day-to-day experiences of irrigation users. At the state level, the absence of a statutory Water Regulatory Authority has constrained the fuller implementation of water rights, entitlements, and Integrated Water Resources Management (IWRM) principles. In addition, overlapping responsibilities within the Irrigation Department have, in some cases, made lines of accountability less clear and reduced the scope for coordinated decision-making. At the district and local levels, external pressures such as industrial pollution, mining-related siltation, urban expansion, interruptions in drinking water supply during canal closures, and catchment deforestation have placed additional stress on both water quantity and water quality. These factors have made the basin more vulnerable to seasonal scarcity and more difficult to manage in a balanced and forward-looking manner. Within the canal network itself, several operational concerns have affected performance. Unlined canal reaches contribute to seepage losses, while the limited presence of flow meters restricts the ability to manage supply on a volumetric basis. Periodic maintenance shutdowns, though sometimes necessary, often disrupt irrigation scheduling and create uncertainty for farmers who depend on timely deliveries. At the outlet level, disparities between head-end and tail-end users, together with soil salinization and yield pressures linked to paddy- and sugarcane-dominated cropping systems, have further complicated irrigation management and intensified farmer concerns. These challenges are further influenced by the variable functioning of Water Users' Cooperative Societies (WUCS), uneven participation in participatory irrigation management, and implementation gaps under the Karnataka Irrigation Act of 1995. Overall, the findings point to the need for a more coordinated, inclusive, and responsive approach to

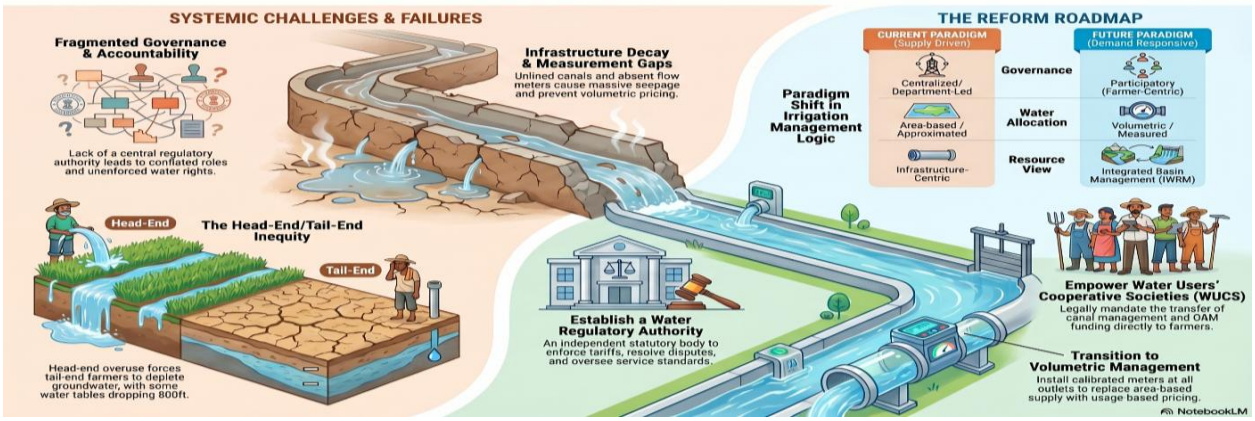
irrigation governance. Such an approach would benefit from stronger regulatory arrangements, greater support for WUCS, canal rehabilitation, improved measurement and monitoring systems, crop diversification, groundwater regulation, and basin-level planning backed by transparent and accessible data systems.

***Index Terms*—Canal Irrigation-Karnataka Governance-Krishna Basin-Water Users' Associations-Participatory Management-Volumetric Supply-Infrastructure Decay-Crop Diversification-Groundwater depletion-IWRM Principles-Regulatory Authority-Equity inequities**

I. INTRODUCTION

Karnataka is one of India's major irrigation-dependent states, with a large share of its agricultural economy relying on surface canal irrigation, particularly in the Krishna River Basin. The state's network of canal irrigation systems – including the Tungabhadra Left Bank Canal (TLBC), the Bhadra system, the Vijayanagar channel, the Gondi system, and the Narayanpur Right Bank Canal of the Upper Krishna Project (UKP) – serves hundreds of thousands of farmers across vast command areas. These systems were designed and built over several decades with the primary objective of providing reliable, equitable, and efficient water supply to agricultural lands. Despite significant public investment in canal construction and reservoir development, the actual performance of these irrigation systems has been far below their design potential. Efficiency losses, inequitable water distribution, deteriorating infrastructure, weakened farmer institutions, and misaligned policies have collectively constrained productivity and sustainability. The challenges are not merely technical; they are deeply rooted in governance structures, institutional arrangements, policy frameworks, and socio-economic dynamics that shape how water is allocated, managed, and used at every level of the system.

The infographic exposes policy gaps and institutional failures undermining canal irrigation in Karnataka's Krishna Basin. Infrastructure decay, unlined canals, and absent volumetric metering cause water loss and inequitable supply favoring head-end farmers. Governance is fragmented; an independent Water Regulatory Authority is needed to enforce rights. Water Users' Cooperative Societies remain ineffective due to weak legal powers and poor farmer participation. The author urges a shift to Integrated Water Resources Management to balance agriculture and ecosystems, recommending actionable reforms—crop diversification, groundwater regulation, extension service modernization—to strengthen resilient rural livelihoods.



The reform of canal irrigation management in Karnataka has been an ongoing concern for decades. The state enacted the Karnataka Irrigation (Amendment) Act, 1995, which laid the legal groundwork for Participatory Irrigation Management (PIM) and the formation of Water Users' Cooperative Societies (WUCS). However, the implementation of this legislation has been partial and uneven, with WUCS functioning poorly in most areas due to insufficient legal backing, lack of institutional support, and absence of genuine transfer of management responsibility to farmers.

