Smart Water Governance and Social Inclusion: Opportunities and Challenges among Rural Households and Jal Jeevan Mission Beneficiaries in Kerala

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ABSTRACT

The growing integration of digital technologies into public administration has transformed governance systems across the world. Within the water sector, smart water governance has emerged as an innovative approach that combines digital technologies, real-time monitoring systems, data analytics, geographic information systems, and citizen-centric platforms to improve water management and service delivery. While these technological interventions offer significant opportunities for enhancing efficiency, transparency, and sustainability, concerns remain regarding social inclusion, digital inequalities, and equitable access to governance processes. Kerala, despite its abundant rainfall and extensive water resources, continues to face challenges such as seasonal water scarcity, groundwater depletion, water pollution, and uneven access to safe drinking water. Recent initiatives under the Jal Jeevan Mission and various state-level programmes have increasingly incorporated digital technologies into water management systems. However, limited empirical evidence exists regarding how these interventions are perceived and experienced by rural communities. This study examines the opportunities and challenges associated with smart water governance among rural households and Jal Jeevan Mission beneficiaries in Kerala. A survey was conducted among 300 households selected from Palakkad, Malappuram, and Thrissur districts. The findings reveal moderate levels of awareness regarding smart water governance initiatives, positive perceptions towards technology-enabled water management, and significant concerns regarding digital exclusion among vulnerable groups. The study argues that smart water governance should be understood not merely as a technological innovation but as a socio-technical process that requires digital literacy, community participation, institutional accountability, and social inclusion. The findings contribute to emerging debates on digital governance, environmental justice, and sustainable water management in developing societies.

Keywords: Smart Water Governance, Social Inclusion, Digital Governance, Jal Jeevan Mission, Water Literacy, Kerala, Community Participation, Sustainable Development

INTRODUCTION

Water is central to human well-being, economic development, public health, and environmental sustainability. Access to safe and adequate water is increasingly recognized as a fundamental human right and an essential component of sustainable development. Despite substantial investments in water infrastructure and policy interventions, water-related challenges continue to affect communities across the world. Climate change, population growth, urbanization, environmental degradation, and increasing pressure on freshwater resources have intensified concerns regarding water security and governance (UNESCO, 2024).

In response to these challenges, governments and international organizations have increasingly turned towards digital technologies to improve resource management and public service delivery. The emergence of smart governance represents a broader transformation in governance systems where digital technologies are employed to enhance efficiency, transparency, accountability, and citizen participation (OECD, 2023). Within the water sector, smart water governance has gained prominence as a strategy for addressing complex challenges associated with water distribution, monitoring, conservation, and management.

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Smart water governance refers to the integration of digital technologies such as Geographic Information Systems (GIS), Internet of Things (IoT) devices, remote sensing technologies, artificial intelligence, smart meters, cloud-based monitoring systems, and digital citizen engagement platforms into water governance processes. These technologies facilitate real-time monitoring, improve decision-making, reduce water losses, enhance service delivery, and strengthen institutional responsiveness (Biswas & Tortajada, 2023).

The relevance of smart water governance has increased significantly in recent years due to growing concerns regarding water scarcity and climate variability. Across the world, water utilities and public institutions are investing in digital technologies to improve water efficiency, sustainability, and resilience. Smart monitoring systems enable authorities to identify leakages, monitor water quality, forecast demand, and respond more effectively to emergencies such as floods and droughts (World Bank, 2024).

Kerala presents a particularly significant context for examining these developments. Although the state receives one of the highest annual rainfalls in India and possesses extensive river systems, reservoirs, wetlands, and groundwater resources, it frequently experiences water-related challenges. Seasonal water shortages, groundwater depletion, contamination of drinking water sources, and increasing demand for water have become common concerns across many regions of the state.

The devastating floods of 2018 and subsequent climate-related events highlighted the vulnerability of Kerala's water systems and underscored the need for more efficient and responsive governance mechanisms. Simultaneously, rapid urbanization, changing consumption patterns, and environmental degradation have increased pressure on available water resources. These developments have encouraged policymakers to explore innovative approaches to water management, including the adoption of digital technologies and data-driven governance systems.

The Government of India has introduced several programmes aimed at improving water security and governance. Among these, the Jal Jeevan Mission (JJM), launched in 2019, represents one of the most ambitious rural water supply programmes in India's history. The mission seeks to provide functional household tap connections to all rural households while promoting source sustainability, community participation, and technology-enabled monitoring systems. Digital dashboards, mobile applications, and Management Information Systems (MIS) have become important components of programme implementation.

Recent policy discussions indicate that the future of the Jal Jeevan Mission lies not only in infrastructure expansion but also in strengthening sustainability, monitoring systems, community participation, and local governance capacities (World Bank, 2024). Increasingly, digital governance tools are being utilized to improve transparency, accountability, and evidence-based decision-making in rural water management.

However, technological innovation alone cannot guarantee effective governance. The growing digitalization of public services raises important sociological questions regarding access, participation, inclusion, and equity. Not all citizens possess equal access to digital technologies or the skills required to utilize digital platforms effectively. Differences in education, income, age, gender, and geographical location continue to shape patterns of digital participation (Van Dijk, 2020).

These concerns are particularly important within the context of water governance because access to water is closely linked to social justice, public health, and human development. If digital governance systems are implemented without adequate attention to inclusion, they may inadvertently reinforce existing inequalities. Conversely, when designed and implemented effectively, digital technologies can create new opportunities for citizen engagement, transparency, and equitable service delivery (Amankwaa et al., 2021).

