Interdisciplinary Journal of Computing & AI

IJCAI Interdisciplinary Journal of Computing & AI

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# Artificial Intelligence in Rural Water Governance: Challenges, Opportunities, and Sustainable Pathways for India

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ARTICLE INFO.

**Keywords:** Water governance; Artificial intelligence, Rural India, Sustainable water management, Public policy
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Manuscript received: 6 February 2026/Accepted April 16 2026
Published online: 17 April 2026
https://doi.org/10.5281/zenodo.19625242



**Cite as**: A. Basu, A. Chatterjee and D. Kundu, "Artificial Intelligence in Rural Water Governance: Challenges, Opportunities, and Sustainable Pathways for India", Interdisciplinary Journal of Computing & AI (IJCAI), vol. 1, no. 1. Aspiration Publishing Trust (DARPAN ID: WB/2025/0887371), p. 86-121, Apr. 2026. doi: 10.5281/zenodo.19625242.

ABSTRACT

Experts predict that by 2025 water demand will increase 55% leading to severe water scarcity. Artificial intelligence (AI) has the potential to revolutionize water management, and optimize water usage and improve efficiency in managing water resources, especially in developing nations like India where poverty and limited resources pose challenges. Despite its benefits, AI faces technical challenges, data security, ethical dilemmas, and stands out to be barriers for small-scale farmers. Addressing these issues and maximizing AI's potential can lead to significant improvements in global water security and agricultural sustainability, in rural India. TaKaDu, an Israeli water management system, powered by artificial intelligence, is gaining international recognition for its 24/7 monitoring platform that effectively tracks leaks and faulty taps, saving water, time, and money. In 2020, Tucson, Arizona implemented AI technology from VODA.ai to proactively manage its water system, predicting pipe breaks using machine learning. If we simultaneously analyze these models the Israeli water conservation system can be implemented in the Indian scenario, with some changes. With the growing population and diminishing water resources, India faces challenges in water management, especially in rural areas where water scarcity poses threats to agriculture, health, energy, and the environment. In rural India, ineffective water monitoring not only exacerbates scarcity but also exposes communities to serious health risks arising from contaminated groundwater. By harnessing AI's capabilities for real-time monitoring, accurate predictions, and improved decision-making, India can enhance its water management practices and create a more sustainable future. This paper will focus on different schemes like Jal Shakti, Jal Sanchay, Jal Jeevan, PM Krishi Sanchay Yojana etc., for rural water management and highlight how implementation of AI presents significant opportunities to transform water management practices in India and globally, promoting sustainable agricultural practices, efficient water usage, and improved water security for all.

## 1 Introduction

India's rural water governance structures appear to be at a crossroads, where the institutions, ecology, and legal systems are all failing in their efforts to manage the country's water resources. The traditional form of environmental law in India, which is still very reactive and enforcement-minded in nature, is often challenged by the impacts of climate change, groundwater depletion, poor water quality, and increasing demands in domestic and agricultural use. There is a lack of information on water governance and protection in India, despite the fact that the country has a vast body of laws on environmental protection and water resource management. In light of these structural challenges, the application of artificial intelligence (AI) and data-driven technology has been identified as a promising approach to water governance. AI-based systems, through real-time monitoring, predictive analysis, and decision-support systems, have the potential to improve regulatory capacity by transforming water governance from a reactive enforcement approach to an anticipatory and continuous regulation approach. In the context of rural water governance, these technologies have the potential to improve groundwater observation, identify contamination, predict water shortages, and optimize infrastructure planning. Nevertheless, the application of AI technology in environmental governance not only improves the efficiency of administration but also changes the very nature of regulation by transforming how regulatory knowledge is constructed, discretion is exercised, and accountability is allocated. This raises fundamental legal issues that need to be addressed. Existing concepts of environmental regulation in India are based upon administrative discretion, post-facto enforcement, and judicial control. However, a system of regulation inspired by artificial intelligence is based upon probabilistic reasoning, prioritisation by algorithm, and automated forms of insight which may both inform or control human decision-making in this regard. While this may be to the advantage of such systems of regulation, it is also argued to undermine fundamental concepts of legality, transparency, decentralisation, and democratic accountability in the context of rural environments which exhibit socio-economic inequality and a lack of effective mechanisms for addressing grievances. Essentially, the question is not whether artificial intelligence is feasible in the context of rural water regulation, but to what extent its incorporation changes or influences fundamental concepts of regulation or legality.

In light of this, this study addresses two related research questions: first, how and to what extent would the incorporation of AI into India's rural water governance alter the traditional models of environmental regulation, and what legal protections would be required to maintain accountability and legitimacy in such a change? This explores how data-driven decision-support, predictive analytics, and ongoing monitoring alter regulatory power, discretion, and institutional accountability, this study situates AI within the larger framework of regulatory governance theory. The study conceptualizes AI as a type of regulatory modality whose use has moral and constitutional ramifications rather than as a neutral technological tool.

Secondly, in the comparative experience of AI-Enabled water governance three countries have attained significance: Israel, Singapore and the Netherlands. In this comparative study it is revealed that such countries have a spectrum of different social, political and economical approaches to AI regulation and water management. We identify a model of centralized sovereignty another model of public utility and a model of decentralization. The model of centralized sovereignty is revealed in Israel, reflects the statutory state ownership of all water resources consolidates planning, regulation, and AI-enabled monitoring within a single national legal authority [1]. Singapore demonstrates the statutory public utility model, where a single statutory regulator incorporates smart grid and AI-enabled monitoring technology into a legally codified public utility framework without changing the institutional power dynamics [2]. Whereas Netherlands reflects the coordinated decentralized approach with legally independent regional water boards integrating AI-assisted predictive management into a polycentric governance structure synchronized by national statutory frameworks [3]. In larger and more demographically complex states legislative fragmentation and federal transaction becomes impediment in regulatory design. As a result, these jurisdictions are analysed as unique points of reference for comprehending how AI might be incorporated into various legal frameworks rather than as transplantation models. Through such comparative experiences, the paper aims at deducing design principles instead of any institutional models for the Indian context. These design principles would involve legal institutionalisation around data as a regulatory tool, the development of accountability for algorithm-assisted decision-making, checks to prevent any technocracy, and the maintenance of democratic participation in data governance scenarios. This comparative exercise will highlight aspects on the role of law in enabling, limiting, or sanctioning the regulation of AI governance for the environment.

The paper's methodology combines regulatory theory, comparative public law ideas, and doctrinal study of Indian water and environmental law in a techno-legal and regulatory governance approach. It makes the case that legal institutions' ability to incorporate AI into inclusive, transparent, and democratically accountable regulatory frameworks is more important for the long-term viability of AI integration in rural water governance in India than technology advancement alone. By doing this, the article hopes to further a legally grounded understanding of innovation in environmental governance and add to the growing discussions on AI as a regulatory tool. Figure 1 shows the schematic view of the paper. After the introduction, the second part deals with the conceptual and operational foundation of Artificial Intelligence and Water Governance. The third section deals with the Legal and Institutional Framework for the Rural water Governance in India. The fourth part deals with the Comparative Experience of AI Enabled Water Governance. The fifth part deals with the Opportunities for Integrating Artificial Intelligence within India's Rural Water Governance Framework. The sixth part deals with the Artificial Intelligence, Risk, and the Fragility of Legitimacy in Rural Water Governance. The seventh part deals with Sustainable and Legally Viable Pathways for AI-Driven Rural Water Governance in India followed by the policy recommendation in the conclusion.

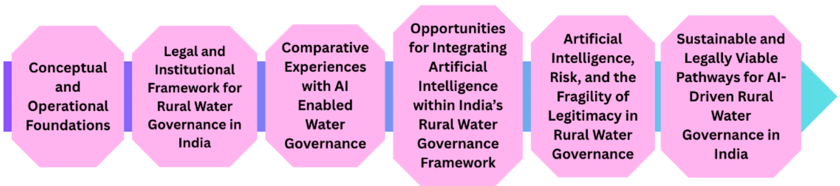


**Fig. 1** A sequential framework outlining the conceptual basis, legal context, comparative insights, opportunities, risks, and sustainable pathways for integrating AI into rural water governance in India.