There is no equivalent of a Water Regulatory Authority that can enforce water rights, entitlements, and service standards across different user groups and sectors. The policy framework governing canal irrigation in Karnataka is also inadequate from the perspective of Integrated Water Resources Management (IWRM). Sectoral water allocation does not adequately account for competing uses – drinking water, agriculture, industry, and the environment – and there are no comprehensive basin plans that integrate these demands within hydrologically coherent planning units. The state water policy has not been fully aligned with IWRM principles, and there is no single apex water regulatory body equivalent to the Electricity Regulatory Authority that can provide cross-sectoral oversight. This research paper systematically examines the policy issues in canal irrigation management in Karnataka across multiple levels, from state-level governance down to the individual farm outlet. It draws evidence directly from field consultations conducted with farmers, government officials, and civil society organizations across the Krishna Basin canal systems, as documented by the author in a comprehensive policy advocacy checklist (un-published). The paper is organized around five core objectives:

1. To introduce the context and significance of canal irrigation policy reform in Karnataka;
2. To identify and categorize the key policy issues at different administrative and operational levels;
3. To analyse these issues in terms of their causes, consequences, and inter-linkages;
4. To discuss the implications of the analysis for policy and institutional reform; and
5. To derive clear inferences and actionable policy prescriptions from the evidence gathered.

The paper adopts a multi-level, multi-stakeholder framework for analysis, recognizing that effective irrigation policy reform requires action simultaneously at the state, district, block, village, catchment, canal, and outlet levels. By synthesizing evidence from different canal systems and consultation processes, the paper aims to provide a comprehensive basis for targeted policy advocacy in Karnataka's canal irrigation sector.

II. METHODOLOGY

This study integrates primary fieldwork with a systematic review of secondary literature and administrative records to identify governance, operational, and environmental drivers of canal irrigation failure in Karnataka's Krishna Basin. Primary data derive from extensive field consultations across representative systems—Tungabhadra Left Bank Canal, Bhadra, Vijayanagar Channel, Gondi, and Narayanpur Right Bank Cana. Fieldwork employed semi-structured interviews with a cross-section of stakeholders: head-, mid- and tail-end farmers, Water Users' Cooperative Society (WUCS) leaders, irrigation department officials at state and district levels, and local actors including agripreneurs, groundwater users, and municipal planners. Detailed field notes recorded stakeholder narratives on service reliability, institutional interactions, outlet-level inequities, maintenance regimes, and socio-ecological impacts; systematic observations documented canal conditions, outlet operations, seepage, siltation, and adjacent land uses. Interview transcripts were thematically coded to surface recurring policy gaps, elite capture dynamics, maintenance cycles, and farmer adaptation strategies. Purposive sampling ensured inclusion of sites under diverse pressures—industrial

pollution, mining-driven siltation, urban encroachment, and catchment deforestation—enabling robust triangulation between lived experiences and documentary evidence.

III. KEY INSIGHTS FROM LITERATURE REVIEW

Jagannath NR's 2015 field document provides primary evidence from Karnataka's Krishna Basin canal systems, highlighting farmer grievances through FGDs across TLBC, Bhadra, Gondi, Vijayanagar, and Narayanpur RBC. It reveals chronic issues like unreliable water supplies, head-tail inequities, and non-functional WUCS, emphasizing the need for policy checklists to amplify farmer voices against government-NGO mismatches.

The Karnataka Irrigation (Amendment) Act 1995 establishes the legal foundation for PIM and WUCS formation, mandating cooperative societies for canal O&M. However, implementation gaps persist, as evidenced by weak institutional empowerment and limited farmer authority in decision-making. Central Water Commission's 2003 PIM guidelines offer a national blueprint for WUCS, promoting decentralized management and cost recovery. These directly inform reform recommendations, stressing capacity-building and monitoring to enhance irrigation efficiency in states like Karnataka. Global Water Partnership's 2000 IWRM paper defines integrated management across social, economic, and environmental dimensions, serving as the theoretical core for basin-level planning. It critiques siloed approaches, advocating cross-sectoral coordination essential for Karnataka's water-stressed commands. Karnataka's 2002 State Water Policy sets baseline norms but falls short on IWRM principles, lacking robust basin planning and environmental flows. This policy gap underscores the paper's call for alignment with national frameworks to address over-exploitation. India's National Water Policy 2012 benchmarks state policies against IWRM, emphasizing basin-level allocation and conjunctive use. It highlights Karnataka's deviations, supporting arguments for regulatory authorities to enforce equitable distribution. KNNL's 2010 Narayanpur RBC reports detail UKP command development, documenting infrastructure deficits and sedimentation issues. These primary sources validate field-level critiques of O&M failures in Lateral 15 outlets. CADA's 2008 annual reports track WUCS formation and extension efforts, revealing poor performance in canal maintenance and farmer training. They provide empirical data on institutional bottlenecks in Karnataka's irrigation commands. Mollinga and Bolding's 2004 edited volume frames irrigation reforms as political contests, not mere technical fixes. It bolsters the paper's thesis that Karnataka's PIM struggles stem from governance power dynamics in Asia and beyond. Vermillion's 1997 IMT review synthesizes global evidence, showing mixed outcomes from management transfers due to inadequate support. This critiques Karnataka WUCS quality, urging stronger post-formation nurturing. Meinzen-Dick et al.'s 2002 study analyses collective action in Indian canals, identifying factors like command size and leadership for WUA success. It explains WUCS dysfunctions, recommending nested enterprises for scalability. Brewer et al.'s 1999 IMT analysis of India, including Karnataka, documents policy-process mismatches in performance. It supports PIM reform by highlighting the need for adaptive implementation beyond top-down mandates. Narain's 2003 EPW article critiques India's water institutions, advocating regulatory bodies for pricing and allocation. This aligns with recommendations for a Karnataka Water Regulatory Authority to curb inequities. Swain's 2004 review exposes IMT gaps in India, including elite capture in WUAs. It reinforces arguments for inclusive WUCS reforms to ensure genuine participatory governance. Mukherji et al.'s 2009 groundwater governance volume warns of over-exploitation in Indo-Gangetic basins, mirroring Karnataka's canal-groundwater nexus. It supports conjunctive use strategies to mitigate depletion. Ostrom's 1990 Governing the Commons provides design principles for collective action, foundational for WUCS

empowerment. Principles like boundaries and sanctions address Karnataka's common-pool dilemmas. Uphoff's 1986 work pioneer's farmer participation processes, stressing iterative engagement for irrigation success. It informs prescriptions for rebuilding trust in Karnataka's alienated WUCS. Jairath's 2001 WUA cases in India reveal operational failures from poor incentives. These empirical insights critique Karnataka's WUCS effectiveness, advocating legal and financial autonomy. Shah and Kumar's 2008 dam assessment evaluates canal-fed storages, noting O&M neglect. It justifies infrastructure rehabilitation alongside volumetric controls for sustainable performance. Biswas's 2004 IWRM reassessment cautions against uncritical adoption, favouring pragmatic adaptations. This nuances the paper's IWRM advocacy for Karnataka's context-specific reforms.