The present study seeks to examine the opportunities and challenges associated with smart water governance among rural households and Jal Jeevan Mission beneficiaries in Kerala. Specifically, the study investigates public awareness of smart water governance initiatives, perceptions regarding technology-assisted water management, levels of digital readiness, and experiences of social inclusion within governance processes.

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REVIEW OF LITERATURE

The concept of water governance has evolved considerably over the past few decades. Earlier approaches focused primarily on infrastructure development, engineering solutions, and centralized management systems. Contemporary perspectives emphasize governance as a multidimensional process involving institutions, policies, communities, and stakeholders. Water governance is increasingly understood as the set of political, social, economic, and administrative processes through which water resources are managed and allocated (OECD, 2021).

According to the OECD (2021), effective water governance requires transparency, accountability, participation, equity, and coordination among multiple actors. Governance is no longer viewed solely as a government responsibility but as a collaborative process involving public institutions, local communities, civil society organizations, and private stakeholders.

The emergence of digital technologies has significantly influenced governance systems across the world. Digital governance refers to the use of information and communication technologies to improve public administration, service delivery, decision-making, and citizen engagement. Recent studies suggest that digital technologies have the potential to transform governance by improving efficiency, reducing administrative delays, enhancing transparency, and strengthening accountability (OECD, 2023).

Within the water sector, smart water governance has emerged as a promising approach for addressing contemporary challenges. Smart water systems utilize digital technologies to monitor water resources, manage infrastructure, collect real-time data, and support evidence-based decision-making. Biswas and Tortajada (2023) argue that digital transformation is becoming an essential component of modern water governance due to increasing environmental uncertainties and growing pressures on water resources.

Research indicates that smart technologies can significantly improve operational efficiency. Smart meters, sensors, remote monitoring systems, and data analytics platforms enable authorities to detect leakages, monitor consumption patterns, assess water quality, and optimize distribution networks. These technologies contribute to cost reduction, improved service delivery, and enhanced sustainability (World Bank, 2024).

The integration of digital technologies into water governance has also been linked to climate adaptation and resilience. UNESCO (2024) highlights the role of digital systems in supporting drought preparedness, flood forecasting, groundwater monitoring, and disaster risk reduction. Real-time information systems enable governments to respond more effectively to environmental challenges and improve resilience in vulnerable regions.

Contemporary Perspectives on Smart Water Governance and Digital Inclusion

Recent scholarship increasingly emphasizes the transformative role of digital technologies in water governance. Smart water governance extends beyond technological efficiency and incorporates digital tools, participatory governance, sustainability, and citizen engagement. Digital technologies facilitate real-time monitoring, predictive analytics, data-driven decision-making, and improved accountability within water management systems (Amankwaa et al., 2021).

The global transition toward digital water management has accelerated due to growing concerns regarding water security, climate change, and environmental sustainability. Advanced technologies such as sensors, smart meters, artificial intelligence, and digital dashboards enable governments and water utilities to improve operational efficiency and optimize resource allocation. Digital transformation contributes to improved service delivery, infrastructure management, and long-term sustainability when supported by effective institutional frameworks (Biswas & Tortajada, 2023).

Recent studies on rural water governance emphasize the importance of community participation in ensuring sustainability. Research on rural water supply programmes indicates that long-term success depends not only on infrastructure provision but also on community ownership, local governance capacity, and institutional

responsiveness. Citizen engagement and participatory decision-making remain critical components of effective governance.

Digital monitoring systems within the Jal Jeevan Mission represent a significant shift in rural water governance. Online dashboards, Management Information Systems, and digital reporting mechanisms provide real-time information regarding service delivery and programme implementation. These systems contribute to improved transparency, accountability, and evidence-based policymaking.

The sustainability of digital governance initiatives is closely linked to digital inclusion. Digital literacy has emerged as a critical factor influencing governance participation. Individuals possessing higher levels of digital competence are more likely to access information, utilize government services, and engage with digital governance platforms. Consequently, digital inclusion has become a central concern within contemporary governance debates (OECD, 2023).

At the same time, scholars caution that technological innovations may create new forms of exclusion if digital access remains uneven. The benefits of digital governance are often shaped by differences in education, income, technological access, and digital skills. While digital technologies create opportunities for improved governance, they may also reinforce existing inequalities if vulnerable populations are unable to access or effectively utilize digital systems (Amankwaa et al., 2021).

Emerging discussions on the future of water governance increasingly stress the need to move beyond infrastructure-focused approaches toward more integrated and participatory models. Sustainable water governance requires the combination of technological innovation, institutional effectiveness, community participation, and social inclusion. The next phase of governance reforms is therefore expected to focus on strengthening local capacities, enhancing citizen engagement, and ensuring equitable access to digital governance systems (World Bank, 2024).

Within Kerala, existing research has primarily focused on groundwater management, watershed development, decentralized planning, water literacy, and community participation. The state's experience with decentralized governance and participatory development provides valuable insights into the role of local institutions in environmental management. However, relatively limited research has examined how digital technologies are transforming water governance and influencing social inclusion among rural households.

The literature collectively suggests that smart water governance should be understood as a socio-technical system in which technology, institutions, communities, and governance structures interact. While digital innovations provide important opportunities for improving efficiency and accountability, their effectiveness ultimately depends on inclusive governance practices that ensure equitable participation and access for all citizens (UNESCO, 2024; Amankwaa et al., 2021).

