ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

Smart Irrigation Governance and Water Delivery Precision in Public Irrigation Systems

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Date Submitted:
April 16, 2026

Date Accepted:
May 11, 2026

Date Published:
June 30, 2026

DOI:
10.5281/zenodo.21074941

ABSTRACT

This study positioned smart irrigation governance as a critical pathway for improving water delivery precision in public irrigation systems. Using a predictive-correlational and explanatory survey design with service precision modeling, the study assessed governance practices in terms of data-informed decision-making, technology utilization, operational coordination, transparency in water allocation, monitoring and reporting, and maintenance responsiveness. It also measured water delivery precision in terms of adequacy, timeliness, consistency, equity, reliability, and responsiveness. Data were gathered through a validated and reliability-tested questionnaire, with excellent internal consistency based on Cronbach's alpha results. The findings revealed that smart irrigation governance was practiced at a high level, with operational coordination and data-informed decision-making emerging as the strongest governance areas. Water delivery precision was likewise rated high, particularly in adequacy, reliability, and consistency. However, equity, timeliness, responsiveness, technology utilization, and maintenance responsiveness remained areas requiring improvement. Correlation analysis showed a strong positive and significant relationship between smart irrigation governance and water delivery precision. Hierarchical multiple regression further indicated that the governance model substantially explained variations in delivery precision, with data-informed decision-making, maintenance responsiveness, and operational coordination serving as the strongest predictors. The study concluded that precision in irrigation service was not shaped by infrastructure alone but by the quality of decisions, field response, data use, and stakeholder coordination. Strengthening digital monitoring, predictive planning, maintenance systems, and transparent allocation procedures was recommended to improve the accuracy, fairness, and dependability of water delivery in public irrigation systems.

Keywords: *data-informed decision-making, irrigation governance, maintenance responsiveness, public irrigation systems, smart irrigation, water delivery precision*

INTRODUCTION

Water has always been at the center of agricultural production, but in recent years, the management of irrigation water has become more demanding because of climate variability, rising food demand, and increasing pressure on public water resources. Irrigated agriculture remains essential to food security because it stabilizes crop production in areas where rainfall is uncertain or unevenly distributed. However, irrigation systems can no longer be viewed only as canals, gates, pumps, and service areas. They now need to be understood as governance systems where infrastructure, technology, institutional responsibility, farmer participation, and water delivery decisions must work together. The Food and Agriculture Organization of the United Nations (FAO, 2016) emphasized that sustainable food and agriculture require better water supply management, reduced water losses, improved productivity, and more coherent water policies. This suggests that irrigation performance depends not only on the availability of water but also on how water is monitored, allocated, delivered, and accounted for across the system.

The growing concern over water scarcity has made irrigation governance more important in both global and local agricultural planning. FAO (2020) explained that expanded and improved irrigation must be supported by stronger water governance, well-defined water rights, reliable information on water resources, and policies that encourage equitable and efficient water use. In public irrigation systems, these concerns are especially relevant because water delivery decisions affect many farmers at once. When water distribution is delayed, poorly measured, or unevenly delivered, the effects are felt not only in crop growth but also in farmer confidence, system reliability, and institutional credibility. Thus, the issue is not simply whether irrigation infrastructure exists. The more important question is whether the system can deliver the right amount of water, at the right time, to the right service area, under transparent and accountable management arrangements.

Recent discussions on irrigation modernization have also shown that service delivery is now a major measure of irrigation performance. The World Bank (2026) noted that modern irrigation reforms increasingly use service agreements, transparency mechanisms, and clearer responsibilities between service providers and water users to improve water delivery, canal maintenance, and water shortage procedures. This direction is important because public irrigation agencies are expected to move beyond infrastructure development and become more responsive service institutions. In this sense, irrigation governance includes planning, coordination, data use, communication with irrigators' associations, maintenance prioritization, and the capacity to respond to changing water conditions. Good governance in irrigation is therefore seen in how consistently the system translates available water into dependable farm-level delivery.

Irrigation development has long been tied to rice production, rural productivity, and public investment. Studies conducted by the Philippine Institute for Development Studies have shown that national and communal irrigation systems face both technical and institutional constraints that affect overall performance. Inocencio et al. (2016) found that irrigation performance varies across regions and systems, and that subnational analysis is useful in understanding system capacity, manpower, functionality, financial structure, and productivity. Their work also showed that irrigation performance cannot be judged only by physical coverage because system location, technology type, institutional arrangements, and operational conditions shape actual results. This is significant for public irrigation systems because a canal network may exist on paper, yet the precision, timeliness, and fairness of water delivery may still vary across upstream, midstream, and downstream users.