# 2 Artificial Intelligence and Water Governance: Conceptual and Operational Foundations

Artificial intelligence in the context of "water governance" refers to a group of computational technologies that include "machine learning," "predictive analytics," and "data modeling," all of which aid in processing vast amounts of "environmental" and "infrastructure-related" data [4]. It does not refer to the autonomously operating system with independent regulatory powers. Furthermore, when we discuss artificial intelligence in the context of "water resource management," we are referring to the integration of "remote sensors," "Internet of Things devices," and "predictive models" that aid in the "evaluation of groundwater levels," "quality," "scarcity," and "demand" [5], [6]. These technologies are more associated with "probabilistic predictions" than they are with "information systems."

It's important to note that AI technologies are not perceived as undermining human judgment, but rather as changing how knowledge relevant to regulation is produced. AI's impact on governance is reframed from responsive regulation to risk prediction, for instance, because of its potential for anticipatory or preventative regulation, particularly with regard to groundwater loss [5], [7]. The ultimate sovereign body still has the authority to enact laws, but algorithmic systems are increasingly dictating the agenda, risk, and resource allocation. This has resulted in a new type of algorithmic regulation that has important ramifications for accountability, transparency, and mandate.

## 2.1 Operational Architecture of AI in Water Resource Management

The operational application of artificial intelligence in water governance refers to the presence of an integrated software system that has an integration of data acquisition, analysis, and finally the outcome of regulations. At the fundamental layer, artificial intelligence and operational water governance employ technologies such as remote sensors, satellite image processing, and the Internet of Things to collect data on the following: groundwater levels, water quality parameters such as the presence of arsenic and fluoride contamination, rainfall patterns, and performance of infrastructures [5], [6]. At the analytical layer, the system employs artificial intelligence and operational water governance to process data and identify anomalies in the data collected at the previous layer, create probability-based predictions, and finally identify areas of regulatory stress or scarcity [4], [5].

Figure 2 conceptualises AI-enabled water governance by illustrating the connection between specific AI applications, the technological architecture that sustains them, and their associated governance outcomes. Key applications identified in the left column are leak detection, monitoring of groundwater quality, predictive analytics of scarcity, and optimisation of smart irrigation. The middle layer represents the enabling infrastructure such as IoT sensors, remote sensing, machine learning algorithms, and decision support systems that convert environmental and infrastructural information into regulatory knowledge. The right-hand column indicates the corresponding governance outcomes, which include minimizing water loss, early detection of contamination, proactive planning, and enhanced agricultural sustainability. This model now illustrates how AI functions to become an integral component of a regulatory support system that reconfigures risk identification and resource allocation, despite the fact that the formal authority to make decisions is vested in the public institutions. This model is significant from a legal perspective because it enables the exercise of regulatory authority at multiple points in the system. Although the public institutions retain the formal authority to make decisions, the outputs of algorithms are increasingly shaping the evidence on which discretion is exercised. This creates a type of algorithmically mediated regulation that raises questions about accountability, transparency, and mandate [7].

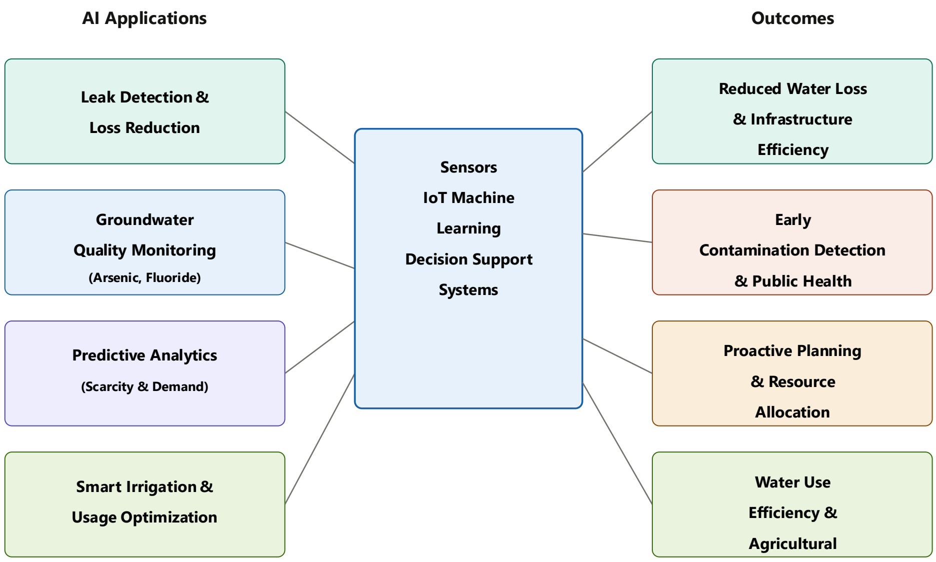


**Fig. 2** Schematic representation of AI-enabled water governance showing the linkage between specific AI applications, the technological infrastructure supporting them, and resulting regulatory and governance outcomes in water resource management.

### 2.2 From Reactive Regulation to Algorithmically Mediated Governance

In Indian water governance, the previous conceptual frameworks for environmental laws have mostly been reactive, based on a model that promotes control and regulation only after a breach has been discovered. Conventional environmental laws are characterized by a compliance-enforcement system that often requires these regulatory mechanisms to respond to those who have violated environmental laws only after an infringement has been reported [8]. The introduction of artificial intelligence techniques, however, has given water governance a new sense of anticipation that goes beyond traditional reactive regulation strategies to one that is predictive to a level above a simple non-compliance condition [7]. However, this mode of anticipatory regulation has its own normative and institutional issues. In other words, the systems of prediction are based on probabilities instead of factual violations. Moreover, any decision made by the algorithmic model will impact the livelihoods, autonomy, and access to vital resources of individuals [9]. It has been argued that even though AI does not supplant traditional regulatory authority, it reconstructs how regulatory knowledge is constructed and how administrative discretion is exercised, and therefore, it acts as a modality of regulation an algorithmically mediated layer of regulation instead of an actual regulator [7].

This shift makes traditional accountability frameworks more difficult to understand since regulatory outcomes might be impacted by proprietary datasets, opaque models, or technical assumptions that are difficult to verify within current administrative law frameworks [9], [10]. In order to maintain transparency, mandate clarity, reviewability, and democratic legitimacy, the shift toward algorithmically mediated, anticipatory governance thus calls for careful institutional and legal calibration. Examining India's institutional and legislative structure for water governance is necessary within this context.

## 3 Legal and Institutional Framework for Rural Water Governance in India

The Indian government states that states should control all water resources which exist within their respective territories. The Indian Constitution establishes that states should have authority to create water-related legislation. The Seventh Schedule contains this information which functions as a state authority control list. The document identifies water supply needs for citizens together with farming irrigation support through canal construction and drainage management and water storage operations. States have the authority to manage their water power resources through their own decision-making processes. The law creates special rules which apply to rivers that cross state boundaries because the Indian Constitution establishes regulations for these situations through Article 262 and Entry 56 of the Union List. Water stands as an agreement which allows states to determine all decisions about water resource management and storage facilities and power generation from water resources. The legal system divides water management responsibilities which show the country has a system for controlling water resources. The states maintain complete authority to create regulations which control water resources in their territories including agricultural and residential water distribution. The states have the authority to manage water resources which they can use for water distribution and irrigation systems [11]. The Union Parliament maintains legislative authority to establish rules about water which flows between different states through inter-state water systems. The Union Parliament creates laws which govern the use of state waters.

The Indian Constitution does not expressly provide a standalone fundamental right to water. However, the judiciary has consistently interpreted Article 21 of the Constitution which guarantees right to life and personal liberty encompassing various unenumerated dimensions of life and livelihood. The right to live with human dignity has been incorporated into Article 21 through broad judicial interpretation, and access to adequate and safe water has been acknowledged as an essential component of the right to life. The jurisprudential foundation for this position was clearly articulated in *Subhash Kumar* v. *State of Bihar* [12], where the Supreme Court held that the right to life includes the right to enjoy pollution-free water and air for the full enjoyment of life. The Court explicitly stated that environmental degradation affecting water quality violates Article 21 [13]. Subsequent judgments have reaffirmed this position. The Court in *A.P. Pollution Control Board* v. *Prof. M.V. Nayudu* [14] emphasized the significance of having access to clean drinking water and acknowledged that water is a basic necessity for living and requires strict regulatory supervision. Similarly, the Court noted that water is a fundamental human need and an important part of the right to life under Article 21 in *Narmada Bachao Andolan* v. *Union of India*, [15] in deciding cases involving dam development. Moreover, the Supreme Court highlighted the preservation of water resources and the environment as public trusts in *Hinch Lal Tiwari* v. *Kamala Devi* [16], connecting these duties to Article 21 of the Constitution. As a result, even though the Constitution does not specifically list a "right to water," court interpretation has solidly incorporated water rights especially the right to clean and drinkable water within the broad purview of Article 21.