Research Gap

Although a growing body of literature examines digital governance, water management, and technological innovation, limited empirical research has explored the relationship between smart water governance and social inclusion within the context of rural Kerala. Existing studies primarily focus on technical dimensions of water management, leaving questions regarding citizen awareness, digital readiness, participation, and inclusion relatively underexplored. The present study seeks to address this gap by examining how rural households and Jal Jeevan Mission beneficiaries perceive and engage with smart water governance initiatives.

Theoretical Framework

The present study is anchored in three complementary theoretical perspectives: Governance Theory, Environmental Justice Theory, and Digital Sociology. Together, these frameworks provide a comprehensive understanding of the relationship between technological innovation, water governance, and social inclusion.

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Governance Theory

Governance theory emphasizes the processes through which collective decisions are made and implemented through interactions among governments, communities, civil society organizations, and private actors. Unlike traditional government-centred approaches, governance theory recognizes the importance of participation, accountability, transparency, and collaboration in addressing complex social and environmental challenges.

Contemporary governance scholars argue that effective governance requires active citizen engagement and the integration of multiple stakeholders into decision-making processes. Within the water sector, governance extends beyond infrastructure management to include policy formulation, institutional coordination, resource allocation, and public participation (OECD, 2021).

Smart water governance can be understood through this perspective as an attempt to strengthen governance processes through digital technologies. Real-time monitoring systems, digital dashboards, mobile applications, and online grievance mechanisms have the potential to improve transparency, responsiveness, and citizen participation. However, governance theory also emphasizes that technological systems must remain socially accountable and responsive to community needs. Consequently, the effectiveness of smart governance depends not only on technological sophistication but also on the quality of institutional arrangements and participatory mechanisms.

Environmental Justice Theory

Environmental Justice Theory focuses on the equitable distribution of environmental benefits and burdens across different social groups. The theory emerged from concerns that marginalized populations frequently experience disproportionate exposure to environmental risks while receiving fewer benefits from environmental policies and development programmes.

Access to safe and adequate water is fundamentally an issue of environmental justice. Water resources are not distributed equally, and disparities often reflect broader patterns of social inequality based on class, caste, gender, location, and economic status. Environmental justice scholars argue that governance systems must ensure both equitable access to environmental resources and meaningful participation in environmental decision-making.

From this perspective, smart water governance should not be evaluated solely in terms of efficiency or technological performance. Rather, it must also be assessed in relation to social inclusion, equity, and access. Questions regarding who benefits from digital innovations, who participates in governance processes, and who may be excluded become central concerns. This theoretical perspective enables the study to examine whether technology-enabled governance contributes to greater inclusion or reproduces existing inequalities.

Digital Sociology

Digital Sociology examines how digital technologies reshape social interactions, institutions, identities, and power relations (Lupton, 2015). Rather than viewing technology as a neutral tool, digital sociology emphasizes the ways in which technological systems influence social behaviour, governance structures, and everyday life.

The increasing integration of digital technologies into governance systems has transformed relationships between citizens and public institutions. Digital platforms mediate access to information, participation opportunities, and public services. Consequently, digital technologies play an increasingly important role in shaping patterns of inclusion and exclusion.

Smart water governance represents an important example of digital governance in practice. Through digital platforms, citizens can access information, report service issues, monitor programme implementation, and engage with public institutions. At the same time, differences in digital literacy, access to technology, and technological competence influence who can effectively participate in these processes.

The digital sociology perspective is particularly relevant for understanding how technological innovations interact with existing social inequalities. It highlights the importance of digital literacy, technological access, and institutional design in shaping governance outcomes.

Together, Governance Theory, Environmental Justice Theory, and Digital Sociology provide a multidimensional framework for examining the opportunities and challenges associated with smart water governance and social inclusion in Kerala.

Objectives and Hypotheses

Objectives of the Study

The study was undertaken with the following objectives:

1. To assess awareness of smart water governance initiatives among rural households in Kerala.
2. To examine public perceptions regarding the use of digital technologies in water management.
3. To analyze the role of the Jal Jeevan Mission in promoting smart water governance.
4. To assess levels of digital readiness among rural households.
5. To examine the relationship between digital literacy and participation in water governance.
6. To identify challenges affecting social inclusion in digital water governance systems.
7. To propose strategies for promoting inclusive and participatory smart water governance.

Research Hypotheses

Based on the literature review and theoretical framework, the following hypotheses were formulated:

H_1: There is a significant relationship between digital literacy and awareness of smart water governance initiatives.

H_2: There is a significant relationship between participation in Jal Jeevan Mission activities and acceptance of smart water governance technologies.

H_3: There is a significant association between educational status and willingness to use digital platforms for water-related services.

H_4: There is a significant relationship between digital readiness and participation in local water governance activities.

METHODOLOGY

Research Design

The study adopted a descriptive cross-sectional survey design complemented by analytical techniques to examine the relationship between smart water governance and social inclusion among rural households in Kerala. A cross-sectional design was considered appropriate because it enables the collection of data from a large number of respondents at a specific point in time, allowing the assessment of awareness, perceptions, digital readiness, and participation patterns.

The study combines descriptive and explanatory elements. While the descriptive component examines the extent of awareness and perceptions regarding smart water governance, the explanatory component

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investigates the influence of socio-economic characteristics, digital literacy, and programme participation on technology acceptance and governance participation.

The study is grounded in a socio-technical perspective that recognizes governance outcomes as products of interactions between technological systems, institutions, and social actors.

Study Area

The study was conducted in three districts of Kerala:

- Palakkad
- Malappuram
- Thrissur

These districts were selected because they represent diverse socio-economic and environmental contexts within the state. The selected districts have experienced varying levels of water stress, groundwater dependence, and implementation of Jal Jeevan Mission interventions.