III-KEY ISSUES AT DIFFERENT LEVELS

The policy issues in canal irrigation management in Karnataka manifest differently across administrative and operational levels. The following section presents a structured overview of the principal issues at each level, as documented through field consultations and stakeholder engagement processes across the Krishna Basin canal systems.

3.1 State Level

At the apex level, the most significant policy gaps relate to regulatory architecture and integrated planning. The state currently lacks a water regulatory authority with the mandate and authority to enforce water rights, entitlements, and service delivery standards. The existing state water policy is not fully aligned with IWRM principles, particularly with regard to basin-level planning, cross-sectoral integration, and demand management. Sectoral water allocation – between agriculture, drinking water, industry, and the environment – is conducted without a coherent forward-looking framework that accounts for growing demand, climate variability, and competing uses.There is also no legal framework that clearly mandates and empowers basin-level planning bodies, making it difficult to resolve inter-sectoral and inter-district water conflicts. The concept of environmental flows has not been institutionalized. The roles and responsibilities for regulation, management, and operation of irrigation systems remain conflated within the Irrigation Department, without the separation necessary for accountability and efficiency.

3.2 District Level

At the district level, industrial pollution of water bodies is a significant policy concern. Within the Krishna Basin, major industries are permitted to discharge treated effluents into rivers under legal provisions, but enforcement of treatment standards and monitoring of effluent quality is weak. The cumulative impact of industrial discharges on irrigation water quality has not been systematically assessed. Coordination between the Irrigation Department, the Karnataka State Pollution Control Board, and district administrations is fragmented and often reactive rather than proactive.

3.3 Block Level

At the block level, issues relate primarily to the environmental impacts of mining, urbanization, and the lack of multi-stakeholder governance platforms. Mining activities – particularly the transportation of ore without adherence to prescribed environmental norms – contribute to dust pollution and sediment loading in water bodies. Silt accumulation from mines and degraded forest areas reduces the effective storage capacity of reservoirs, compromising water availability for downstream irrigators. Urbanization is leading to increased discharge of municipal sewage into rivers, affecting water quality for downstream irrigation

use. There is also a critical need for effective multi-stakeholder platforms at the block level to coordinate watershed development, irrigation management, and downstream water governance. The Irrigation Department's resistance to fully empowering Water Users' Associations (WUAs) is a major institutional constraint. Different departments – agriculture, irrigation, forestry, and watershed development – operate in silos without coordination, leading to policies that undermine each other's effectiveness.

3.4 Village Level

At the village level, the most pressing concerns relate to drinking water security, sanitation, and the sustainability of local water sources. Canal closures for maintenance during summer months significantly affect drinking water supply in many villages, especially where groundwater quality is poor or the water table has declined sharply. Livestock water needs and their interactions with canal water quality are inadequately addressed in existing management frameworks.

Watershed development and drainage line treatments, while beneficial for recharge, have in some cases inadvertently reduced tank storage capacities by up to 33%, highlighting the need for proper guidelines on the extent and design of watershed interventions. The near-extinction of valuable forest species such as sandalwood due to poaching and disease points to broader governance failures with indirect implications for catchment hydrology and water availability.

3.5 Catchment Level

At the catchment level, the key issues revolve around the tension between top-down and bottom-up approaches to natural resource management, and the absence of institutions capable of integrating hydrological science with community-based knowledge. Deforestation in upper catchment areas accelerates soil erosion and increases sediment loads in rivers and reservoirs, reducing their effective life and storage capacity. A very high sedimentation load following rainfall events is indicative of unsustainable land use practices throughout the catchment. The institutional challenge at the catchment level is particularly acute: catchment management bodies are currently oriented towards mobilizing resources for new infrastructure rather than managing existing water resources sustainably. There is an urgent need for science-based catchment management approaches that integrate GIS, hydrological modelling, and community knowledge.

3.6 Canal Level

At the canal level, the dominant issues relate to infrastructure deterioration, measurement deficiencies, and management failures. The closure of main canals for four to five months every year for maintenance affects downstream water availability and disrupts agricultural and drinking water supply. Unlined canals result in high seepage losses, weed growth, sluggish water flow, and mosquito breeding, increasing the disease burden in command areas. The absence of properly maintained and calibrated flow measurement devices at key off-take points is a fundamental operational problem. Without reliable measurement, it is impossible to enforce equitable water distribution, account for losses, or implement volumetric supply. The concept of minimum environmental flows in rivers is not practiced. Upstream-downstream linkages in water allocation and management are poorly understood and institutionally unaddressed.

3.7 Outlet Level

The outlet level is where the failures of upstream governance are most acutely felt by individual farmers. The cumulative policy and management failures at higher levels manifest here as unreliable and inequitable

water supply, deteriorating soil health, declining agricultural productivity, and financial distress for farmers. Key issues at the outlet level include:

1. Absence of volumetric water supply and pricing, with allocation remaining area-based and supply-driven;
2. Non-functional measuring devices and absent control structures, making equitable distribution impossible;
3. Soil degradation due to waterlogging, salinity, and excessive chemical fertilizer use;
4. Declining adoption of improved cultivation practices such as the System of Rice Intensification (SRI);
5. Rising cost of inputs and labour, with disproportionate burdens on small and marginal farmers;
6. Levy and collection of water charges in contravention of the Karnataka Irrigation Act, 1995;
7. Insufficient and inequitable water sharing between head-end and tail-end farmers;
8. Absence of information on water schedules, leading to over-use and wastage at the head-end.

3.8 Canal System-Specific Issues (Krishna Basin)

Field consultations across the major canal systems in the Krishna Basin revealed system-specific issues that add further texture to the policy landscape:

Tungabhadra Left Bank Canal (TLBC)

Paddy and sugarcane continue to dominate cropping patterns despite their high water demand and the ecological pressures they impose on command areas. The shift away from these crops has been partial and market-driven rather than policy-supported. Minimum support price mechanisms are ineffective. Agricultural extension services are absent or non-functional. The results of soil tests are not communicated to farmers on time. Tail-end water deprivation is acute, with illegal pump sets exacerbating inequitable distribution. Labor costs have risen sharply, making traditional paddy cultivation economically unviable for many farmers.