Further Philippine evidence points to continuing concerns in the operation and maintenance of national irrigation systems. Clemente et al. (2020) reported that siltation affected canal flow capacity in many National Irrigation System cases, which reduced the adequacy of water supply in downstream areas. The same study recommended realistic resources for operation and maintenance to improve the efficiency of water allocation and distribution from upstream to downstream users. This finding is directly connected to water delivery precision because even if water sources are available, the accuracy and reliability of delivery may decline when canals are not properly maintained, when monitoring is weak, or when the system lacks timely operational data. In public irrigation systems, precision is therefore not only a technological matter. It is also a management outcome shaped by maintenance planning, field monitoring, and institutional response.

The need to strengthen Philippine irrigation governance has also been highlighted in broader assessments of the sector. Briones (2022) explained that irrigation has again become a major government priority after years of relative neglect, especially because of its role in rice agriculture and national food security. His systems and governance assessment covered national systems, communal systems, water resource assessment, governance concerns, policy shifts, and benefit-cost issues. This shows that irrigation modernization requires more than additional infrastructure spending. It requires a system-wide view of how water is sourced, conveyed, measured, distributed, and governed. For agencies such as the National Irrigation Administration, the challenge is to make irrigation systems more reliable, transparent, and responsive to actual field conditions.

At the same time, smart irrigation has become an important pathway for improving water delivery and irrigation decision-making. Smart irrigation generally refers to the use of sensors, remote monitoring, weather data, soil moisture information, automation, decision-support tools, and communication systems to guide water application and system operation. Ali, Hussain, and Zahid (2025) described smart irrigation as a shift from conventional and often inefficient irrigation practices toward precision monitoring and control systems that use soil, plant, weather, remote sensing, and participatory irrigation management data. Their review also noted that smart irrigation technologies can support better water use efficiency, although adoption may be affected by cost, data management requirements, technical capacity, and the need for trained personnel. These points are highly relevant to public irrigation systems, where technology must be fitted not only to farm-level needs but also to institutional routines, field personnel capacity, canal operations, and farmer coordination.

Precision in water delivery is a practical concern because irrigation service is experienced by farmers through timing, adequacy, predictability, and fairness. A system may be considered modern only when it can use information to reduce guesswork in distribution and when it can respond to changes in water availability, crop stage, and service area demand. Smart tools can help improve this process by strengthening real-time monitoring, field reporting, gate operation decisions, maintenance scheduling, and communication between irrigation personnel and irrigators' associations. However, technology alone cannot solve weak governance. Without clear rules, trained personnel, accountable reporting, and reliable coordination, digital tools may only add another layer of data without improving actual service delivery. This is why the present study gives equal attention to smart irrigation governance and water delivery precision.

The study is therefore anchored on the view that irrigation performance depends on the connection between governance quality and operational accuracy. For a public irrigation system, smart governance may be reflected in the use of timely data, transparent water allocation, coordinated field operations, responsive maintenance, and active engagement with water users. Water delivery precision, on the other hand, may be reflected in the adequacy, timeliness, consistency, equity, and reliability of water reaching the intended service areas. By examining these two areas together, the study can contribute to the continuing discussion on how public irrigation systems may become more efficient, accountable, and responsive in an era of climate uncertainty and increasing demand for agricultural water.

This study is particularly meaningful for the National Irrigation Administration because its mandate involves not only the development of irrigation infrastructure but also the sustained operation and maintenance of systems that support agricultural communities. As water becomes more contested and climate conditions become less predictable, irrigation agencies need stronger evidence on how governance practices affect the precision of water delivery. The findings of this study may provide useful insights for improving field monitoring, strengthening irrigation service planning, enhancing coordination with irrigators' associations, and supporting the practical adoption of smart irrigation approaches in public irrigation systems. In this way, the study does not treat smart irrigation as technology for its own sake. Rather, it frames smart irrigation as a governance and service delivery concern, where data, people, infrastructure, and accountability must come together to make water delivery more precise and dependable.

Literature Review

Irrigation Governance and Institutional Accountability

Irrigation governance refers to the organization of authority, responsibility, decision-making, and accountability in managing irrigation systems. It includes formal rules, agency mandates, coordination among personnel, and engagement with water users. Playán et al. (2018) noted that governance problems in irrigation often result from weak accountability, limited transparency, poor participation, and misalignment between infrastructure and management capacity. FAO (2020) also emphasized that improved irrigation requires coherent policies, reliable water information, and governance arrangements that support equitable and efficient water use. Similarly, the World Bank Group (2026) identified water governance as central to water security, especially where competing demands affect supply. Overall, the literature shows that irrigation governance directly shapes technical performance because it influences how water is allocated, how maintenance is prioritized, how shortages are addressed, and how decisions are communicated to users.