The districts also provide variation in terms of:

- Rural population density
- Digital infrastructure availability
- Water resource conditions
- Community participation in local governance

Such diversity strengthens the representativeness and analytical value of the study.

Universe of the Study

The universe of the study consisted of all rural households benefiting from Jal Jeevan Mission interventions within selected Panchayats of Palakkad, Malappuram, and Thrissur districts.

The focus on Jal Jeevan Mission beneficiaries was based on the programme's emphasis on technology-enabled monitoring, community participation, and decentralized water governance.

Sampling Design

A multistage sampling technique was employed to obtain a representative sample of rural households benefiting from the Jal Jeevan Mission (JJM) across the selected districts of Kerala. The sampling process involved three stages.

Stage I: Selection of Districts

Three districts, Palakkad, Malappuram, and Thrissur, were purposively selected based on the following criteria:

- Extent of Jal Jeevan Mission implementation.
- Variation in water resource conditions and groundwater dependence.
- Geographic representation of central and northern Kerala.

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- Differences in digital infrastructure and socio-economic development.

The selection of these districts ensured diversity in environmental, technological, and governance contexts, enabling meaningful comparison across study locations.

Stage II: Selection of Panchayats

Two Gram Panchayats were selected from each district using purposive sampling in consultation with district authorities and local government officials. The Panchayats were selected based on the following criteria:

- Active implementation of Jal Jeevan Mission.
- Predominantly rural population.
- Availability of updated beneficiary household lists.
- Operational Village Water and Sanitation Committees (VWSCs) or similar community-based water management institutions.
- Accessibility for field data collection.

Selecting Panchayats with similar programme implementation ensured comparability while retaining contextual diversity.

Stage III: Selection of Households

The final sampling units consisted of beneficiary households enrolled under the Jal Jeevan Mission. Household lists were obtained from Panchayat offices and Village Water and Sanitation Committees. A systematic random sampling procedure was adopted to minimize selection bias.

The sampling interval (**k**) was determined by dividing the total number of beneficiary households in each Panchayat by the required sample size. A random starting point within the first sampling interval was selected, after which every *k*th household was included in the study until the required sample size was achieved.

If a selected household was unavailable after two visits or declined participation, the immediately succeeding household on the beneficiary list was selected to maintain the predetermined sample size.

Demographic Representation

To enhance representativeness, proportional allocation was employed so that each district contributed an equal number of respondents (100 households). During household selection, efforts were made to ensure adequate representation of different demographic groups, including:

- Male and female respondents.
- Different age groups.
- Educational levels.
- Occupational categories.
- Household income groups.
- Social categories where applicable.

Although probability sampling was used at the household level, proportional demographic representation helped capture variations in perceptions of digital governance and social inclusion across socio-economic groups.

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Sample Size Determination

A total sample of **300 households** was selected.

The sample size was considered statistically adequate for:

- Descriptive analysis
- Mean score analysis
- Chi-square tests
- Correlation analysis
- Multiple regression analysis

The sample was proportionately distributed across the selected Panchayats to ensure geographic representation.

Sample Distribution

District	Number of Respondents
Palakkad	100
Malappuram	100
Thrissur	100
Total	300

Sources of Data

Primary Data

Primary data constituted the major source of information.

Data were collected directly from respondents using a structured interview schedule.

Face-to-face interviews were preferred because they facilitate better response rates and reduce non-response errors, particularly among respondents with varying literacy levels.

Secondary Data

Secondary information was obtained from:

- Jal Jeevan Mission reports
- Kerala Water Authority publications
- Government of Kerala reports
- Ministry of Jal Shakti documents
- Census reports
- Academic journals

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- Books
- International reports from OECD, UNESCO, and the World Bank

Secondary data were used to contextualize findings and support interpretation.

Research Instrument

Primary data were collected using a structured interview schedule comprising five sections designed to measure socio-demographic characteristics, water governance, digital readiness, awareness of smart water governance, and social inclusion.

Section A: Socio-Demographic Characteristics

- Age
- Gender
- Educational attainment
- Occupation
- Monthly household income
- Family size

Section B: Water Access and Governance

- Primary source of drinking water
- Reliability of water supply
- Perceived water quality
- Participation in local water management
- Satisfaction with water services

Section C: Smart Water Governance Awareness

This section measured respondents' awareness of digital and technology-enabled water governance initiatives using items adapted from studies on e-governance, smart governance, and digital public service delivery.

Indicators included:

- Awareness of digital water monitoring systems.
- Knowledge of smart metering technologies.
- Awareness of online complaint and grievance mechanisms.
- Familiarity with Jal Jeevan Mission digital platforms.
- Awareness of ICT-based water management initiatives.

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Section D: Digital Literacy and Readiness

Digital literacy items were adapted from internationally recognized digital competence frameworks, particularly the European Digital Competence Framework (DigComp) and previous digital literacy research.

The section included measures relating to:

- Smartphone ownership.
- Internet accessibility.
- Frequency of internet use.
- Ability to operate smartphones and mobile applications.
- Ability to access online government services.
- Confidence in using digital technologies.

Section E: Social Inclusion and Participation

Items assessing social inclusion were adapted from established frameworks on participatory governance, social inclusion, and community engagement.

The section measured:

- Participation in Gram Sabha meetings.
- Membership in Village Water and Sanitation Committees.
- Access to water-related information.
- Opportunity to express opinions during decision making.
- Perceived fairness and inclusiveness in water governance.
- Overall perception of inclusion in local governance.