Bhadra System

WUCS functioning is mixed, with few individuals effectively controlling societies. Membership fees are often paid by a handful of active members rather than the beneficiary community as a whole. The MoU between WUCS and KNNL/CADA is signed but not operationalized. Water demand management is not linked to volumetric supply. Transparency and accountability within WUCS are critically weak.

Vijayanagar Channel

The physical condition of the Annicut and channel is poor, leading to unreliable water supply and yield reduction. Water charges are being paid to the Revenue Department rather than being retained for canal Operation and Maintenance (O&M). WUCS were formed on a target basis without adequate community mobilization, and most are non-functional. The need for an alternative lift irrigation scheme and canal modernization is widely recognized.

Gondi System

WUCS face frequent water shortages and lack response from KNNL and CADA on management issues. Seepage from the Bhadra canal during the rainy season causes residential damage and waterlogging. CADA is understaffed, limiting support for agricultural extension and WUCS strengthening. Salinity, waterlogging, and weed growth in unlined canals are recurring problems.

Narayanpur Right Bank Canal (UKP)

This system highlights the potential for improved water use efficiency through the System of Rice Intensification and green manuring, as well as the challenge of shifting from village-level to outlet-level water management logic. Productivity differentials between head-end, middle-reach, and tail-end areas

require deeper analysis. The challenge of organizing labor groups for canal irrigation and managing competitive wages is prominent.

IV. ANALYSIS OF ISSUES AT DIFFERENT LEVELS

A systematic analysis of the issues documented above reveals several cross-cutting structural problems that operate simultaneously at multiple levels and reinforce each other. The analysis is organized around four principal dimensions: governance and institutional, infrastructure and technical, agronomic and economic, and environmental and ecological.

4.1 Governance and Institutional Analysis

4.1.1 Fragmented Regulatory Architecture

A fundamental governance failure in Karnataka's canal irrigation sector is the absence of a unified, empowered regulatory authority. The functions of water resource regulation, canal management, and operational oversight remain fragmented across multiple agencies – the Irrigation Department, KNNL, CADA, Revenue Department, and Panchayati Raj Institutions – without clear lines of accountability. This fragmentation results in coordination failures, inconsistent enforcement of the Karnataka Irrigation Act, 1995, and the absence of a coherent state water policy grounded in IWRM. The analogy with the Electricity Regulatory Authority is instructive: a dedicated Water Regulatory Authority with statutory powers to set water tariffs, enforce service standards, adjudicate disputes, and oversee equitable allocation across sectors would provide the institutional foundation for genuine irrigation sector reform. Without such a body, water rights remain administratively defined rather than legally enforceable, and water entitlements across sectors – agriculture, drinking water, industry, environment – lack a transparent and accountable allocation mechanism.

4.1.2 Dysfunctional Water Users' Cooperative Societies (WUCS)

The analysis of WUCS functioning across all five canal systems reveals a consistent pattern of institutional failure. While WUCS were mandated under the Karnataka Irrigation Act and formed through government-led campaigns, they were established largely on a target basis without adequate community mobilization, awareness creation, or genuine transfer of management responsibility. The consequences are predictable: elite capture (few individuals controlling societies), low membership engagement, non-operationalized MoUs, absence of water management activities, and no independent O&M financing capacity. A critical policy gap is that Irrigation Department engineers lack awareness of WUCS roles and responsibilities, leading to a default continuation of departmental water management without meaningful farmer participation. The levy and collection of water charges in contravention of the Karnataka Irrigation Act further undermines the financial sustainability of the PIM model. WUCS remain paper institutions in most canal commands, unable to fulfil their intended role in decentralized water management.

4.1.3 Absence of Decentralized Decision-Making

The principle of decentralized, participatory water governance – central to both the Karnataka Irrigation Act and national IWRM frameworks – has not been operationalized in practice. Decision-making on water scheduling, allocation, and distribution remains centralized within the Irrigation Department, with farmers having no formal channel for expressing demand or grievances. Water schedules are arbitrarily implemented without farmer consultation. This lack of accountability drives over-extraction by head-end farmers, non-compliance with rotation schedules, and widespread canal tampering.

4.2 Infrastructure and Technical Analysis

4.2.1 Deteriorating Canal Infrastructure

The physical condition of canal infrastructure across all systems is a major constraint on irrigation performance. Unlined canals suffer from high seepage losses, weed growth, and reduced conveyance efficiency. Canal lining, where it exists, is frequently cracked and dilapidated. Regulators and control structures are absent or non-functional. The absence of proper flow measurement devices at off-take points means that water allocation is managed by approximation rather than by measurement, making equitable distribution structurally impossible.

The financial sustainability of O&M is a systemic problem: water charges collected are insufficient to cover maintenance costs, and the government's fiscal capacity to fund adequate maintenance is constrained. This creates a vicious cycle in which poor maintenance leads to poor service delivery, which reduces farmers' willingness to pay water charges, which in turn reduces maintenance funding.

4.2.2 Absence of Volumetric Water Management

The shift from area-based to volumetric water supply and pricing – a cornerstone of both the Karnataka Irrigation Act and IWRM frameworks – has not been implemented in any of the surveyed canal systems. Water quotas are not fixed at the outlet level. Measuring devices are non-functional. Supply remains largely continuous and supply-driven rather than demand-responsive. This prevents the implementation of rational water pricing, efficient distribution, and demand management incentives.

4.3 Agronomic and Economic Analysis

4.3.1 Crop Pattern Misalignment

The persistence of paddy and sugarcane as the dominant crops in most canal command areas represents a major agronomic and economic challenge. These crops have very high water requirements relative to their economic returns and impose severe pressures on soil health through waterlogging, salinity, and chemical input overuse. Despite the stated policy objective of crop diversification, the enabling conditions for diversification – soil testing services, market linkages, storage facilities, extension support, and assured markets for alternative crops – are largely absent. The mismatch between official crop localization policy and actual farmer practice is striking. Farmers deviate from recommended crop patterns not out of ignorance but because the market, logistical, and informational conditions necessary for alternative crops have not been created. Policy must address these enabling conditions rather than merely mandating crop diversification.