### 3.1 Legal Framework relating to Water Management in India

The legal framework for water resource management in India consists of various laws. The Water Act serves as the primary legislation which handles water quality standards throughout various regions. The Water Act functions as the Water (Prevention and Control of Pollution) Act, 1974 [17] to establish water quality standards for all regions. The Water Act serves as a law which protects India from water contamination while it protects all water bodies that exist in the country. The Water Act functions as a vital tool which enables India to manage its water resources through its system of water resource management [18]. The Water Act functions as a part of the legal structure which regulates water resources throughout India. The Act established the Central Pollution Control Board under Section 3 and State Pollution Control Boards under Section 4 as organizations which maintain water cleanliness. According to Section 17 of the Act the State Pollution Control Boards operate independently to perform water pollution assessments and they need to show their authority for water quality testing and document evaluation and rule enforcement. The central government makes sure everyone follows the rules all over the country. The law establishes particular rules which govern all water bodies that exist in rural areas which get contaminated through sewage and agricultural waste.

The Central Pollution Control Board together with State Pollution Control Boards serve as essential organizations which protect our water bodies from pollution.

The Environment Protection Act operates under the name EPA as a legal framework which defends our natural surroundings. The Water Act functions alongside this law which they both operate together. The Indian Constitution created the EPA through its Article 253 which serves as its legal foundation. The article requires nations to implement all international agreements which they have previously signed. The EPA grants the government extensive authority to protect both our natural environment and our water resources. The Environment Protection Act functions as the EPA which enables the government to perform necessary actions for protecting our environment and water resources [19]. The government holds authority to perform environmental protection activities which safeguard all natural resources including water bodies that exist throughout national territories. The government needs to protect environmental resources together with water supplies because they hold major importance. The government holds responsibility to protect environmental health in all regions which include both rural and metropolitan areas including major cities. The protection of water resources stands as a fundamental requirement for this mission. governing body.

The 'Central Ground Water Authority serves as a fundamental resource which enables water resource management. Groundwater requires the most urgent attention when it comes to water resource management. The Environment Protection Act created the Central Ground Water Authority as its established governing body The 'Central Ground Water Authority' has the responsibility to protect all groundwater resources which are used by people for their needs. The country needs to handle its groundwater resources through both protection systems and management systems. The agreement serves as a solution which helps people who reside in rural areas. The community depends on groundwater resources. The community operates numerous borewells. The 'Central Ground

Water Authority' issues 'No Objection Certificates' to people who require groundwater access for their purposes. The document provides instructions which guide people to protect their water resources while ensuring environmental safety and groundwater replenishment. The Central Ground Water Authority works to protect our groundwater supply which exists in sufficient quantities [20]. The Central Ground Water Authority functions under the Environmental Protection Agency to handle problems which exist outside the scope of current legislation. The national government lacks any established laws which protect groundwater resources. The Central Ground Water Authority is working to solve the existing groundwater problem.

The Supreme Court of India delivered a vital ruling during 1999 which involved the A.P. Pollution Control Board against M.V. Nayudu case. The Supreme Court of India established that the state must establish proper systems to defend its water resources from any harm. The state must follow environmental and water laws because these regulations require them to do so. The Supreme Court of India requires states to develop systems which will defend their water resources. The Supreme Court of India views this matter as an essential component which belongs to environmental protection work. The *A.P. Pollution Control Board,* v. *M.V. Nayudu* case [14] shows that the state has a responsibility to protect the water resources as part of environmental laws [21].

### 3.2 Policy and Administrative Schemes

The government has established rules which operate through systems to provide clean water access for residents who live in various regions. The established rules receive support from national plans and programs which ensure rural communities access safe drinking water. The Government of India established the Jal Jeevan Mission (JJM) as their official program. The JJM aims to deliver drinking water through dedicated taps to every rural home before the year 2024. The JJM operates through a core system which protects water sources and performs water testing and educates communities about water purity and encourages local participation in the Jal Jeevan Mission. The JJM maintains its status as an essential program which provides water resources to rural populations. The Ministry of Jal Shakti has established particular directives which Jal Jeevan Mission leaders must follow to perform their duties. The group wants to make sure the Jal Jeevan Mission works through their preferred execution method [22]. The Ministry of Jal Shakti monitors the Jal Jeevan Mission to ensure all activities follow the established operational guidelines.

The Jal Shakti Abhiyan (JSA) operates as a water conservation initiative which works to protect every drop of water while establishing systems for sustainable water resource management. The Jal Shakti Abhiyan focuses on two main objectives which involve rainwater storage and groundwater reservoir expansion and environmental protection for water-related ecosystems. These things are very important for getting water to people who live in villages. The Jal Shakti Abhiyan operates its water supply activities because certain regions lack access to water resources. Although the JSA provides an institutional mechanism for rural drinking water services and source sustainability, its operational guidelines do not include a mechanism for artificial intelligence-based monitoring and predictive decision support systems. This paper argues that AI-based tools can be normatively and institutionally integrated with the existing Jal Jeevan Mission to enhance source sustainability, groundwater protection, and climate resilience. The integration will not alter the legal authority of the Mission but will improve its evidentiary and anticipatory capabilities within the existing administrative structure.

Figure 3 is a conceptual model showing the potential institutional integration of AI tools into initiatives for rural water conservation and climate resilience. The left side column mentions the AI applications for rainfall and runoff modeling, geospatial AI and computer vision, groundwater recharge and quality assessment, and decision support systems for watersheds. The right-side column mentions the ecological and governance outcomes of the AI applications, which include efficient rainwater harvesting, conservation of traditional water bodies, groundwater recharge, and climate-resilient watershed development. The arrows represent the process of translating environmental data into decision-support systems. This model takes into account the AI application as a decision support system in the existing governance framework but not as a regulatory authority.


**Fig. 3** Proposed Integration of AI Tools within Rural Water Conservation Frameworks

The Pradhan Mantri Krishi Sinchayee Yojana is another thing. The Pradhan Mantri Krishi Sinchayee Yojana wants to make use of water for irrigation. The Pradhan Mantri Krishi Sinchayee Yojana aims to provide water access to every agricultural field through its program which they call "Har Khet Ko Paani". The Pradhan Mantri Krishi Sinchayee Yojana includes water preservation methods which help farmers produce higher crop yields [23].

The government uses these systems as operational guides which help them manage their official responsibilities. The government follows these guidelines to direct its operations because these documents do not possess legal authority. The organization members possess strong influence because they channel financial support to appropriate locations which enables them to establish customized state strategies and perform monitoring activities. The courts have declared these schemes essential for State performance because they enable people to access safe drinking water and clean water which the State needs to provide under Article 21.

The main objective of ‘JJM and JSA missions’ moves beyond simple legal compliance. The leaders of these operations establish conditions which states must follow to obtain funding along with other forms of support. Things operate by following this system. The government must act because Article 21 establishes that people require basic water availability. The government needs to follow JJM and JSA because these documents guide their operational strategies although they do not possess legal authority.

### 3.3 Institutional Architecture and Governance Challenges

The rural water sector in India receives assistance through a hierarchical system which operates through different levels. The system connects three levels of government which include the national government and the state government and the local government. At the level there are ministries such as the Ministry of Jal Shakti. The Ministry of Jal Shakti creates water sector policies for India which the government funds while monitoring their operational success. The Ministry of Jal Shakti maintains partnerships with water-focused organizations which include the CPCB and the CGWA and the water mission directorates. The water sector in India receives support through the combined efforts of these organizations.

The state level requires water authorities including water boards and irrigation departments to enforce all established regulatory requirements. The organization develops strategies which match the actual state of water resources. The states maintain their right to develop water regulations through their established authority. These laws serve to fulfil state-specific requirements through their establishment of guidelines for groundwater management and canal operations. The organization establishes rules which determine how water should reach the population that requires it. The state pollution control boards actively participate in this procedure. They help keep the water clean.

States have the authority to create water-related regulations which only affect their specific jurisdiction. The Panchayati Raj Institutions serve as vital resources for water resource management throughout their operational areas. They must handle all operational aspects which require their attention. The Gram Panchayats maintain responsibility for developing and operating water supply systems which they control. The state government has granted these organizations the power to carry out this work. Article 243G of the Constitution enables Panchayati Raj Institutions to provide essential services which include drinking water and sanitation and hygiene facilities for their communities [24]. The Panchayati Raj Institutions function as active participants in each of these activities. The organization needs to solve its current work challenges while it needs to confirm that all employees follow company rules. The federal government and the states have some overlap, which can cause problems with our water policy. The situation leads to state water disputes which fail to reach proper solutions.