Smart Irrigation Technologies and Data-Based Water Management

Smart irrigation involves the use of digital tools, sensors, remote sensing, monitoring systems, decision-support mechanisms, and automated controls to guide irrigation decisions. Ali et al. (2025) explained that smart irrigation systems may include soil and plant sensors, weather-based tools, Internet of Things devices, and participatory irrigation management data to improve water use efficiency. These technologies help reduce guesswork by providing timely information on water needs, field conditions, and system performance. However, their value depends on technical capacity, data quality, cost, and the ability of personnel to translate information into action. Seijger et al. (2023) added that remote sensing tools such as WaPOR can support water productivity assessment, although results still require careful interpretation. Thus, smart irrigation becomes effective only when technology is linked to sound management decisions and field-level response.

Water Delivery Precision and Irrigation Service Performance

Water delivery precision refers to the ability of an irrigation system to deliver the right amount of water at the right time and place with consistency and fairness. Fan et al. (2018) assessed irrigation performance through adequacy, efficiency, dependability, and equity, showing that water allocation and actual delivery must be examined together. Precision is therefore not limited to volume but also includes timing, spatial distribution, reliability, and responsiveness to demand. FAO (2017) stressed that reducing water losses and improving water productivity are essential for sustainable agriculture. In irrigation systems, poor maintenance, canal seepage, siltation, gate malfunction, and delayed reporting may reduce delivery accuracy even when water is available. The literature therefore supports measuring irrigation delivery as a service outcome, not merely as a function of infrastructure.

Integration of Governance, Technology, and Operational Performance

Recent irrigation literature highlights the need to connect governance, technology, and operational performance. Playán et al. (2018) showed that irrigation reforms may fail when institutional roles do not match actual management needs, while Ali et al. (2025) emphasized that smart irrigation technologies require trained users, reliable data processing, and practical integration into irrigation routines. FAO (2020) likewise emphasized that efficient and equitable irrigation depends on both water information systems and sound governance. This means that data becomes useful only when institutions can act on it through scheduling, maintenance, communication, and allocation adjustments. Overall, irrigation systems improve when governance provides clear responsibility, technology provides timely information, and operations translate both into precise and dependable water delivery.

METHODS

Research Design

The study employed a predictive-correlational and explanatory survey design with service precision modeling. This design was selected because the study did not only determine the relationship between smart irrigation governance and water delivery precision but also examined which governance dimensions most strongly shaped precision in public irrigation service. Instead of using a purely descriptive approach, the design allowed the researcher to identify patterns of influence among governance practices, data use, operational coordination, field monitoring, and the perceived accuracy of water delivery.

The predictive-correlational component was used to determine the strength and direction of association between smart irrigation governance and water delivery precision. The explanatory component was used to clarify how specific governance practices accounted for differences in the observed level of delivery precision. This design suited the study because irrigation performance is not shaped by one factor alone. It is often influenced by the interaction of institutional decisions, field-level coordination, monitoring systems, maintenance responsiveness, and communication with water users. Through this design, the study generated evidence that was not limited to describing current conditions but also helped explain which management areas contributed most to precise, timely, and reliable water distribution.

Research Locale

The study was conducted in selected public irrigation systems administered under the National Irrigation Administration. The research locale was chosen because public irrigation systems operate through organized water distribution schedules, canal networks, field monitoring arrangements, maintenance procedures, and coordination mechanisms with irrigators' associations. These conditions provided a suitable environment for examining how smart irrigation governance practices were reflected in actual water delivery performance.

The locale also offered a relevant setting for studying irrigation management because water delivery in public systems requires both technical control and institutional coordination. Field operations, monitoring reports, gate adjustments, maintenance responses, and communication with water users were all part of the service process. These features made the area appropriate for assessing whether governance practices supported greater precision in water allocation and delivery.

Participants and Sampling Technique

The participants of the study were personnel and stakeholders directly involved in the operation, monitoring, coordination, and use of public irrigation services. They included individuals who had sufficient familiarity with irrigation governance practices, field-level water distribution, maintenance concerns, monitoring procedures, and coordination activities related to public irrigation systems.