4.3.2 Agricultural Extension Failure

Across all canal systems, agricultural extension services are described as absent, ineffective, or limited to the distribution of subsidized inputs rather than providing genuine agronomic advice. Soil health card distribution is incomplete, and test results are not communicated to farmers on time. Awareness of improved cultivation practices – SRI, green manuring, bio-fertilizers, crop rotation – is low. Raithu Samparka Kendras are not functioning effectively in most irrigated areas. This absence of knowledge support contributes directly to declining yields, soil degradation, and rising cultivation costs.

4.4 Environmental and Ecological Analysis

4.4.1 Groundwater Over-Exploitation

A paradoxical consequence of poor canal water service delivery is the accelerated over-exploitation of groundwater. Tail-end farmers, unable to access canal water reliably, have increasingly turned to groundwater as a conjunctive irrigation source. Free electricity for groundwater pumping has removed the price signal that would otherwise discourage over-extraction. The result is a progressive decline in water tables in many canal command areas – in some cases to depths of 200–800 feet – posing a severe threat to long-term agricultural and domestic water security.

4.4.2 Environmental Degradation

The cumulative environmental footprint of canal irrigation mismanagement is substantial. Soil degradation through waterlogging, salinity, and alkalinity is spreading. Excessive pesticide and fertilizer use is contaminating surface and groundwater. Catchment deforestation is accelerating erosion and reservoir sedimentation. Industrial and municipal effluents are degrading river water quality. The concept of environmental flows has not been incorporated into water allocation frameworks, meaning that downstream ecosystems and wetlands receive no guaranteed base flow. Biodiversity loss is occurring across the command areas.

V. DISCUSSION ON THE ANALYSIS

The analysis presented above reveals that canal irrigation management in Karnataka is characterized by systemic, multi-level failures that are deeply interconnected. This section discusses the most critical inter-linkages and their implications for policy reform.

5.1 The Governance-Performance Nexus

The most fundamental conclusion from the analysis is that technical and agronomic problems in canal irrigation are, at their core, governance problems. Poor canal maintenance, inequitable water distribution, soil degradation, and declining agricultural productivity are all proximate symptoms of deeper governance failures: unclear water rights, dysfunctional farmer institutions, fragmented regulatory architecture, and absent accountability mechanisms. Addressing these technical problems without addressing their governance roots will yield only temporary improvements.

The PIM framework embodied in the Karnataka Irrigation Act, 1995 was correctly designed to address these governance failures, but its implementation has been superficial. WUCS were formed as administrative targets rather than genuine farmer institutions. Management responsibilities were nominally transferred without the corresponding legal authority, financial resources, or capacity support. The Irrigation Department has not undergone the cultural and organizational transformation necessary to function as a service provider to farmer institutions rather than as a control authority over irrigation water.

5.2 The Equity Dimension

Canal irrigation systems in Karnataka are characterized by profound equity failures. The head-end / tail-end problem is structurally embedded in the design and management of canal systems: head-end farmers have reliable access and frequently over-irrigate, while tail-end farmers receive insufficient or no water, are forced to rely on expensive groundwater, and face yield penalties and financial distress. This inequity is

compounded by the absence of volumetric measurement and pricing, which would make over-use at the head-end visible and financially costly.

The equity implications of the current system extend beyond immediate water access. The progressive decline in groundwater tables, driven partly by tail-end farmers' compelled reliance on groundwater, poses an existential threat to the long-term agricultural viability of tail-end areas. The economic distress of small and marginal farmers – squeezed between rising input costs, falling output prices, and unreliable water supply – is accelerating rural impoverishment and land consolidation, with significant social consequences.

5.3 The Information and Knowledge Gap

Effective water management at every level is constrained by a pervasive lack of reliable data and information. Water flows are not measured at key points in the system. Crop areas and yields are not accurately recorded. Soil health data is collected but not analysed or communicated to farmers. Groundwater levels are not systematically monitored. Without a reliable information base, it is impossible to plan water allocations rationally, enforce equitable distribution, evaluate management performance, or make evidence-based policy decisions. The cultural resistance to data sharing among water resource agencies – where data is treated as a bureaucratic asset rather than a public good – is a major institutional barrier to IWRM. Addressing this will require not only technical investments in monitoring and information systems but also a fundamental change in organizational culture and accountability.

5.4 The Financial Sustainability Problem

Canal irrigation systems in Karnataka face a deepening financial crisis. Water charges are insufficient to cover O&M costs. The low willingness to pay among farmers – itself a rational response to poor service delivery – limits the revenue base. Government fiscal transfers for irrigation maintenance are inadequate and declining. This financial unsustainability drives the physical deterioration of canal infrastructure, which in turn worsens service delivery and further erodes willingness to pay, creating a reinforcing downward spiral. The solution to this problem is not simply to raise water charges; that would be politically unacceptable and financially inequitable for poor farmers who receive poor service. The solution requires a parallel improvement in service delivery quality – demonstrated through reliable water supply, equitable distribution, and transparent management – that creates a value proposition for farmers to pay. Volumetric pricing, linked to service standards enforced by a regulatory authority, is the institutional mechanism through which financial sustainability and service quality can be jointly improved.

5.5 The Need for Integrated Water Resources Management (IWRM)

The analysis strongly supports the adoption of IWRM as the overarching framework for water governance reform in Karnataka. The current sectoral, departmental approach to water management – in which agriculture, drinking water, industry, and the environment are managed by separate agencies with separate budgets and without coordination – is incapable of addressing the complex, cross-sectoral challenges documented in this paper. IWRM requires the adoption of the river basin as the primary unit of water resource planning and management. It requires the integration of surface water, groundwater, and rainwater harvesting within a unified management framework. It requires the allocation of water across competing uses through a transparent, accountable, and scientifically-informed process. And it requires the genuine empowerment of basin-level governance bodies, including farmer institutions, to participate in decision-making. Karnataka's state water policy needs to be fundamentally revised to embrace these principles.

VI. INFERENCES FROM THE DISCUSSION

Based on the evidence gathered, the analysis conducted, and the discussion presented above, the following inferences can be drawn. These inferences are structured as policy prescriptions targeted at different levels of governance and action.

6.1 Inference on Governance Reform

The establishment of an independent, statutory Water Regulatory Authority for Karnataka is the single most important institutional reform needed. This body should have the mandate and powers to: set enforceable water entitlements across sectors; regulate water tariffs based on service quality standards; adjudicate inter-sectoral and inter-user water disputes; oversee the performance of irrigation agencies and WUCS; and ensure compliance with environmental flow requirements. Without such an authority, fragmented governance will continue to undermine all other reform efforts. The Karnataka Irrigation Act, 1995 needs to be amended and strengthened to provide genuine legal backing for PIM, including mandatory transfer of management responsibility for distributary and minor canals to WUCS, provision of corresponding financial resources and O&M funds to WUCS, and enforceable accountability mechanisms for both WUCS and the Irrigation Department.