Operational Definition of Key Variables

Smart Water Governance Awareness

Refers to respondents' knowledge and understanding of technology-enabled water management systems, digital monitoring tools, and online governance mechanisms.

Digital Literacy

Refers to the ability to access, understand, evaluate, and utilize digital technologies and online services effectively.

Social Inclusion

Refers to the extent to which individuals perceive themselves as having access to information, participation opportunities, and decision-making processes related to water governance.

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Technology Acceptance

Refers to respondents' willingness to utilize and support digital technologies in water management and governance.

Measurement Scale

Responses to attitudinal statements were recorded using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Response	Score
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

Composite scores were computed by averaging the responses to items within each construct. Higher scores indicated greater awareness, stronger digital readiness, higher perceived social inclusion, and greater acceptance of smart water governance technologies.

Pilot Study

A pilot study was conducted among 30 households from a Panchayat outside the final study area.

The pilot study helped:

- Assess clarity of questions
- Improve sequencing of items
- Estimate survey duration
- Test reliability of scales
- Identify potential field challenges

Necessary modifications were incorporated before final data collection.

Reliability Analysis

Internal consistency reliability of the research instrument was assessed using Cronbach's Alpha, which is widely accepted for evaluating the reliability of multi-item scales.

Construct	Number of Items	Cronbach's Alpha
Smart Water Governance Awareness	8	0.85
Digital Literacy	7	0.83
Social Inclusion	8	0.87

Technology Acceptance	6	0.84
Overall Instrument	29	0.88

All Cronbach's Alpha values exceeded the recommended threshold of 0.70 (Nunnally & Bernstein, 1994), indicating satisfactory internal consistency.

Validity of the Instrument

Content Validity

Content validity was established through expert review by specialists in sociology, rural development, water governance, extension education, and research methodology. Experts evaluated each item for clarity, relevance, and adequacy in representing the intended constructs. Their recommendations were incorporated into the final instrument.

Construct Validity

Construct validity was established by adapting measurement items from validated scales reported in previous studies on digital governance, digital literacy, technology acceptance, and social participation. The conceptual framework was informed by:

- Governance Theory.
- Environmental Justice Theory.
- Digital Sociology.
- Technology Acceptance Model (TAM).
- Digital Competence Framework (DigComp).

The adapted items were modified to suit the context of rural water governance in Kerala while preserving their conceptual meaning.

Face Validity

Face validity was assessed during the pilot survey. Respondents evaluated the questionnaire for clarity, language appropriateness, and ease of understanding. Minor revisions were made to improve wording and sequencing before the main survey.

Ethical Considerations

The study adhered to established ethical standards.

The following measures were adopted:

- Informed consent was obtained from all respondents.
- Participation was voluntary.
- Confidentiality of information was maintained.
- Personal identifiers were removed during data analysis.
- Data were used exclusively for academic purposes.

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Data Processing and Analysis

Collected data were coded, tabulated, and analyzed using SPSS.

The following statistical techniques were employed:

Descriptive Statistics

- Frequency
- Percentage
- Mean
- Standard Deviation

Composite Indices

- Smart Water Governance Awareness Index (SWGAI)
- Digital Readiness Index (DRI)
- Social Inclusion Index (SII)

Inferential Statistics

- Chi-square Test
- Pearson Correlation
- Multiple Regression Analysis

These techniques enabled the identification of patterns, relationships, and predictors associated with smart water governance and social inclusion.

Reliability and Validity

Reliability Analysis

Reliability of the instrument was assessed using Cronbach's Alpha.

Table 1 Reliability Statistics

Scale	**Cronbach's Alpha**
Smart Governance Awareness Scale	0.85
Digital Literacy Scale	0.83
Social Inclusion Scale	0.87
Technology Acceptance Scale	0.84
Overall Instrument	0.88

The overall reliability coefficient of 0.88 indicates a high level of internal consistency and confirms the reliability of the instrument.

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Validity

Content Validity

The questionnaire was reviewed by experts in sociology, water governance, rural development, and research methodology to ensure relevance and adequacy of measurement.

Construct Validity

Construct validity was ensured through alignment with:

- Governance Theory
- Environmental Justice Theory
- Digital Sociology

The indicators used in the study were derived from established literature on governance, digital inclusion, and water management.

Construction of Indices

To facilitate analysis, three composite indices were developed.

Smart Water Governance Awareness Index (SWGAI)

The index measured awareness regarding:

- Smart monitoring systems
- Digital water governance platforms
- Jal Jeevan Mission digital tools
- Online grievance mechanisms

Classification

Category	Score Range
Low Awareness	0–33
Moderate Awareness	34–66
High Awareness	67–100

Digital Readiness Index (DRI)

The Digital Readiness Index was constructed using indicators such as:

- Smartphone ownership
- Internet usage
- Digital skills
- Experience using online public services

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Classification

Category	Score Range
Low	0–33
Moderate	34–66
High	67–100

Social Inclusion Index (SII)

The Social Inclusion Index assessed:

- Access to governance information
- Participation in meetings
- Representation in decision-making
- Access to digital platforms

Classification

Category	Score Range
Low	0–33
Moderate	34–66
High	67–100

Results and Statistical Analysis

Socio-Demographic Profile of Respondents

Table 2 Distribution of Respondents by Gender

Gender	Frequency	Percentage
Male	145	48.3
Female	155	51.7
Total	300	100.0

The sample consisted of a nearly equal representation of male and female respondents, ensuring balanced perspectives regarding water governance and digital participation.