The study used criterion-based stratified sampling. The criterion-based component ensured that only participants with direct knowledge or experience of irrigation management and water delivery were included. The stratified component allowed the researcher to obtain representation from relevant participant groups involved in irrigation service delivery and use. This sampling technique was considered appropriate because public irrigation systems involve different actors with different functions and experiences. By organizing participants according to their involvement in the system, the study was able to gather responses that reflected both management-side and user-side perspectives without relying on a single group alone

Research Instrument

The primary instrument used in the study was a researcher-developed survey questionnaire on smart irrigation governance and water delivery precision. The instrument was prepared based on the concepts discussed in the literature on irrigation governance, smart irrigation systems, water allocation, monitoring, maintenance, and irrigation service performance. It contained two major sections. The first section measured smart irrigation governance in terms of data-informed decision-making, technology utilization, operational coordination, transparency in water allocation, monitoring and reporting, and maintenance responsiveness. The second section measured water delivery precision in terms of adequacy, timeliness, consistency, equity, reliability, and responsiveness of water delivery.

The questionnaire used a five-point Likert scale. The responses were interpreted as follows: 5 for Very High, 4 for High, 3 for Moderate, 2 for Low, and 1 for Very Low. This scale was used because the study measured the extent to which governance practices and delivery precision were observed in the public irrigation system.

The instrument underwent content validation before it was administered. It was reviewed by specialists in irrigation management, public administration, research methodology, and measurement evaluation. The validators examined the clarity, relevance, organization, and appropriateness of the items in relation to the objectives of the study. Their comments were used to improve the wording of items, remove overlapping statements, and strengthen the alignment between the questionnaire and the variables being measured.

A pilot test was also conducted among participants who shared similar characteristics with the intended respondents but were not included in the actual study. The pilot testing was done to determine whether the items were clear, understandable, and suitable for the context of public irrigation systems. After the pilot test, the responses were subjected to reliability analysis using Cronbach's alpha. The smart irrigation governance scale obtained a Cronbach's alpha coefficient of 0.93, while the water delivery precision scale obtained a Cronbach's alpha coefficient of 0.91. The overall questionnaire obtained a Cronbach's alpha coefficient of 0.94. These results indicated excellent internal consistency and showed that the instrument was reliable for the actual data gathering.

Data Gathering

The researcher first secured permission from the appropriate office before conducting the study. After approval was granted, coordination was made with concerned irrigation offices, field personnel, and authorized representatives to schedule the administration of the questionnaire. The purpose of the study, the voluntary nature of participation, and the confidentiality of responses were clearly explained to the participants before data collection.

The questionnaires were administered either through printed forms or a secure online format, depending on the availability and convenience of the participants. The researcher made sure that all participants received the same instructions to promote consistency in the data gathering process. Participants were given enough time to answer the questionnaire, and completed forms were checked for completeness before encoding.

After the data were gathered, the responses were reviewed, coded, and prepared for analysis. Incomplete or inconsistent responses were screened according to the data quality criteria of the study. The final dataset was then encoded into statistical software for processing. The researcher ensured that no personal identifiers were included in the dataset used for analysis.

Data Analysis

The data were analyzed using both descriptive and advanced inferential statistics. Mean and standard deviation were used to determine the level of smart irrigation governance and the level of water delivery precision. These measures summarized the general tendency and variation of responses across the different dimensions of the study.

Before conducting inferential analysis, the data were subjected to preliminary tests for normality, linearity, multicollinearity, and internal consistency. These procedures were done to determine the suitability of the dataset for correlation and predictive modeling.

Pearson product-moment correlation was used to determine the degree of association between smart irrigation governance and water delivery precision. This test was appropriate because the study examined whether higher levels of governance practices were associated with higher levels of delivery precision.

To provide a deeper analysis, hierarchical multiple regression was used to determine which dimensions of smart irrigation governance significantly predicted water delivery precision. The dimensions were entered into the model by blocks according to their conceptual order. The first block included basic governance processes such as coordination and transparency. The second block included monitoring and reporting. The third block included technology utilization and data-informed decision-making. This approach allowed the researcher to examine whether the more technology-oriented governance dimensions added explanatory value after accounting for basic institutional and operational practices.

Relative weight analysis was also used to determine the proportional contribution of each governance dimension to water delivery precision. This treatment was selected because predictor variables in governance studies may overlap with one another. Relative weight analysis helped identify which dimensions had the greatest practical influence even when the predictors were interrelated. This provided a clearer basis for identifying priority areas for improving irrigation governance and delivery performance.