We need to apply the rules from Article 262 to work through the solutions for these existing problems. The people who handle water management in towns and villages face two major challenges because they lack both proper training and sufficient financial resources to perform their duties effectively. The current water management systems we operate will probably fail to produce good results when used in the future. The water schemes lack sustainability because the community members who should manage them do not have enough knowledge or money or technical skills to run them correctly. Water schemes create problems because of the following situation. The three institutions which control pollution and provide water and run local government systems fail to work together effectively which leads to weak control of rural water quality and pollution levels that affect community health.

### 3.4 AI in Rural Water Conservation and Climate Resilience

There is growing recognition that AI is a crucial enabling tool for water conservation measures in rural areas. Areas that are facing problems with groundwater depletion, rainfall fluctuation, and hydrologic variability as a result of climate change require water conservation measures [25]. The authorities' tardiness and the lack of coordinated efforts have been cited as reasons for criticizing the current water conservation strategies [26]. Improved predictive analysis and risk assessment in the future are guaranteed by AI systems. Figure 2 shows how AI tools used in rural water conservation are functionally linked to the corresponding governance and ecological outcomes. The key AI-based tools mentioned in the left column are rainfall-runoff modeling, computer vision and geospatial analysis, groundwater recharge and quality analysis, and predictive decision support systems. Although the right column highlights outcomes such as successful rainwater harvesting, sustainable groundwater recharge, revivals of traditional water bodies, and climate-resilient watershed planning, the central arrows indicate the conversion of environmental data into valuable insights.

Substantively, these technologies provide scope for the early identification of stress areas, variability of recharge, and seasonality of scarcity through the use of machine learning and architecture of remote sensing platforms [25], [26]. These layers are interdependent parts of a system, not a linear sequence of a process, wherein hydrological modeling feeds the analytics of recharge, and the consequences of conservation strengthen long-term resilience in the watershed basin. Though AI systems enhance decentralised systems and institutions, like the Gram Panchayat, through stronger evidence base of decision-making, they pose normative questions of probability in governance, data asymmetry, and accountability [19]. AI-based rural water conservation must therefore be seen not only as the modernization of water conservation but, more substantially, as a shift towards a preventative system of environmental governance.

# 4 Comparative Experiences with AI Enabled Water Governance: Legal and Regulatory Models

The experiences of Israel, Singapore, and the Netherlands reveals a spectrum of different approaches to AI regulation and integration in water management: a model of centralised sovereignty, a model of statutory public utility, and a model of coordinated decentralisation, respectively. The model of centralised sovereignty is represented by the experience of Israel, where state ownership and control in accordance with the Basic Water Law facilitate a single entity's control over water data and real-time compliance assessment in a vertically integrated system. The model of statutory public utility is represented by the experience of Singapore, where AI is part of the PUB's regulatory model to improve water efficiency and accountability without affecting the allocation of power between institutions. The model of coordinated decentralisation is represented by the experience of the Netherlands, where AI technologies are used by autonomous regional water boards to improve predictive management in a harmonised but polycentric system of water management based on institutional coordination and data interoperability.

## 4.1 Israel: Centralized Legal Mandate and AI-driven Water Monitoring

The Israeli national law on the legal cut-off can be traced to the Basic Water Law in 1955 [1], which was based on the principle of all the water resources, located within the territory of the State of Israel, to belong to the State as properties, and that possessing of water resources as property does not exist. The law entrusts the executive of all powers of decision making and appropriate use of water resources to the national level by depriving the sub-national authorities of the options of autonomous management of water resources. The other feature of the Israeli water regulation system is the national legal authority on ownership and administration of the water resources [27].

In the given framework, planning, regulation and management of the overall water sector, including ground water, drinking water supply, desalting output, waste water reuse, interregional transfer system of water like the National Water Carrier lies in the hands of the State of Israel through national crisis management agencies.

This government ownership has facilitated the joint effort in water usage, conservation, drought resistance, and water real-time observation. Israeli legal system reflects such policy orientation of the legislative and administrative level which prioritizes collective sustainability and equitable distribution, which are impermissibly connected with compliance and enforcement regime within the territory.

The Israeli Water Authority is the top of the national water management system in Israel, as it is a government structure and it is positioned under the Ministry of infrastructure and water issues [28]. Planning, regulatory, quality and supply in the water sector in Israel has been devolved to the Israeli Water Authority which serves as a centre of policy making and management in the sector [28]. The duties of the Water Authority may entail the following: Ensuring the long-term availability of water: quality, amount, and financial consistency Event managing sewage and effluent water to the desired levels; Coordination of national policy through the Water Authority Council- multi ministerial organ that permits prominent strategic choices. The governance model puts the heavy regulatory burden on the national level with the orientation being on efficiency and national compliance. This model also supports the international and regional transboundary water cooperation of Israel, by incorporating the data and monitoring needs in the broader legal systems.

Within the past few years, the state of Israel has been using artificial intelligence technology within its water governance and compliance system. Although the primary legislation has not yet incorporated AI on a statutory level, the application of the same is already being carried out on an operational level by state actors such as Mekorot, which is the national water carrier in Israel. For example, Mekorot has installed AI-capable monitoring systems such as the "AquaRing" system in remote stations of the National Water Carrier system [29]. It uses machine learning and spectral analysis to provide timely alerts for water quality, safety, and other unexpected trends, and has minimized response times for detection to ensure that these comply with national water quality standards. The AI-powered data analytics platforms are increasingly incorporating data from remote sensors that can enable the authorities to make anticipatory decisions and point out potential problems with respect to contamination, pressure anomalies, and inefficiencies in the system [30]. The platforms are synthesizing millions of data points every day in their support of compliance verification and responsiveness in the water governance system. Consequently, this implies that the integration of AI tools is effective in extending the Israeli legal regime's ability to monitor continuous compliance, thus aligning technological development with the legal requirements at the national level that regulate water as a public good.

### 4.2 Singapore: AI within statutory public utility regulation

The Singapore water regulatory framework is a statutory framework that is codified under the Public Utilities Act and enforced by the Public Utilities Board (PUB), which is the National Water Agency in Singapore. The Public Utilities Act (Chapter 261) [2] is the statutory framework under which the water sector in Singapore is regulated; it provides for the establishment of the PUB as the sole statutory authority that regulates the water supply sector [2]. As provided for in the Act, one of the PUB's functions is to ensure that water resources are provided sustainably and efficiently at all stages, from catchment and production to distribution, treatment, and reclamation [2]. The regulatory function of PUB encompasses water quality, supply reliability, pricing, and infrastructure robustness [30]. The legislative approach adopted by the Singaporean government recognizes the fact that water is a public utility that requires comprehensive regulation throughout the value chain. In this regard, PUB is the main actor that has the ability to license, regulate technology standards, control operations, and enforce compliance with the statutory requirements set out under the water safety regulations, including the Environmental Public Health (Water Suitable for Drinking) Regulations [30].

The Smart Water Grid project in Singapore is the institutional manifestation of the need to integrate digital and AI technology into the legal framework of water governance [31]. PUB has systematically developed sensoring, digital communication, and analytics infrastructure in the water distribution sector to facilitate real-time monitoring and decision support.

These smart technologies enable automatic leak detection, anomaly detection, and predictive maintenance that will improve PUB's regulatory control by minimizing non-revenue water, optimizing asset management, and facilitating proactive measures to address system breakdowns before they cause supply continuity problems [31].

Smart water meters, together with AI-informed analytics, not only provide optimization for PUB's operational efficiency but also strengthen the framework of compliance reporting in accordance with the Public Utilities Act [32]. The smart water meters provide daily automated consumption reports through a digital network in a secure manner, thus improving transparency and regulatory compliance by synchronizing consumption behavior with regulatory efficiency standards [32]. In Singapore, AI and digital monitoring technologies have, therefore, become essential components of regulatory accountability to support PUB's supervisory role in accordance with the requirements of national utilities law.