Table 3 Educational Status of Respondents

Education Level	Frequency	Percentage
Primary	52	17.3

Secondary	118	39.3
Higher Secondary	74	24.7
Graduate and Above	56	18.7
Total	300	100.0

The findings indicate a relatively diverse educational profile, with the majority of respondents having completed secondary education.

Results and Statistical Analysis

Awareness of Smart Water Governance

The Smart Water Governance Awareness Index (SWGAI) was developed to assess respondents' knowledge regarding digital water governance initiatives, smart monitoring systems, online grievance mechanisms, and technology-enabled water management services.

Table 4 Smart Water Governance Awareness Index

Awareness Level	**Frequency**	**Percentage**
Low	54	18.0
Moderate	164	54.7
High	82	27.3
Total	300	100.0

The findings indicate that a majority of respondents (54.7%) possessed a moderate level of awareness regarding smart water governance initiatives. Approximately 27.3 percent reported high awareness, while 18 percent demonstrated low awareness. These findings suggest that although digital governance initiatives are becoming increasingly visible within rural communities, awareness remains uneven.

Sources of Information Regarding Smart Water Governance

Respondents were asked to identify their primary sources of information regarding water governance programmes and digital initiatives.

Table 5 Sources of Information

Source	**Percentage***
Television	74
WhatsApp	68
Panchayat Meetings	59
Krishi Bhavan	45
Social Media	41

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Newspapers	38

*Multiple responses were recorded.

Television emerged as the most influential source of information, followed by WhatsApp and Panchayat meetings. The findings demonstrate the growing importance of digital communication platforms in disseminating governance-related information.

Perceived Benefits of Smart Water Governance

Respondents were asked to evaluate various benefits associated with smart water governance using a five-point Likert scale.

Table 6 Mean Score Analysis of Perceived Benefits

Variable	**Mean Score**	**Rank**
Improved Water Monitoring	4.31	I
Better Service Delivery	4.22	II
Transparency and Accountability	4.11	III
Reduced Water Wastage	4.08	IV
Improved Community Participation	3.87	V

The findings reveal strong public support for technology-assisted water management. Improved water monitoring received the highest mean score (M = 4.31), indicating that respondents perceived digital technologies as particularly useful for improving water management efficiency.

Digital Readiness Index

The Digital Readiness Index (DRI) was developed using indicators such as smartphone ownership, internet access, digital skills, and use of online public services.

Table 7 Digital Readiness Index

Category	**Frequency**	**Percentage**
Low	66	22.0
Moderate	144	48.0
High	90	30.0
Total	300	100.0

Nearly half of the respondents (48%) demonstrated moderate levels of digital readiness. While digital infrastructure has expanded significantly, variations in digital competence continue to influence participation in governance processes.

Social Inclusion Index

The Social Inclusion Index (SII) assessed respondents' access to information, participation opportunities, and representation within water governance processes.

Table 8 Social Inclusion Index

Category	Frequency	Percentage
Low	48	16.0
Moderate	171	57.0
High	81	27.0
Total	300	100.0

Most respondents reported moderate levels of inclusion. However, the presence of low inclusion scores among a significant minority highlights continuing barriers to meaningful participation.

Correlation Analysis

Pearson's correlation coefficient was used to examine relationships among key study variables.

Table 9 Correlation Matrix

Variables	r-value
Digital Literacy × Governance Awareness	0.63**
Governance Awareness × Participation	0.58**
Digital Readiness × Technology Acceptance	0.66**
Social Inclusion × Participation	0.61**

p < .01

The results indicate moderate to strong positive relationships among the variables. Higher levels of digital literacy were associated with greater awareness of smart governance initiatives, while increased governance awareness contributed to greater participation in local water governance activities.

Chi-Square Analysis

Hypothesis 1

H_1: There is a significant relationship between digital literacy and awareness of smart water governance initiatives.

Table 10 Digital Literacy and Governance Awareness

Test Statistic	Value
χ^2	18.45
df	4
p-value	.001

The Chi-square value was statistically significant ($\chi^2 = 18.45$, $p < .001$). Therefore, the hypothesis is accepted. Respondents with higher levels of digital literacy demonstrated significantly greater awareness of smart water governance initiatives.

Hypothesis 2

H_2: There is a significant relationship between participation in Jal Jeevan Mission activities and technology acceptance.

Table 11 JJM Participation and Technology Acceptance

Test Statistic	Value
χ^2	14.22
df	4
p-value	.007

The results indicate a statistically significant relationship between participation in Jal Jeevan Mission activities and acceptance of digital water governance technologies.

Hypothesis 3

H_3: There is a significant association between educational status and willingness to use digital platforms for water-related services.

Table 12 Educational Status and Digital Platform Usage

Test Statistic	Value
χ^2	21.87
df	6
p-value	.001

Educational attainment significantly influenced willingness to use digital governance platforms.

Hypothesis 4

H_4: There is a significant relationship between digital readiness and participation in local water governance activities.

Table 13 Digital Readiness and Governance Participation

Test Statistic	Value
χ^2	16.92
df	4
p-value	.003

The findings support the hypothesis and indicate that digitally prepared households participate more actively in governance processes.

Multiple Regression Analysis

To identify factors influencing acceptance of smart water governance technologies, a multiple regression model was estimated.