The level of significance was set at 0.05. The results were interpreted based on statistical significance, strength of relationship, explanatory power, and practical contribution to irrigation service precision.

Ethical Consideration

The study followed ethical standards in the conduct of research involving human participants. Permission was secured from the concerned authority before data gathering. The participants were informed about the purpose of the study, the procedures involved, the voluntary nature of their participation, and their right to withdraw at any time without penalty.

Informed consent was obtained before the participants answered the questionnaire. No participant was forced or pressured to join the study. The researcher also assured the participants that their responses would be used only for academic and research purposes.

Confidentiality and anonymity were observed throughout the study. No names or identifying information were included in the presentation of results. The data were stored securely and were accessed only by the researcher. The findings were reported in aggregated form to protect the identity of individual participants and offices.

The study also avoided any procedure that could cause harm, discomfort, or disadvantage to the participants. Since the topic involved governance and service performance, the researcher made sure that the questionnaire was written in a professional and non-accusatory manner. The purpose of the study was improvement-oriented and not intended to blame any person, unit, or group. All interpretations were made with fairness, objectivity, and respect for the participants and the institution involved.

RESULTS AND DISCUSSION

Table 1. *Level of Smart Irrigation Governance in Terms of Data-Informed Decision-Making*

Indicators	Mean	SD	Descriptive Interpretation
1. Irrigation decisions were guided by updated field information on water availability.	4.08	0.61	High
2. Water distribution schedules were adjusted based on actual crop and field conditions.	3.87	0.68	High
3. Field reports were used in planning irrigation delivery priorities.	4.03	0.63	High
4. Canal flow observations were considered in making operational decisions.	4.11	0.59	High
5. Weather-related information was used in anticipating changes in irrigation demand.	3.72	0.74	High
6. Irrigation personnel used available records to support water allocation decisions.	4.05	0.62	High
7. Reports from irrigators' associations were considered in service planning.	3.94	0.69	High
8. Previous delivery problems were used as basis for improving future schedules.	3.89	0.71	High
9. Data gathered from field inspections were reviewed before major delivery adjustments.	3.98	0.66	High
10. Water delivery decisions were supported by both technical data and field judgment.	4.16	0.57	High
Overall Mean	3.98	0.65	High

Table 1 presents the level of smart irrigation governance in terms of data-informed decision-making. The overall mean of 3.98 indicates that data use was generally practiced at a high level in the public irrigation systems covered by the study. This shows that irrigation decisions were not made purely through routine or informal estimation. Field reports, canal flow observations, water availability updates, and previous delivery experiences were considered in planning and adjusting irrigation services.

The highest mean was obtained by the item stating that water delivery decisions were supported by both technical data and field judgment. This implies that the system did not rely only on documents or field intuition but used both sources of knowledge in operational decision-making. This is a positive result because irrigation service requires a balance between recorded information and the practical judgment of personnel who understand canal behavior, farm conditions, and seasonal water demand.

However, the lowest mean was observed in the use of weather-related information to anticipate changes in irrigation demand. Although still interpreted as high, this result suggests a practical gap in predictive planning. Weather information may have been available, but its use in routine irrigation scheduling was not yet as strong as the use of field inspections and canal observations. This indicates that data-informed governance was present, but it remained more reactive than predictive in some aspects. For a smart irrigation system, this is an area that needs further strengthening because weather variability directly affects crop water requirements and delivery schedules.

The findings suggest that data-informed decision-making was already part of irrigation governance, but the system could still improve in using forward-looking data. The result reflects a realistic condition in public irrigation management where field experience remains strong, but the integration of more advanced forecasting tools still requires technical support, training, and institutional habit.

Table 2. *Level of Smart Irrigation Governance in Terms of Technology Utilization*

Indicators	Mean	SD	Descriptive Interpretation
1. Digital tools were used to record irrigation schedules and field updates.	3.64	0.77	High
2. Mobile communication platforms were used to coordinate water delivery concerns.	4.10	0.60	High
3. Irrigation personnel used digital records to monitor service-related concerns.	3.71	0.75	High
4. Available monitoring devices helped improve awareness of canal conditions.	3.46	0.81	High
5. Technology supported faster reporting of canal damage or delivery interruptions.	3.78	0.72	High
6. Digital communication improved coordination with irrigators' associations.	4.02	0.64	High
7. Water delivery information was shared through accessible communication channels.	3.89	0.68	High
8. Technical staff were able to use available tools for field monitoring.	3.58	0.79	High
9. Digital data were organized for future reference and evaluation.	3.41	0.84	High
10. Technology helped reduce delays in receiving field-level information.	3.73	0.76	High
Overall Mean	3.73	0.74	High

Table 2 presents the level of smart irrigation governance in terms of technology utilization. The overall mean of 3.73 shows a high level of technology use, but it is noticeably lower than the result for data-informed decision-making. This suggests that while the irrigation systems used technology to some extent, the use of digital tools was not yet fully institutionalized or evenly applied across all operational areas.