6.2 Inference on WUCS Reform

The formation and strengthening of WUCS must be fundamentally redesigned. Formation processes must prioritize community mobilization, farmer awareness, and genuine participatory design over administrative target-setting. WUCS must be provided with clear, legally enforceable mandates including the authority to manage water distribution, collect and retain water charges for O&M, regulate intra-outlet water sharing, and interface directly with KNNL and CADA on water management matters. Capacity building programs for WUCS leaders and members must be institutionalized and practically oriented, addressing local conditions rather than generic training content.

6.3 Inference on Water Measurement and Volumetric Management

The transition from area-based to volumetric water supply and pricing is essential for both efficiency and equity in canal irrigation. This requires, as a first step, the systematic installation, calibration, and maintenance of flow measurement devices at all key points in the distribution system – main canal off-takes, distributary heads, minor canal heads, and outlet points. Water quotas must be fixed at the outlet level, communicated to farmers in advance, and adhered to through a transparent rotation scheduling system. Volumetric pricing, linked to the volume of water delivered rather than the area commanded, should be progressively introduced as measurement infrastructure is established.

6.4 Inference on Infrastructure Rehabilitation

A prioritized, time-bound program of canal infrastructure rehabilitation is essential. This should include canal lining of key distributaries and minors to reduce seepage losses, repair and installation of control structures and regulators, installation of flow measurement devices at off-take points, and rehabilitation of drainage infrastructure to address waterlogging. Infrastructure rehabilitation must be accompanied by improved O&M systems, with clear responsibilities assigned to either the Irrigation Department or WUCS and with adequate and predictable funding mechanisms.

6.5 Inference on Agricultural Extension and Support

Revitalizing agricultural extension services in canal command areas is a policy priority of high urgency. This requires increased staffing of agricultural assistants and CADA extension workers, mandatory soil testing and timely communication of results to farmers, promotion of crop diversification away from paddy and sugarcane towards less water-intensive but economically remunerative crops, and strengthening of Raithu Samparka Kendras as genuine information and advisory centers. Market development – including cold storage, farmer producer organizations, and fair price procurement – must be integrated with agricultural extension to make crop diversification economically viable.

6.6 Inference on Groundwater Management

A dedicated groundwater regulatory framework is urgently needed in Karnataka. The current policy of providing free electricity for groundwater pumping, while politically popular, is economically and ecologically indefensible: it accelerates groundwater depletion, creates water conflicts, causes waterlogging and salinity, limits cost recovery in the energy sector, and undermines the financial viability of surface canal irrigation. A transition towards metered electricity for groundwater pumping, possibly with targeted subsidies for small and marginal farmers, combined with groundwater abstraction limits and aquifer monitoring, is essential for long-term water security.

6.7 Inference on Environmental Integration

Karnataka's water policy must incorporate an explicit environmental dimension, including: mandatory reservation of environmental flows in all rivers; protection of wetlands and riparian ecosystems; regulation of industrial and municipal effluent discharge into irrigation water sources; and integration of catchment management with downstream irrigation management. Catchment-level governance bodies, adequately empowered and resourced, should coordinate land use, forestry, watershed development, and irrigation management within hydrologically coherent catchment units.

6.8 Inference on Information Systems

Investment in a comprehensive, integrated water information system for Karnataka is a prerequisite for evidence-based IWRM. This system should include: real-time monitoring of canal flows and reservoir levels; systematic groundwater table monitoring across canal command areas; regular soil health surveys and crop production assessments; GIS-based mapping of land use, canal systems, and command areas; and a publicly accessible data portal. A culture of data transparency and sharing must be institutionalized, with data treated as a public resource rather than a bureaucratic asset.

6.9 Inference on IWRM and Basin Planning

Karnataka's state water policy should be comprehensively revised to align with IWRM principles. Basin plans should be prepared for all major river basins in Karnataka, with the river basin as the primary unit of water resource planning. These plans should integrate surface water, groundwater, and rainwater harvesting; allocate water across competing uses through a transparent, multi-stakeholder process; incorporate environmental flow requirements; and set out clear mechanisms for monitoring, evaluation, and adaptive management. The preparation and implementation of basin plans should involve all relevant agencies and stakeholder groups, including farmer institutions, civil society organizations, and local governments.

6.10 Overarching Inference: A Paradigm Shift

The overarching inference from this research is the need for a fundamental paradigm shift in how canal irrigation is conceived, governed, and managed in Karnataka. The current paradigm – characterized by supply-driven, departmentally-managed, infrastructure-centric irrigation – is demonstrably failing to deliver the outcomes that the billions of rupees invested in these systems were intended to achieve. The new paradigm must be demand-responsive, participatory, basin-integrated, and environmentally sustainable. It must place farmers – particularly women and marginal farmers – at the center of irrigation management rather than at the periphery of departmental operations. It must treat water as an economic, social, and environmental good, to be allocated and managed transparently, equitably, and efficiently. And it must be backed by a robust legal and institutional framework that empowers farmer institutions, enforces accountability, and integrates water management across sectors and administrative levels.

The evidence from Karnataka's canal irrigation systems is not merely a catalogue of problems; it is a roadmap for reform. The voices of farmers, government officials, and civil society organizations documented in this paper provide a clear and actionable foundation for a comprehensive policy advocacy agenda. The urgency of that agenda is underscored by the progressive deterioration of canal systems, the deepening financial distress of irrigated farmers, the accelerating depletion of groundwater, and the growing vulnerability of agricultural livelihoods to water scarcity and climate variability.