### 4.3 Netherlands: Predictive Water Governance and Institutional Coordination

These intelligent technologies provide for automatic leak detection, anomaly detection, and predictive maintenance that will enhance PUB's regulatory control function by reducing non-revenue water, ensuring effective asset management, and enabling proactive responses to system failures before they result in supply shortages [31]. The smart water meters, together with AI-related analytics, not only play a crucial role in ensuring the optimal efficiency of PUB but also facilitate the enforcement of the compliance reporting framework as stipulated in the Public Utilities Act [32]. The smart water meters have the ability to automatically transmit their readings on a daily basis via a digital network in a secure manner, hence enhancing the transparency and enforceability of regulations by ensuring that consumption behavior is consistent with the regulatory efficiency standards [32]. AI and digital monitoring technologies have, therefore, become a critical component of regulatory accountability in support of PUB's supervisory role in Singapore.

The Netherlands has a multi-layered system of water governance, which is based on constitutional obligation, statute, and decentralized powers, and which seeks to balance national policy guidelines, regional autonomy, and decentralized responsibilities [33]. The Dutch system of water governance is famous for its high degree of institutional coordination and development towards integrated flood and water resource management [33]. Unlike the highly centralized systems of, for example, Israel, for example, the Dutch system is characterized by decentralization and functional coordination between the national government, the provinces, and the regional water authorities (water boards), which are specialized public bodies entrusted with the statutory authority to manage water systems. These regional water authorities are legal entities distinct from the state and have the legal duty to exercise continuous control over surface water, flood defenses, drainage, and water quality in specific hydrological areas [34]. The regional water authorities have the powers to make bylaws, license, tax, and perform all acts and operations as provided for in the Regional Water Authorities Act [34].

The framework of institutional coordination in the Netherlands is based on collaborative governance structures such as the Delta Programme, which involves national government departments, provinces, municipalities, water boards, and other stakeholders to develop overall resilience strategies for climate change, sea-level rise, flood risk, and sustainable use of water resources [35].

The governance ecosystem now recognizes AI systems together with digital technologies as helpful tools for predictive water management through their ability to track groundwater levels and their ability to forecast floods and generate early warning alerts. The Netherlands needs to establish specific laws about AI usage for water management but regional authorities together with

Rijkswaterstaat have started developing systems which combine past hydrological information with current sensor data to enhance their prediction capabilities for dealing with climate changes [36]. Authorities must share data according to the principles of predictive governance because water boards together with national authorities exchange standardized environmental information and they conduct system modeling with risk evaluation and operational scheduling. The flow of data between institutions serves as input for regulatory bodies to develop proactive public safety protection measures which prioritize water system resilience. The Netherlands needs predictive water governance to function because it depends on institutional coordination through robust statutory rules which modern water management institutions operate with AI systems and data sharing technology [37].

# 5 Opportunities for Integrating Artificial Intelligence within India's Rural Water Governance Framework

The comparative experiences highlighted in the previous section show that there is a common understanding that informs the regulation of water governance through the use of artificial intelligence: that is, the transformative potential of artificial intelligence in water governance is realized not when the latter is treated as a technological intervention but when it is treated as a mode of regulation in law. This is especially pertinent in the context of India, which has a tradition of rural water governance that is heavily influenced by a broad but not very effectively operationalized legal regime. The Water (Prevention and Control of Pollution) Act, 1974 [38], and the Environment (Protection) Act, 1986 [39] are examples of legislation that grant broad powers in the regulation of water but whose actual effect in rural water governance is limited due to information problems and the delay in the implementation of the law [40].

From the regulatory governance theory perspective, the challenge with rural water systems is not the lack of norms but the inability of the regulatory institutions to continuously observe, interpret, and react to the intricate environmental situations. The traditional command-and-control regulatory model is based on the presumption of known facts and known violations, which is questionable in the context of the uncertain, non-linear, and cumulative effects of climate change on rural water systems. AI, with its capacity to aggregate large volumes of data, can help achieve what regulatory theorists term information-centered regulation [41].

## 5.1 Real Time Water Quality and Quantity Monitoring as Continuous Regulation

Monitoring has always been in a marginal position in Indian water regulation. Although environmental legislation has formally acknowledged the importance of monitoring in the context of enforcing water regulations, the lack of manpower, financial, and geographical resources has constrained the role of monitoring in Indian water regulation, particularly in rural areas. The absence of documentation of groundwater extraction, rural water quality, and infrastructure efficiency has led to reactive and sometimes incomplete decisions by Indian water regulators [42].

The development of AI-based sensor technologies and machine learning technologies promises to revolutionize the role of monitoring in Indian water regulation by enabling the continuous and real-time monitoring of rural environments [43]. From a regulatory theory perspective, the development of AI-based technologies and machine learning technologies promises to revolutionize Indian water regulation by enabling the transition to continuous regulation, whereby compliance is viewed as a continuous process rather than an event.

The regulatory importance of this change is considerable. Monitoring minimizes informational asymmetry between the regulator and the regulated, a perennial problem in rural environmental regulation. It also increases the legitimacy of legal standards by making the enforcement of the law less arbitrary and more informed [44]. What is particularly noteworthy is that these advantages do not require any expansion of the regulator's powers. Instead, AI increases the effectiveness of the enforcement of existing legal standards by providing the necessary information for their exercise.

Nonetheless, as the literature on regulatory theory points out, monitoring is not a neutral activity. What is monitored, how the data is interpreted, and who has access to the data are normative decisions. What the advent of AI offers is not the generation of data per se, but the integration of the monitoring system into the legal standards and requirements for monitoring [45].

### 5.2 Predictive Analytics and the Restoration of Water Regulation Towards Prevention

Traditionally, Indian rural water governance has followed a reactive regulatory paradigm. In this model, regulatory and legal interventions are made in response to water contamination, depletion, or system failure. This reactive approach to water governance mirrors the more general command and control approach to environmental governance. This approach assumes stable environmental conditions and violations. Such assumptions are no longer tenable in the face of climate change, where water risks are gradual, contextual, and often cross-boundary.

The advent of predictive analytics using AI offers the potential to break out of the reactive regulatory paradigm and develop anticipatory and preventive approaches to water governance. This is because, through the use of historical data coupled with climatic, land, and consumption patterns, AI predictive analytics can help identify potential risks before they escalate into violations or crises. This, therefore, creates an opportunity to develop a water governance system that is anticipatory in nature [46].

The development of such a process holds wider normative implications for environmental law in India, which judicially has acknowledged the precautionary principle but has never operationalized it as an administrative practice [47]. Predictive analytics holds the prospect of providing a tool for the operationalization of the precautionary principle as an administrative practice for the very first time, thereby empowering the state to take early interventionist measures. The danger here comes from an aspect of regulatory theory that warns about the potential for predictive analytics to obscure uncertainty and perpetuate biases. The opportune thing to do here is to utilize predictive analytics as a tool for judicial reasoning and judgment [48].

### 5.3 Evidence Based Planning, Resources, Allocation, and Adaptive Governance

Another opportunity provided by AI comes in the area where there can be bridging of the space between policy formulation and hydrological conditions at a local level for rural water governance. For instance, large-scale initiatives such as the Jal Jeevan Mission and the PM Krishi Sinchayee Yojana have been concerned with developing infrastructure and coverage targets, where certain assumptions are made during the formulation. While this has assisted in improving access to water, it has also led to concerns about sustainability, source reliability, and equity [49].

From the perspective of water governance, AI can assist in integrating various data sets related to water availability, agricultural demand, demographic changes, and climate change. This is useful in moving towards adaptive regulation, where regulatory strategies change over time in response to new evidence, as opposed to static approaches that assume regulatory strategies will remain the same. The significance of adaptive governance is now widely recognized in environmental law [50].

In decentralised systems, particularly Panchayati Raj systems, access to such analytical capabilities may assist in the participation of the system in the regulatory systems. Despite being constitutionally empowered, decentralised systems are often not informational resource-rich enough to engage with other systems [51]. Being constitutionally empowered as shared informational systems, AI systems may assist in the resolution of the capability issue for decentralised decision-making systems without undermining decentralised decision-making. This is reminiscent of the theory of polycentric governance, which is based on shared rules and information.

## 5.4 Transparency, Accountability, and the Democratic Potential of Data- Driven Regulation.

In India, transparency has been cited as one area that requires improvement in water governance in relation to groundwater extraction, allocation, and infrastructure management. This is an area where AI-driven water governance tools can potentially address the gap by enhancing the accessibility and understandability of regulatory information to various stakeholders.

Data visualization tools and reporting can potentially interpret and convey regulatory information in a manner that can be understood and utilized by various stakeholders in water resources management, such as the community and civil society organizations. In relation to regulatory governance in particular, there is a possibility that AI-driven mechanisms in water resources management can help in the improvement of responsive regulation. Responsive regulation refers to a regulatory activity aimed at using feedback provided by different stakeholders in the decision-making processes by regulatory bodies. According to literature, there exists no automatic connection between digitization and transparency in the management of water resources in India; as such, there is a need to enact laws that have touched on issues such as transparency in line with the use of technology in promoting democratic participation rather than technocracy.