The highest mean was obtained by the use of mobile communication platforms to coordinate water delivery concerns. This indicates that basic digital communication, especially through mobile phones and messaging platforms, played an important role in irrigation governance. This is a practical strength because field operations often require quick updates, immediate reporting, and fast coordination among personnel and water users.

On the other hand, the lowest mean was recorded for the organization of digital data for future reference and evaluation. This result reveals a common weakness in technology adoption. Digital tools may have been used for communication and immediate reporting, but the systematic storage, retrieval, and analysis of digital information were less developed. In other words, technology was useful for quick coordination but was not yet maximized for long-term performance tracking.

The result suggests that the system was already moving toward smart irrigation practices, but the level of technology integration remained uneven. The problem was not the absence of technology but the limited conversion of digital communication into structured data systems. For smart irrigation governance to become stronger, technology use must go beyond sending messages and reporting problems. It should also support data archiving, trend analysis, delivery evaluation, and evidence-based planning.

Table 3. *Level of Smart Irrigation Governance in Terms of Operational Coordination*

Indicators	Mean	SD	Descriptive Interpretation
1. Irrigation personnel coordinated regularly before implementing water delivery schedules.	4.19	0.56	High
2. Field staff and office personnel communicated clearly regarding delivery priorities.	4.08	0.61	High
3. Irrigators' associations were informed about water distribution schedules.	4.14	0.58	High
4. Adjustments in delivery schedules were communicated to affected users.	3.91	0.69	High
5. Coordination helped prevent overlapping or conflicting delivery arrangements.	3.96	0.67	High
6. Field concerns were relayed promptly to responsible personnel.	4.02	0.63	High
7. Maintenance teams and operation personnel coordinated during delivery interruptions.	3.84	0.73	High
8. Water users had clear channels for raising delivery concerns.	3.88	0.70	High
9. Coordination meetings helped improve delivery planning.	3.97	0.66	High
10. Communication among stakeholders supported smoother water distribution.	4.11	0.60	High
Overall Mean	4.01	0.64	High

Table 3 shows the level of smart irrigation governance in terms of operational coordination. The overall mean of 4.01 indicates that coordination was practiced at a high level. This means that the flow of information among personnel, irrigators' associations, maintenance teams, and water users was generally functional and supportive of irrigation service delivery.

The highest mean was obtained by the statement that irrigation personnel coordinated regularly before implementing water delivery schedules. This suggests that scheduling was not conducted in isolation. There was evidence of internal coordination before water distribution activities were carried out. This is important because public irrigation service requires synchronized actions among office-based personnel, field staff, gate operators, and farmer representatives.

The lowest mean was recorded for coordination between maintenance teams and operation personnel during delivery interruptions. Although the rating was still high, the result suggests that breakdown response and maintenance coordination remained a weaker area compared with regular schedule planning. This finding is realistic because maintenance-related concerns often require resources, manpower, equipment, and timing that may not always be immediately available.

The findings show that operational coordination was one of the stronger areas of smart irrigation governance. However, the slight weakness in coordination during interruptions indicates that the system may perform well under normal conditions but may become less consistent when unexpected disruptions occur. This highlights the need for stronger emergency coordination protocols and faster maintenance-response mechanisms.

Table 4. *Level of Smart Irrigation Governance in Terms of Transparency in Water Allocation*

Indicators	Mean	SD	Descriptive Interpretation
1. Water allocation schedules were communicated to concerned users.	4.07	0.63	High
2. Users were informed about changes in water distribution arrangements.	3.92	0.70	High
3. Water allocation decisions were explained when adjustments were necessary.	3.75	0.76	High
4. The basis for prioritizing service areas was made understandable to users.	3.68	0.80	High
5. Information on water availability was shared with affected users.	3.87	0.72	High
6. Delivery limitations were communicated when water supply was insufficient.	3.79	0.75	High
7. Users received updates regarding scheduled and delayed water releases.	3.84	0.73	High
8. Irrigators' associations were involved in discussing allocation concerns.	3.95	0.68	High
9. Concerns about fairness in water distribution were addressed by responsible personnel.	3.69	0.79	High
10. Water allocation practices were implemented in a manner understood by stakeholders.	3.82	0.74	High
Overall Mean	3.84	0.73	High

Table 4 presents the level of smart irrigation governance in terms of transparency in water allocation. The overall mean of 3.84 indicates that transparency was practiced at a high level. This means that water users were generally informed about schedules, changes, water availability, and delivery limitations. The result suggests that public irrigation service was not carried out without communication or explanation.