VII. CONCLUSION

1. Urgent Need for a Statutory Water Regulatory Authority**:** Karnataka's canal irrigation systems suffer from fragmented governance, with no unified body to enforce water rights, tariffs, or service standards. Field evidence from Krishna Basin canals like TLBC and UKP shows persistent inequities and inefficiencies due to conflated roles within the Irrigation Department. Establishing an independent Water Regulatory Authority—modelled on electricity regulators—would set enforceable entitlements across sectors, adjudicate disputes, and drive accountability, forming the cornerstone of reform.
2. Revitalizing Participatory Irrigation Management through WUCS**:** WUCS, mandated by the 1995 Karnataka Irrigation Act, remain dysfunctional across systems like Bhadra and Gondi due to elite capture, non-operational MoUs, and lacking legal empowerment. Genuine reform demands community-led formation, mandatory management transfer for distributaries, and O&M fund retention. This shift from target-based creation to participatory empowerment would foster decentralized decision-making and financial self-reliance.
3. Transition to Volumetric Water Supply and Pricing**:** Area-based, supply-driven allocation perpetuates head-tail inequities and wastage, as seen in all surveyed canals without functional meters. Installing calibrated flow devices at off-takes and outlets, fixing outlet-level quotas, and linking pricing to volume delivered would enable demand-responsive management. This technical upgrade, paired with transparent rotations, is essential for efficiency and equity.
4. Comprehensive Canal Infrastructure Rehabilitation**:** Deteriorating unlined canals, absent regulators, and annual closures cause seepage, weeds, and unreliable supply in TLBC, Vijayanagar, and others. A time-bound program for lining, repairs, drainage fixes, and measurement infrastructure—funded predictably and assigned to WUCS or departments—breaks the maintenance-cost spiral. Prioritizing distributaries would quickly boost conveyance efficiency and farmer trust.
5. Aligning Crop Patterns with Water Availability**:** Paddy and sugarcane dominance in water-scarce commands like TLBC imposes ecological strain despite diversification policies. Enabling shifts via soil

testing, extension on SRI/green manuring, market linkages, and FPOs would promote low-water crops. Policy must create economic incentives, not just mandates, to match agronomy with hydrological realities.

6. Rebuilding Agricultural Extension Services: Non-functional extension in all systems leaves farmers without timely soil data, SRI advice, or market info, fueling yield declines and input overuse. Revitalizing Raithu Samparka Kendras with staffed assistants, mandatory testing, and integrated support would empower adoption of sustainable practices. This knowledge bridge is vital for productivity and resilience.
7. Curbing Groundwater Over-Exploitation**:** Poor canal reliability drives tail-end farmers to deep bore wells, aided by free power, depleting aquifers to 800 feet in commands. A regulatory framework with metered electricity, abstraction limits, and monitoring—subsidized for marginal farmers—would promote conjunctive use. This prevents long-term collapse of irrigated agriculture.
8. Institutionalizing Environmental Flows and Protection**:** Absent environmental flows, effluents, and sedimentation degrade rivers and reservoirs across Krishna Basin. Mandating base flows, effluent standards, and wetland safeguards in policy would sustain ecosystems. Integrating these via a Water Regulatory Authority ensures irrigation doesn't sacrifice biodiversity.
9. Empowering Catchment-Level Multi-Stakeholder Bodies**:** Top-down catchment management ignores erosion from deforestation and mining, slashing reservoir capacity. Science-based bodies blending GIS, hydrology, and community input—coordinating forestry, watersheds, and irrigation—would balance upstream land use with downstream needs. Bottom-up integration is key to hydrological coherence.
10. Bridging District and Block-Level Pollution Gaps**:** Industrial effluents and urban sewage pollute Krishna waters, while mining silt burdens reservoirs. Coordinated platforms linking Pollution Control Board, Irrigation, and panchayats for proactive monitoring and enforcement would protect quality. Block-level forums could align urbanization with irrigation sustainability.
11. Enhancing Village-Level Water Security: Canal closures disrupt drinking/livestock needs amid falling groundwater; watershed works sometimes shrink tanks. Guidelines for integrated local management—prioritizing sanitation, recharge, and forest protection—would secure village resilience. Addressing these micro-impacts builds broad support for reforms.
12. Adopting Basin-Level IWRM Planning**:** Sectoral silos ignore competing demands, lacking basin plans. Revising state policy for Krishna-scale integration of surface/groundwater, multi-stakeholder allocation, and adaptive monitoring would enable forward-looking management. This hydrological unit aligns policy with climate variability.
13. Closing the Information and Data Deficit: Unmeasured flows, unreported yields, and siloed data hinder rational planning. A public GIS portal for real-time canal/groundwater/soil monitoring would enable evidence-based decisions. Culturally shifting data to a public good unlocks IWRM potential.
14. Achieving Financial Sustainability via Service-Quality Linkage**:** Inadequate charges and O&M funding create a downward spiral, eroding infrastructure. Volumetric pricing tied to regulator-enforced standards would justify payments through reliable service. This virtuous cycle recovers costs while serving farmers equitably.
15. Paradigm Shift to Demand-Responsive, Farmer-Centric Irrigation**:** Karnataka's supply-driven model fails amid scarcity; evidence demands participatory, basin-integrated governance centering marginal farmers. Backed by legal reforms, empowered WUCS, and IWRM, this shift delivers productivity, equity, and sustainability—transforming investments into resilient livelihoods.