Dependent Variable

Technology Acceptance Score

Independent Variables

- Educational Status
- Digital Literacy
- Participation in Jal Jeevan Mission Activities
- Household Income

Table 14 Multiple Regression Analysis Predicting Technology Acceptance

Variable	B	Beta	t-value	p-value
Constant	1.214	–	3.87	.001
Educational Status	0.182	.201	3.24	.002
Digital Literacy	0.364	.412	6.78	.000
JJM Participation	0.291	.338	5.46	.000
Household Income	0.118	.124	2.11	.036

$R^2 = .54$

Adjusted $R^2 = .52$

$F = 41.82$ ($p < .001$)

The regression model explains approximately 54 percent of the variance in technology acceptance. Digital literacy emerged as the strongest predictor, followed by participation in Jal Jeevan Mission activities. These findings indicate that technology acceptance is shaped not only by access to infrastructure but also by human capabilities and community engagement.

DISCUSSION

The findings of the study provide important insights into the opportunities and challenges associated with smart water governance among rural households in Kerala. The moderate levels of awareness observed among respondents suggest that digital water governance initiatives are gradually becoming visible within rural communities. This finding reflects the growing influence of digital governance programmes and technology-enabled public service delivery systems.

The significant relationship between digital literacy and governance awareness supports findings from previous studies emphasizing the importance of digital competencies in shaping participation in governance processes (Amankwaa et al., 2021; OECD, 2023). Individuals possessing greater digital skills are more likely to access information, engage with governance platforms, and utilize digital services effectively.

The findings also demonstrate strong public support for technology-enabled water management. Respondents perceived improved monitoring, enhanced transparency, better service delivery, and reduced water wastage as major benefits of smart governance. These findings are consistent with recent studies suggesting that digital technologies can improve efficiency and accountability within water management systems (Biswas & Tortajada, 2023).

Participation in Jal Jeevan Mission activities significantly influenced technology acceptance. Beneficiaries actively involved in programme activities displayed greater trust in digital governance systems and higher willingness to utilize technology-based services. This finding underscores the importance of community participation in fostering acceptance of governance innovations.

The Social Inclusion Index revealed moderate levels of inclusion, suggesting that although digital governance initiatives create new opportunities for participation, barriers remain. Elderly populations, economically disadvantaged households, and individuals with limited digital skills continue to face challenges in accessing digital services. These findings reinforce concerns regarding the digital divide and highlight the need for targeted inclusion strategies.

From a sociological perspective, the findings demonstrate that smart water governance is not merely a technological intervention but a socio-technical process involving institutions, communities, technologies, and governance structures. The effectiveness of digital innovations depends on their integration with local participation, institutional capacity, and social inclusion mechanisms.

Digital Society and Emerging Challenges

The increasing adoption of digital technologies in water governance reflects broader transformations associated with the emergence of digital society. While technological innovations provide new opportunities for resource management and service delivery, they also generate significant social and governance challenges.

One of the most important concerns identified in the study is the persistence of digital inequalities. Differences in digital access, education, income, and technological competence influence participation in governance processes. As public services become increasingly digitized, vulnerable populations risk exclusion from important governance mechanisms.

Data governance represents another emerging challenge. Smart water systems generate large volumes of data concerning consumption patterns, infrastructure performance, and household behaviour. While these data can improve planning and efficiency, questions regarding privacy, ownership, security, and ethical use require careful consideration.

The findings also highlight the importance of preserving local knowledge systems. Kerala possesses rich traditions of community-based water management and indigenous conservation practices. Smart governance should complement rather than replace these knowledge systems.

Climate change further increases the importance of adaptive governance. Digital technologies can support resilience through forecasting systems, groundwater monitoring, and disaster preparedness. However, technological solutions must be integrated into broader social and environmental strategies.

Smart Water Governance and Sustainable Development Goals

The study demonstrates the relevance of smart water governance for achieving multiple Sustainable Development Goals (SDGs).

SDG 6 (Clean Water and Sanitation): Digital technologies improve monitoring, service delivery, and sustainable water resource management.

SDG 10 (Reduced Inequalities): Inclusive digital governance can improve access to information and services among marginalized populations.

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SDG 11 (Sustainable Cities and Communities): Smart water systems contribute to sustainable resource management and resilient communities.

SDG 13 (Climate Action): Real-time monitoring and forecasting systems strengthen climate adaptation and disaster preparedness.

SDG 16 (Peace, Justice and Strong Institutions): Digital governance promotes transparency, accountability, and citizen participation.

The findings indicate that smart water governance can contribute simultaneously to environmental sustainability, social inclusion, and institutional strengthening.

Policy Recommendations

The findings of the study indicate that while smart water governance offers considerable opportunities for improving water management and service delivery, its long-term success depends on the extent to which technological innovation is integrated with social inclusion, institutional capacity, and community participation. Based on the empirical findings, the following policy recommendations are proposed.

Strengthen Digital Water Literacy

Digital literacy emerged as one of the strongest predictors of governance awareness and technology acceptance. Therefore, digital literacy programmes should be integrated with existing water literacy and community development initiatives.

Training programmes may focus on:

- Accessing digital water governance platforms
- Using mobile applications for water-related services
- Understanding digital monitoring systems
- Reporting water-related issues through online mechanisms
- Accessing government information and services

Special attention should be given to women, elderly populations, and marginalized communities to ensure equitable participation.

Establish Smart Water Information Centres

Local Self-Government Institutions (LSGIs) can establish Smart Water Information Centres at the Panchayat level to support citizen engagement and digital participation.

These centres may function as:

- Information hubs for water governance programmes
- Digital support centres for accessing services
- Community resource centres for water literacy activities
- Training centres for digital governance awareness

Such centres can help bridge the gap between technological systems and citizens.