The opportunity, therefore, would be the legalization of AI-driven transparency with community-centric approaches that treat the community as stakeholders in regulation rather than data subjects; this could potentially build up accountability and legitimacy in rural water governance models [52].

## 5.5 Opportunity as Regulatory Transformation Rather Than Technological Fix

Taking the issue into consideration, it can be fairly fathomed that the role of AI in assisting with water in country areas is not merely about efficiency or an upgrade to an old system. As long as we think of AI as a tool for making services more efficient, we will, to a great extent, miss the real regulatory meat that comes with AI [53] Technologically and legally, AI can actually change the way water law works; it will help us move from mere rules enforcement when something comes up to a more ongoing, information-driven approach to regulating things.

From the water governance point of view, AI systems can help to integrate different data sets on water availability, agricultural demand, demographic changes, and climate change. Looking at everything that has been written about how this regulation actually works, it's not really about putting down some rules for people to follow. It's really more of a constant thing, just watching and waiting, and trying to figure everything out. In India, as far as dealing with the regulation of water supply in the countryside, there is usually a huge disconnect between what the rules aim to do and what they actually are doing. It really illustrates the level to which our systems can't keep things running the way they are supposed to. AI really excels when our old methods are no longer working quite as well as they used to. So, what does this really bring to the table? The opportunity to totally transform the way that regulatory body's function. This is not a superficial level; this is a really deep level. This is not really about looking backwards to determine whether or not the rules were followed. It's really about looking ahead to determine potential risk [54].

Significantly, what this is stating is not that the rule of law is superseded by algorithms. Rather, AI is underlining the need for legality to the extent that it makes the normative decisions that underpin the rule of law explicit. Determining what risks to act on, how those risks need to be defined, and what agency is to act in a regulatory manner all need to be spelled out in the law, not the algorithms [55]. Otherwise, it becomes a matter of a technocratic system beyond democratic or legal control. The opportunity, therefore, is not in the automation of such choices but in the legal-technological co-production of the definition of such objectives, limitations, and accountability.

These developments acquire a new meaning and significance if such a reframing is applied, and its connection with the topic is understood, especially when applying such a reframing to the Indian scenario, where measures undertaken under various governmental policies have, to a certain extent, eliminated the necessity for such measures to have a backing of any such legally constituted necessity. Moreover, this reframing of AI, as a regulatory tool, underscores the limits of governmental missions for the effective execution of digital measures and emphasizes the necessity for such measures to have a ground in the laws of the country [56].

Moreover, the regulatory perspective on AI brings out aspects related to the question of power, participation, and exclusion. Based on the theory of regulatory governance, the focus is on the potential of regulatory techniques to influence the power balance of institutions and stakeholders. In this regard, there is the potential for AI systems in rural water governance to marginalize local knowledge, which could be addressed through participation. This opportunity is thus also one that is committed to the values of participation, inclusion, and transparency.

It is thus evident that, in this regard, the AI solution is not one that solves the rural water crisis but one that offers an opportunity for the law to rethink the practice of environmental regulation in the face of ecological uncertainty and administrative constraint. The opportunity does not lie in the technology itself but in the extent to which the law enables, limits, and legitimates the AI system [56]. This connects to the next section, which will discuss the regulatory challenges of AI systems in rural water governance in the absence of legal safeguards.

# 6 Artificial Intelligence, Risk, and the Fragility of Legitimacy in Rural Water Governance

The one that keeps getting mentioned is how it would really help with water management in the countryside. I think they mean it would all just work better, give us more information, help us make decisions faster, and maybe even predict things better than we could on our own. However, the literature on regulatory governance has repeatedly argued that optimisation without legitimacy is unstable. When artificial intelligence systems are introduced into areas as politically contentious and socially embedded as water governance, they do not simply improve the capacity of governance; instead, they transform how power is exercised, legitimated, and contested. This section contends that the central challenge of AI in rural water governance is not failure but regulatory instability, the potential for governance systems to become less accountable, less inclusive, and ultimately less legitimate [57]. Instead of considering data, liability, ethics, and exclusion as separate issues, this section considers them as a set of interconnected points of instability in a single techno-legal system. Failure to address one tends to exacerbate the others.

## 6.1 Data as Infrastructure: From Informational Gaps to Informational Power

AI-governance is based on the premise that data poverty is a challenge that needs to be addressed. In rural water governance, however, data poverty is not an accident but a symptom of institutional neglect and an uneven state presence. It has been observed in recent policy studies that data on groundwater and drinking water in rural India is frequently patchy, outdated, or simply non-existent in the marginalized areas. If AI systems are trained on such uneven data geographies, they are likely to render historical invisibility as algorithmic irrelevance [58].

More problematically, there has been a shift from data as evidence to data as infrastructure, a resource that shapes future regulatory possibilities. Once the AI systems have made a determination of what is relevant data, the regions that do not have a digital footprint are likely to be out of the regulatory scope entirely. This has been noted in recent blogs on environmental governance, which have noted that “data poor regions are governance poor regions in algorithmic systems” [59].

The issue of ownership further cements this inequality. Many of the AI systems that are publicly available are developed by private companies, and as such, they retain control over the architecture of the data and the analysis that is being conducted. Without sufficient legal regulation over the issue of public ownership and access, the water data in rural regions could be locked away in private systems [60]. This is part of a larger concern that the digital public infrastructure is, in the absence of sufficient regulation, quietly shifting the balance of regulation from the state to the technology companies.

### 6.2 From Measurement to Surveillance Ethical Creep in Environmental Monitoring

The water governance system that relies on AI is contingent on the continuous measurement of water quality, usage patterns, groundwater levels, and infrastructure performance. At first, the concept of continuous measurement appears to be normatively unproblematic, if not welcome, in the wake of the scale of rural water problems [61]. However, recent developments in the literature and discourse on water governance have warned that continuous measurement could potentially creep into continuous surveillance, particularly in a context where there is a lack of legal protection and power imbalances.

This is what has been termed, in recent governance blogs, the phenomenon of ethical creep. This refers to the gradual extension of data beyond its original use in regulation. In the context of rural water governance, an AI system intended for the purpose of contamination or leakage detection may begin to profile household water consumption, agricultural patterns, or seasonal livelihood patterns [61].

Most importantly, environmental governance has continued to remain on the fringes of data protection debates. While Indian constitutional jurisprudence has recognized informational privacy as an integral part of the right to privacy, the extension of data protection with respect to sectoral governance has remained at an embryonic stage [62].

Furthermore, it has recently been contended that data protection literature has ignored the fact that data on the environment has been considered public data, thus overlooking the fact that it has the ability to reveal intimate socio-economic patterns when algorithms are employed on it [63]. The failure of data protection principles with respect to the use of AI monitoring on the environment has resulted in a vacuum that allows intrusive practices to flourish.

From a regulatory governance perspective, excessive surveillance may undermine the very purpose it sets out to achieve. The literature on legitimacy in regulatory governance suggests that communities are likely to be compliant with environmental regulations when they perceive such governance to be legitimate. In such scenarios, the use of AI-based monitoring systems, acting as opaque surveillance technologies, might negate such perceptions, as such histories may have existed, for example, in rural India. Ethical considerations, thereby, are not just desirable; they are functional imperatives [64].

### 6.3 Algorithmic Advice, Administrative Discretion, and the Dilution of Responsibility

As these AI systems transform their role beyond those of simple monitoring tools and towards their role as tools in decision-making, they inevitably have a part to play in the shaping of regulatory decisions. This may potentially include a role in predictive analytics in decisions concerning infrastructure, drought, groundwater extractions, or emergency water supplies, among others. Though not ultimately responsible for actually deciding outcomes, recent research has noted that, in fact, these systems exert a powerful normative influence that ultimately limits the possible discretion in decision-making that administrative authorities possess.

This creates complex issues of accountability. Administrative law in India is based on principles of decision-making that are reasonable, transparent, and reviewable. However, these systems increasingly rely on probabilistic models that are not transparent, even to their creators. Recent blogs on law and technology have noted that this represents the emergence of "decision-making without reasons," where decisions are justified on the basis of technical authority rather than legal authority [65].