VIII. RECOMMENDATIONS

1. Establish a Statutory Water Regulatory Authority at State Level: Enact legislation for an independent Karnataka Water Regulatory Authority to enforce water rights, entitlements, tariffs, and service standards across sectors. Mandate basin-level planning under IWRM, separating regulation from Irrigation Department operations. Empower it to resolve inter-sectoral conflicts, institutionalize environmental flows, and oversee agencies like KNNL/CADA—mirroring electricity regulators to end fragmented governance.
2. Strengthen Enforcement Against District-Level Industrial Pollution: Require district administrations to conduct cumulative impact assessments of industrial effluents on Krishna Basin irrigation water, with mandatory real-time monitoring by Karnataka State Pollution Control Board. Form joint task forces with Irrigation Department for proactive enforcement of treatment standards. Impose penalties linked to pollution levels and redirect fines to canal O&M funds.
3. Create Block-Level Multi-Stakeholder Governance Platforms: Launch block-level forums uniting Irrigation, Agriculture, Forestry, and Watershed departments to coordinate against mining dust/silt, urban sewage, and siloed policies. Empower Water Users' Associations (WUAs) with veto on incompatible developments. Develop binding protocols for ore transport norms and sewage treatment to protect reservoir capacity and downstream quality.
4. Secure Village-Level Drinking and Livestock Water During Closures: Revise maintenance schedules to minimize summer canal closures, integrating village drinking/livestock needs via piped off-takes or contingency tanks. Issue guidelines capping watershed interventions at 10% tank capacity loss, with pre-approval audits. Combat forest poaching through community patrols and hydrology-linked incentives to sustain local sources.
5. Form Science-Integrated Catchment Management Institutions: Establish catchment bodies blending GIS, hydrological modelling, and farmer knowledge for sustainable land use, targeting deforestation-driven sedimentation. Shift focus from new infrastructure to existing resource management, with annual erosion audits post-rains. Mandate 20% upper-catchment afforestation tied to downstream irrigation allocations.
6. Implement Staggered Canal Maintenance and Lining Programs: Introduce rotational maintenance to limit annual closures to 2 months, preserving downstream supply. Prioritize lining 50% of unlined canals in Krishna systems within 3 years to cut seepage/weeds/mosquitoes. Enforce minimum environmental flows and map upstream-downstream linkages for equitable allocation.
7. Enforce Outlet-Level Volumetric Supply and Equity Measures: Install/calibrate meters and control structures at all outlets, shifting to fixed volumetric quotas with head-tail rotations publicized weekly. Penalize head-end overuse and illegal pumps; subsidize tail-end access. Align water charges with the 1995 Act, promoting SRI to combat soil degradation and input costs.
8. Tailor System-Specific Reforms for Krishna Basin Canals: For TLBC, enforce crop diversification via MSP for alternatives and extension; ban illegal tail-end pumps. In Bhadra/Gondi, operationalize WUCS MoUs with KNNL/CADA staffing boosts and transparency audits. Modernize Vijayanagar anicut/channel with lift schemes; analyze UKP productivity gradients for labor cooperatives.
9. Redesign WUCS for Genuine Participatory Empowerment: Replace target-based formation with mobilization drives, granting WUCS legal authority for distribution, charge collection/retention, and

KNNL interfacing. Provide tailored capacity building and amend 1995 Act for mandatory distributary handovers, countering elite capture seen in all systems.

10. Roll Out State-wide Infrastructure and Volumetric Upgrades: Launch a 5-year program for regulators, lining, drainage rehab, and meters at all off-takes/outlets. Introduce demand-responsive volumetric pricing post-installation, breaking the O&M funding cycle through WUCS-managed budgets and service-linked incentives.
11. Revamp Extension for Crop Diversification and Soil Health: Staff Raithu Samparka Kendras and CADA with 2x assistants per block for mandatory, timely soil testing and SRI/green manuring training. Integrate FPOs, cold storage, and procurement for low-water crops, overriding paddy/sugarcane dominance in water-stressed commands.
12. Reform Groundwater Policy to Promote Conjunctive Use: Phase out free electricity for pumps, introducing metered tariffs with marginal farmer subsidies, abstraction caps, and aquifer monitoring. Link canal reliability improvements to reduced groundwater reliance, averting 200-800ft declines and salinity in tail-ends.
13. Embed IWRM with Comprehensive Basin Planning and Data Systems: Revise state water policy for basin-centric plans integrating surface/groundwater, multi-stakeholder allocations, and environmental flows. Build a public GIS portal for real-time flows, soils, and yields; foster data-sharing culture. Empower basin bodies with farmer/CSO input for adaptive, cross-sectoral management.

IX. ACKNOWLEDGMENT

My deepest gratitude goes to my professional network for their invaluable insights, feedback, and unwavering support throughout the writing of this paper. Their expert guidance was instrumental in shaping the analysis and perspectives presented. I am equally thankful to my family for their constant love, patience, and understanding, which provided essential strength and motivation. This endeavour would not have been possible without the collective support of my colleagues and loved ones.

X. ETHICAL CONSIDERATIONS

This research uses publicly available secondary data with ethical adherence to proper citations, acknowledging the deployment of AI tools where necessary and avoiding confidentiality breaches.

XI. LIST OF ACRONYMS

1. TLBC — Tungabhadra Left Bank Canal
2. UKP — Upper Krishna Project
3. PIM — Participatory Irrigation Management
4. WUCS — Water Users Cooperative Societies
5. IWRM — Integrated Water Resources Management
6. KNNL — Karnataka Neeravari Nigam Limited
7. CADA — Command Area Development Authority
8. WUA — Water Users Association
9. OM — Operation and Maintenance

10. FGD — Focus Group Discussion
11. GIS — Geographic Information System
12. SRI — System of Rice Intensification
13. MSP — Minimum Support Price
14. FPO — Farmer Producer Organization
15. CSO — Civil Society Organization

XII. REFERENCES & FURTHER READING

[1] Jagannath, NR (2015) — Primary field evidence base; most directly aligned with TLBC, Bhadra, Gondi, Vijayanagar, and Narayanpur RBC case material.
[2] Government of Karnataka (1995) — Legal basis for PIM and WUCS; essential for institutional reform analysis.
[3] IWMI (2006) — Directly examines Karnataka's irrigation sector, WUCS, PIM, and IWRM challenges.
[4] Meinzen-Dick, Raju and Gulati (2002) — Strong empirical evidence on collective action and canal irrigation organization in India.
[5] Brewer et al. (1999) — Major Indian IMT/PIM reference; useful for reform performance and implementation gaps.
[6] Swain (2004) — Critical review of IMT in India; directly supports WUCS dysfunction analysis.
[7] Mollinga and Bolding (2004) — Strong conceptual support that irrigation problems are governance problems.
[8] Ostrom (1990) — Foundational theory for collective action, WUCS governance, and institutional design.
[9] CWC (2003) — National PIM guidelines; useful benchmark for WUCS reform.
[10] Government of India (2012) — National Water Policy; baseline for IWRM and basin planning.
[11] Government of Karnataka (2002) — State policy benchmark; important for policy gap critique.
[12] Narain (2003) — Strong support for regulatory authority and institutional restructuring.
[13] Cullet (2009) — Excellent legal analysis of water law reform in India.
[14] Shah (2009) — Key groundwater governance reference, especially for free electricity and depletion.
[15] Kumar et al. (2008) — Useful for groundwater-agriculture-climate nexus.
[16] Chambers (1988) — Classic South Asian canal irrigation text; useful for equity and head-tail issues.
[17] Burt and Styles (1999) — Strong technical basis for control structures and measurement devices.
[18] Plusquellec (2009) — Useful on canal modernization challenges.

[19] Poff et al. (1997) — Essential for environmental flow arguments.
[20] CPCB (2013) — Supports pollution and water quality degradation claims.