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Promote Inclusive Digital Governance

Digital governance initiatives should be designed to accommodate the needs of diverse social groups.

Specific measures may include:

- Multilingual interfaces
- User-friendly applications
- Offline support mechanisms
- Assisted digital services
- Accessibility features for elderly users

Inclusive design can reduce barriers to participation and prevent digital exclusion.

Integrate Water Literacy and Digital Literacy

The findings suggest that awareness and participation are closely linked. Consequently, water literacy programmes should be integrated with digital literacy initiatives.

Educational campaigns should focus on:

- Water conservation
- Groundwater protection
- Climate resilience
- Smart water technologies
- Citizen responsibilities in water governance

Integrated literacy programmes can strengthen community engagement and sustainability.

Strengthen Community Participation

The study demonstrates that participation in Jal Jeevan Mission activities positively influences technology acceptance. Therefore, community participation should remain a central component of smart governance initiatives.

Strategies may include:

- Strengthening Village Water and Sanitation Committees
- Conducting regular public consultations
- Encouraging citizen monitoring
- Supporting participatory planning processes
- Facilitating community feedback mechanisms

Digital technologies should complement rather than replace face-to-face participation.

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Build Institutional Capacity

Successful implementation of smart water governance requires adequate institutional capacity.

Capacity-building initiatives should target:

- Panchayat officials
- Kerala Water Authority personnel
- Jal Jeevan Mission functionaries
- Community volunteers
- Water committee members

Training should focus on digital tools, data management, participatory governance, and citizen engagement.

Develop Robust Data Governance Frameworks

As smart governance systems increasingly rely on data collection and analysis, clear policies regarding data management are essential.

Policy frameworks should address:

- Data privacy
- Data ownership
- Data security
- Ethical use of information
- Citizen consent

Transparent data governance systems can enhance public trust and legitimacy.

Promote Citizen Science and Community Monitoring

Citizen science approaches can strengthen local participation in water governance.

Communities can contribute to:

- Water quality monitoring
- Reporting infrastructure problems
- Mapping local water resources
- Monitoring conservation activities

Such initiatives can generate locally relevant data while strengthening community ownership.

Utilize Kerala's Digital Governance Infrastructure

Kerala's expanding digital governance ecosystem provides opportunities for integrating smart water governance within existing platforms.

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Future initiatives can build upon:

- Digital Kerala Mission
- K-SMART platform
- E-governance services
- Panchayat digital infrastructure

Integration can improve efficiency and reduce duplication of efforts.

Contribution to Knowledge

The present study contributes to the emerging field of digital environmental governance by examining the intersection of technology, water management, and social inclusion within the context of rural Kerala.

The study makes four significant contributions.

First, it provides empirical evidence regarding public awareness, digital readiness, and perceptions of smart water governance among rural households and Jal Jeevan Mission beneficiaries. While much of the existing literature focuses on technical dimensions of smart water systems, the present study highlights citizens' experiences and perspectives.

Second, the study demonstrates that digital literacy functions as a critical enabling factor influencing governance awareness, participation, and technology acceptance. The findings indicate that technological infrastructure alone is insufficient; human capabilities and digital competencies play equally important roles in determining governance outcomes.

Third, the study highlights the continuing importance of community participation and decentralized governance institutions within technology-enabled governance systems. The findings reinforce Kerala's long-standing emphasis on participatory development and local self-governance.

Fourth, the study develops a socio-technical understanding of smart water governance by demonstrating that technological innovation, institutional capacity, social inclusion, and citizen participation are mutually reinforcing. This perspective contributes to contemporary debates within digital sociology, governance studies, and environmental sociology.

The study therefore expands understanding of how digital technologies can support sustainable and inclusive water governance in developing societies.

CONCLUSION

The increasing integration of digital technologies into water governance has transformed the ways in which water resources are monitored, managed, and governed. Smart water governance represents an important shift from conventional infrastructure-centred approaches towards data-driven, participatory, and technologically enabled governance systems.

The findings of the present study indicate that rural households in Kerala generally perceive smart water governance positively and recognize its potential benefits for improving water management and service delivery. Moderate levels of awareness, relatively high levels of technology acceptance, and positive perceptions regarding transparency, monitoring, and efficiency demonstrate the growing acceptance of digital governance initiatives.

The study also revealed significant relationships between digital literacy, governance awareness, participation, and technology acceptance. Digital literacy emerged as a particularly important factor influencing engagement

with governance systems, suggesting that technological innovations are most effective when accompanied by investments in human capabilities and capacity development.

At the same time, the study identified several challenges associated with smart governance. Digital inequalities, institutional capacity constraints, data governance concerns, and risks of social exclusion continue to affect the implementation of technology-driven governance systems. These findings highlight the limitations of purely technological approaches to water management.

From a sociological perspective, smart water governance should be understood as a socio-technical process rather than a purely technical intervention. The success of digital governance depends not only on technological infrastructure but also on social inclusion, democratic participation, institutional accountability, and community engagement.

Kerala's experience demonstrates that the future of sustainable water governance lies in integrating digital innovation with decentralized governance institutions, local knowledge systems, and community participation. Such an approach can contribute to equitable, resilient, and environmentally sustainable water governance capable of addressing contemporary developmental and environmental challenges.

Ultimately, smart water governance should not be viewed as an end in itself but as a means of promoting water security, social justice, and sustainable development. The challenge for policymakers is to ensure that technological progress remains inclusive, participatory, and responsive to the needs of all sections of society.

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