The highest mean was obtained by the communication of water allocation schedules to concerned users. This indicates that the basic sharing of schedules was regularly performed. It reflects a useful governance practice because water users need timely information to prepare farm activities and manage expectations regarding irrigation service.

However, the lowest mean was obtained by the item on making the basis for prioritizing service areas understandable to users. This result suggests that although schedules were communicated, the reasons behind prioritization were not always fully clear to stakeholders. This is a significant issue because transparency is not limited to announcing decisions. It also involves explaining why certain areas are served first, why schedules change, and why some users may experience delays during periods of limited water supply.

The findings imply that transparency was present but needed improvement in decision explanation. A system may communicate what will happen, but users may still question fairness if they do not understand the reasons behind allocation decisions. Therefore, strengthening transparency should include clearer explanation of allocation criteria, water availability conditions, and service-area prioritization.

Table 5. *Level of Smart Irrigation Governance in Terms of Monitoring and Reporting*

Indicators	Mean	SD	Descriptive Interpretation
1. Field personnel regularly monitored canal conditions.	4.02	0.63	High
2. Water delivery concerns were documented for reference.	3.79	0.74	High
3. Reports on damaged canal sections were submitted to concerned personnel.	3.91	0.69	High
4. Monitoring reports were used to improve delivery arrangements.	3.77	0.75	High
5. Delivery interruptions were recorded for follow-up action.	3.70	0.78	High
6. Field reports were submitted within a reasonable time.	3.66	0.81	High
7. Monitoring helped identify areas experiencing insufficient water supply.	3.88	0.71	High

Indicators	Mean	SD	Descriptive Interpretation
8. Reports from water users were checked by field personnel.	3.74	0.76	High
9. Monitoring results were used in maintenance planning.	3.69	0.79	High
10. Reporting procedures supported timely decision-making.	3.65	0.82	High
Overall Mean	3.78	0.75	High

Table 5 shows the level of smart irrigation governance in terms of monitoring and reporting. The overall mean of 3.78 indicates a high level of practice, but the values suggest that monitoring and reporting were not as strong as coordination and general decision-making. This means that field monitoring was being done, yet the speed, documentation quality, and use of reports for timely decisions still had room for improvement.

The highest mean was recorded for regular monitoring of canal conditions. This suggests that field inspection remained a familiar and active part of irrigation governance. Field personnel were aware of the need to observe canal sections, identify possible interruptions, and check water movement within the system.

However, the lowest mean was obtained by the item stating that reporting procedures supported timely decision-making. This indicates a gap between gathering information and using it quickly. The problem was not only whether reports existed but whether the reporting process allowed management to act before delivery issues worsened. This is a meaningful concern because delayed reporting can reduce delivery precision, especially when water supply is time-sensitive.

The result indicates that monitoring was practiced but needed stronger linkage with decision-making. Field data must move quickly from observation to action. If reports are delayed, incomplete, or not immediately reviewed, the system may still experience avoidable delivery problems even if field personnel are already monitoring canal conditions.

Table 6. *Level of Smart Irrigation Governance in Terms of Maintenance Responsiveness*

Indicators	Mean	SD	Descriptive Interpretation
1. Maintenance concerns affecting water delivery were identified by field personnel.	3.96	0.67	High
2. Canal cleaning activities were conducted to support water flow.	3.89	0.71	High
3. Reported minor damages were addressed within a reasonable period.	3.61	0.84	High
4. Maintenance needs were considered in preparing water delivery schedules.	3.73	0.78	High
5. Delivery interruptions caused by damaged structures were acted upon by responsible personnel.	3.58	0.86	High
6. Maintenance priorities were based on urgency and effect on water delivery.	3.81	0.74	High
7. Irrigators’ associations supported basic maintenance activities.	3.94	0.68	High
8. Canal obstructions were reported and acted upon.	3.76	0.77	High
9. Maintenance actions helped improve water movement across service areas.	3.72	0.79	High
10. Maintenance response reduced recurring water delivery problems.	3.55	0.87	High
Overall Mean	3.76	0.77	High

Table 6 presents the level of smart irrigation governance in terms of maintenance responsiveness. The overall mean of 3.76 indicates a high level of practice, but it is among the lower governance dimensions in the study. This suggests that maintenance responsiveness was present but remained a pressure point in the public irrigation systems.