The result is a diffusion of responsibility. If the negative consequences of algorithmic recommendations such as the denial of access to water for some villages or the preferential treatment of some villages over others need to be explained, it is no longer clear who would be held legally accountable. This issue of diffusion of responsibility was addressed in recent literature on regulation as the phenomenon of structured deniability, where the absence of responsibility is systematically created rather than simply being possible.

In the context of rural water management, where grievance redress mechanisms are weak to begin with, the diffusion of responsibility is a particularly problematic issue. Without any legal obligation to explain and contest algorithmic recommendations, the risk of the gradual undermining of the ideal of the rule of law arises [66].

### 6.4 Procurement, Platforms, and the Quiet Reallocation of Regulatory Power

The governance implications of AI are typically considered at the level of outcomes, but recent policy debates have highlighted the importance of procurement as an area of regulatory transformation. Procurement decisions about which AI systems to use, on what terms, and with what standards are an important influence on governance well before systems are operational.

In the context of rural water governance, procurement is often carried out by entities with limited technical capacity and performance pressures. This is an environment conducive to the phenomenon that recent digital governance blogs have termed platform lock-in, whereby public authorities adapt their regulatory practices to the features of particular technological platforms, rather than seeking to influence the platforms themselves through law. Ultimately, this can lead to fragmented architectures in which different states or districts use different, indeed incompatible, platforms [66].

This is a nuanced but important change in the locus of regulatory power. With the regulation of data standards, models, and update cycles in the hands of private entities, the extent to which the state can influence the direction of regulatory policy is limited. Recent articles on digital public infrastructure have cautioned against the dangers of this model, where the result could be the emergence of a form of delegated platform governance in the place of democratic public governance, unless checked.

The absence of mandatory impact assessments of algorithms, transparency clauses, and exit strategies in public procurement contracts also increases the risk of AI systems outliving political cycles and policy priorities, effectively embedding particular regulatory logics into governance by default rather than by choice [67].

### 6.5 Exclusion, Algorithmic Legibility, and the Reproduction of Rural Inequality

One of the least discussed but most significant risks of AI-enabled governance is tied to its politics of legibility. In other words, AI systems function by breaking down complex social and ecological systems into standardised categories that a machine can read. However, recent work in critical governance theory highlights that such processes of legibility are inherently biased towards certain types of knowledge while excluding others. In the context of rural water governance, this creates a risk of reinforcing historical inequalities by systematically privileging regions, households, and practices that meet the data expectations of AI systems [67].

Recent development and policy issues have highlighted how digitally enabled governance systems have tended to privilege certain communities with good connectivity, administrative knowledge, and stable settlements. In contrast, seasonal migrant communities, informal settlements, and ecologically vulnerable regions have tended to be less represented in these data systems, making them less legible to AI systems that inform governance decisions. This lack of legibility will slowly translate into exclusion as governance becomes increasingly reliant on data-driven decisions to make priority interventions [68].

Apart from access and infrastructure, there are also epistemic forms of exclusion, which revolve around AI systems that use aggregated hydrological and consumption data and often ignore existing knowledge systems, water-sharing practices, and community adaptation mechanisms that have been developed to deal with ecological uncertainty. Recent blogs on participatory environmental governance argue that exclusion of knowledge systems not only undermines social justice but also undermines the effectiveness of environmental regulations, as they become less responsive to local variability.

From a regulatory governance perspective, there are deep and abiding concerns about democratic legitimacy. Environmental regulations that systematically fail to recognize certain communities or knowledge systems cannot be seen to be fair or inclusive. The problem is not simply that certain groups or knowledge systems are excluded, but that exclusion becomes normalized through technical rationality, which remains sheltered from critical evaluation through claims to objectivity and efficiency. Without legal and institutional interventions to challenge these dynamics, AI could entrench a form of technocratic governance that, while formally rational, is substantively unjust [68].

### 6.6 Governing Risk Before Scale: Embedding Legitimacy in AI System Design

The above discussed analysis illustrates that the risks in AI-supported RWG are not circumstantial and dependent on effective implementation but rather inherent in the regulation by algorithm. Understanding risks in this manner is crucial for an effective legal response.

The theory of regulatory governance has long highlighted that effective regulation is not only dependent on the regulation's content but also on the institutional context in which the regulation is implemented. In the context of AI and RWG, the institutional context is defined in the design phase in which decisions on data sources, analytical tools, thresholds for intervention, and institutional responsibilities are programmed in the system design. Once programmed, they create a form of regulatory inertia that limits future legal and regulatory options [63].

An effective legal response to the risks in AI-supported RWG thus requires that the legal response moves from a post-regulatory to an ex-ante legal design. This means that legal frameworks need to articulate in advance the limits on data collection, allocation of responsibilities for algorithm-assisted decisions, and procedural rights for communities. In the absence of such articulation, algorithmic regulation risks operating as de facto regulators without legal authorization and accountability [68].

This design-oriented approach to understanding AI and its implications can also reshape how we think about efficiency and legitimacy. While AI systems can and should be justified on the grounds of their predictive accuracy and efficiency, regulatory governance research has argued that efficiency gains at the expense of transparency and contestability undermine long-term regulatory governance capacity. Regulatory governance systems that cannot be challenged, explained, or corrected risk generating resistance, judicial review, and institutional distrust. These would be highly destabilising effects in a rural water governance context in which legitimacy deficits already exist.

Ex ante legal design can also perform a distributive function in relation to AI and its implications. By requiring legal design to address questions of visibility and whose knowledge is relevant, law can address the risk that AI and algorithmic systems will privilege standardised and data-rich contexts. This will be a significant consideration in a rural context in which there may be significant ecological and socio-economic variability [68].

In the final analysis, the governance of risk before scale is not about the restraint of technology, but is, rather, the very condition of sustainable innovation. AI can be used to improve the governance of rural water resources, but this is only the case if it is embedded in the legal framework that sustains the importance of accountability, inclusiveness, and control. This is the conceptual link to the next section, which looks at the possibilities of realizing these normative imperatives as institutional pathways for AI water governance in India.

# 7 Sustainable and Legally Viable Pathways for AI-Driven Rural Water Governance in India

Through the above discussions, the purpose has been served by establishing and confirming that artificial intelligence cannot be accepted or disapproved of as an important factor in governance and instability, respectively, independently as an administrative device or an agent of instability. The real value and significance of artificial intelligence regulation and its use as a tool pertain merely and more specifically to challenges of reconfiguring and reorganizing the present institutional landscape, as well as systems of authority and notions of legality, which becomes an important focus in dealing with the subject of this section.

## 7.1 Learning from Comparative Regulatory Models: Institutional Design as Opposed to Technological Sophistication

The regulatory viability of AI-enabled water governance is less a function of technological sophistication and more a function of authority and responsibility configuration as illustrated by its relative experience. Different jurisdictions have developed distinct regulatory architectures for AI-enabled water governance, shaped by different constitutional and governance cultures. Nevertheless, there is a degree of convergence around some design principles [69].

In a centralized model like Israel, where water is constitutionally a national resource, AI is implemented through a consolidated statutory authority with clear allocation, monitoring, and enforcement powers. In this model, AI-enabled monitoring is simply an extension of existing legal mandates and allows for a universal standard for data and real-time regulatory intervention. While this model is clear and coordinated, it also centralises power and responsibility within a single institution.

On the other hand, in Singapore, there is a system of statutorily regulated public utility governance in which AI is integrated. In this system of governance, smart water systems are fully legislated in terms of detailed regulations in relation to

AI-based monitoring in accordance with service standards and audit requirements. This example demonstrates how well-articulated law can ensure accountability in governance structures despite the data-driven approach.

The Netherlands has adopted a different approach in its system of polycentric governance in relation to AI-based water management systems in regional water authorities. In this system of governance, AI-based monitoring is used for predictive and preventive purposes in accordance with data sharing obligations and coordination between different levels of governance [69].

One common aspect of all the above systems of governance is the institutionalisation of data in its capacity as a regulatory tool rather than its usage as a mere product of technology. The comparative approach for India is not one of adopting the above systems but of adopting the design principles of such systems in a manner that can be adapted in the Indian context of multi-level governance in a democratically accountable system of governance.

### 7.2 Institutional and legal Pathways for India: Embedding AI within Democratic Water Governance

The translation of this understanding into the Indian scenario necessitates a consideration of the current legal architecture and the prevailing governance challenges. Rural water governance in India is marked by fragmented power structures, executive schemes, and local capacity gaps. In this scenario, the integration of AI has to be achieved through institutional embedding rather than parallel technological adoption.

- Firstly, adaptive regulatory structures are a prerequisite for the integration of AI in Indian water governance. While the current water and environment regulations offer normative mandates for water governance, there is a lack of specific provisions for data-driven governance. Rather than technology-specific regulations, a more sustainable route for Indian water governance could be the inclusion of enabling clauses in current regulations that provide for AI-based monitoring and decision-support systems with corresponding obligations of transparency, explanation, and review.

- Secondly, capacity building at the local level is essential. Panchayati Raj institutions hold a constitutionally important place in the governance of water in the rural area; yet, in the absence of local interpretive capacity building in the process of integrating AI, the chances of further centralisation of power and marginalisation of local voices are high. The theory of regulatory governance clearly indicates that decentralisation can be effective only through institutional competence.

- Thirdly, the process of public-private partnership should be governed through law rather than through contract-based relationships. While the involvement of the private sector may be essential in the development of AI technology, the objectives of regulation should be clearly defined in the public domain. This can be achieved through the development of procurement policies that ensure interoperability, data ownership in the public domain, and audit trails of algorithmic systems.

- Finally, community participation must be institutionalized as an ongoing process of governance, not just a cosmetic exercise. New forms of decision-making and justification are being crafted by AI systems; thus, communities have to be able to query the accuracy of the data, dispute the results of the algorithm, and seek remedies. The institutionalization of grievance and review processes within the structures of AI-enabled governance ensures that regulation does not become technocratically isolated from the communities being regulated [70].

### 7.3 Reconciling Innovation with Legitimacy: Towards a Coherent Governance Paradigm

Collectively, these mechanisms imply that the sustainability of AI-based rural water governance is contingent on the ability of law to inform and shape technological rationality. Innovation and legitimacy are therefore not seen as conflicting values, but as complementary and mutually reinforcing values, contingent on the design of the governance system as a whole, balancing predictive capability with accountability and inclusion.

Regulatory governance theory highlights the point that legitimacy is not created by outcome, but by process, and that it must be intelligible, contestable, and just. For AI-based systems to be seen as improving the effectiveness of regulation, they must be embedded within such a process, and any efficiencies created by less transparent and more exclusive systems risk undermining long-term capability as trust is lost and resistance is mobilized [70].

In this respect, for India, the challenge is as much conceptual as institutional. That is, AI should not be conceived of as a solution for administrative shortcomings but rather as a driver for thinking differently about how environmental regulation is undertaken in an uncertain world [71]. Developing a framework for AI that is legal and institutional has the potential to transcend conventional reactive models of governance towards more anticipatory, inclusive, and resilient models of rural water governance.

This provides a backdrop for the final section of this paper, where there is a synthesis of the various legal and theoretical contributions that have been made and a reflection on the broader implications of AI as a form of regulatory enabler in environmental governance.

# 8 Conclusion

The above analysis shows that the legal issues involved within the AI-based water governance in the rural areas of India have numerous opportunities and challenges too. The issues are not only associated with the gaps in legislation but are also related to issues involving accountability and exclusion. The subsequent set of recommendations will offer a pathway for introducing the concept of AI within the governance of water resources, which not only takes advantage of the latest technologies in regulation but also finds inspiration from the theories and regulation from various parts of the world.

*a. Legal Recognition and Accountability Frameworks for AI in Water Governance*

*Problem*: Obviously, the use of the AI systems in the water governance process is often not accompanied by an explicit legal status and accountability design, creating issues regarding the responsibility of determinations resulting from the use of predictive analytics/monitoring.

*Solution*: Create legal requirements that include and integrate AI systems effectively within water governance systems. These requirements include the legal bases for the use of AI systems, the responsibility of water administrators, and that for explainability. Therefore, by integrating AI systems with water governance laws, it opens the way for the use and application of AI systems to classic decision-making processes; by doing that, it becomes feasible to utilize AI for legal purposes without violating any laws. It also reduces the risk of a decision being made without a reason, as decision-making without a reason invites liability for adverse consequences.

*b. Mandatory Data Governance Standards for Public Sector AI*

*Problem*: AI systems must be fed high-quality, representative data, but increasingly, in the public sector, there are problems with poor data quality, fragmentation, or a lack of governance, resulting in bias, exclusion, or even poor predictions.

*Solution*: Legally binding requirements are necessary for the data quality, interoperability, provenance, and access aspects of AI-enabled governance. Data governance models include data collection, storage, sharing, and auditing; therefore, data should meet the overall requirements of data accuracy, completeness, and fairness before applying AI systems. This enhances reliability and accountability and is consistent with an overall public sector approach that focuses on AI governance in terms of its relationship with the concept of fairness and other transparent aspects of the overall AI lifecycle.

*c. Institutionalised Participatory Mechanisms for AI-Enabled Regulation*

*Problem*: There is the possibility that AI may actually end up marginalising some communities due to a lack of participation and transparency when decisions are made over resources and triggers.

*Solution*: Integrating a participatory component within the 'rules of the game' of AI in water governance. This is achieved through co-design, feedback, and rights to contest AI decisions. Studies on AI in water governance emphasize the role of participation of citizens, along with the development of appropriate norms and ethical parameters, in responsible governance, avoiding technocratic exclusion (Participatory AI literature).

*d. Institutional Capacity Building and Digital Inclusivity Mandates*

*Problem*: Marginalised and rural societies frequently lack the digital infrastructure, literacy, and attendant systems required for effective engagement with, intervention in, and/or benefits from AI-driven water governance.

*Solution*: Develop legislation on the mandate for capacity building and digital inclusion that supports local institutions in engaging with AI systems. In line with the literature on the challenges public sector organizations experience in AI adoption, the government can invest in the development of skills and interpretive capacities that support the meaningful engagement of the local institutions in AI governance, ensuring that AI does not become an elite tool accessible only by those with the ability to afford it, but a public space of regulatory engagement and participation.

*e. Ex Ante Risk and Impact Assessments for AI Deployment*

*Problem*: The risks posed by AI are not necessarily accounted for within existing structures of governance, as the technology can pose unforeseen harms prior to regulatory adaptation; existing regulatory frameworks often fail to require the evaluation of socio-legal and environmental risks prior to use.

*Solution*: Mandatory ex ante risk and impact assessments could be built into the legal framework before the use of AI systems in RW management. Ethical, social, legal, and environmental impacts could be considered in these assessments, which should include independent assessment mechanisms. These assessments thus align with the notion of an emergent model of hybrid governance concerned with risk management across the lifecycle of AI systems, sometimes also called AI governance systematic review.

Needless to say, the paper has also emphasized the need to consider AI not only as an emerging technological solution, but also as an emerging mode of regulation in the rural water governance architecture itself. Thus, as a solution for monitoring, predictive analytics, or even decision support, AI can certainly be seen as addressing the historic challenges related to issues like water scarcity, water quality, and infrastructure performance. With regard to the actual governance issues, however, its implications extend well beyond those of efficiency or effectiveness into important questions of regulatory fragmentation, etc., in India.

By utilizing a regulatory framework of governance, along with a techno-legal perspective, and learning from comparative experiences in country-specific contexts that have been implemented in Israel, Singapore, and the Netherlands, the paper seeks to exemplify how AI enables regulatory governance. However, such a phenomenon can only be achieved in a manner that seeks a conjunction with legally sound architectures. Inasmuch as such a lesson can be learned and implemented in the Indian context, there exists a need to shift from a policy-driven model to a legally derived perspective that seeks the inclusion of AI-developed results assisted through decision-making instruments.

Ultimately, it is a position that sustainable management of rural water supplies cannot be accomplished by means of technology adoption; rather, it was crucial that legal regulation and constraint/limitation of AI development would enable it to play an efficacious role for democratic governance. Thus, there exists a human necessity for a congruence between law and technology that does not only capitalize on the potential for technology use within a body of regulation but also capitalize on the potential for development within a body of regulation and for development itself.

## Acknowledgment

The authors would like to express their sincere gratitude to University of Engineering and Management Kolkata for providing the necessary academic environment, infrastructure, and support to carry out this research work successfully. Also, a grant-in-aid of around INR 15,000 was allocated for this project from the University. The authors also acknowledge the Department of Law, University of Stockholm for active collaboration.

## Contribution of each Author

Abhisikta Basu has conceived the idea of the paper and did the initial drafting. Avishikta Chatterjee has done the comparative analysis of the various countries. Debargha Kundu has done the case analysis in the Indian perspective.

## Conflict of Interest Statement

The authors declare no conflict of interest.

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