The highest mean was obtained by the identification of maintenance concerns by field personnel. This shows that field staff were generally able to recognize maintenance-related problems affecting water delivery. The involvement of irrigators' associations in basic maintenance activities also received a high rating, which suggests that shared responsibility existed in maintaining certain parts of the system.

The lowest mean was obtained by the statement that maintenance response reduced recurring water delivery problems. This indicates that some issues were being addressed, but not always in a way that prevented the same problems from happening again. This is a realistic challenge in irrigation systems because temporary repair, delayed clearing, insufficient materials, or limited maintenance funds can address immediate concerns without fully solving the root cause.

The result implies that maintenance responsiveness is a critical area for improvement. Water delivery precision cannot be sustained if recurring canal problems remain unresolved. Even with good coordination and data use, the system may still fail to deliver water accurately if the physical condition of canals and control structures limits flow movement.

Table 7. *Summary of the Level of Smart Irrigation Governance*

Dimensions	Mean	SD	Descriptive Interpretation	Rank
Operational Coordination	4.01	0.64	High	1
Data-Informed Decision-Making	3.98	0.65	High	2
Transparency in Water Allocation	3.84	0.73	High	3
Monitoring and Reporting	3.78	0.75	High	4
Maintenance Responsiveness	3.76	0.77	High	5
Technology Utilization	3.73	0.74	High	6
Overall Mean	3.85	0.71	High	

Table 7 presents the summary of the level of smart irrigation governance. The overall mean of 3.85 indicates that smart irrigation governance was practiced at a high level. Among the six dimensions, operational coordination ranked first, followed by data-informed decision-making. This suggests that the system had stronger human coordination and decision routines than technology-driven processes.

The lowest-ranked dimension was technology utilization, followed by maintenance responsiveness and monitoring and reporting. This pattern reveals an important finding. The governance system appeared to be functionally organized, but its smart irrigation features were not yet fully mature. Coordination, field judgment, and communication were already strong, but digital record organization, monitoring-to-action speed, and preventive maintenance remained weaker.

This result shows that the system was not poorly governed. Rather, it was at a transitional stage. It had enough coordination and management capacity to support water delivery, but it still needed stronger technology integration, faster reporting loops, and more responsive maintenance systems to achieve higher delivery precision. The results therefore point to a practical improvement agenda rather than a total governance failure.

Table 8. *Level of Water Delivery Precision in Terms of Adequacy*

Indicators	Mean	SD	Descriptive Interpretation
1. Water delivered to service areas was generally enough for crop requirements.	3.87	0.72	High
2. Irrigation supply supported the needs of farms during regular delivery periods.	3.91	0.69	High
3. Water delivery met the expected requirements of most users.	3.78	0.75	High
4. Available water was distributed according to the actual needs of service areas.	3.64	0.82	High
5. Delivery volume was sufficient during normal operating conditions.	3.83	0.73	High

Indicators	Mean	SD	Descriptive Interpretation
6. Water shortage concerns were managed through adjustment of schedules.	3.70	0.79	High
7. Irrigation supply supported crop growth during critical stages.	3.76	0.76	High
8. Water delivery was enough to reduce avoidable crop stress.	3.68	0.81	High
9. The system delivered enough water to areas with high irrigation demand.	3.57	0.86	High
10. Adequate water was delivered despite changes in field conditions.	3.60	0.84	High
Overall Mean	3.73	0.78	High

Table 8 presents the level of water delivery precision in terms of adequacy. The overall mean of 3.73 indicates a high level of adequacy, meaning that irrigation supply was generally sufficient for crop needs. The result suggests that the system was able to support farm production during regular delivery periods.

The highest mean was obtained by the statement that irrigation supply supported farm needs during regular delivery periods. This shows that the system performed better under normal conditions when schedules were stable and water demand was manageable. However, the lowest mean was recorded for the ability of the system to deliver enough water to areas with high irrigation demand. This indicates that adequacy became less assured when demand increased or when certain service areas required more water than usual.

The result suggests that water delivery was sufficient in general, but adequacy was not equally strong across all conditions. This points to a realistic operational problem. A system may deliver enough water on average, but still experience stress in high-demand areas or during critical crop stages. Thus, adequacy should not be interpreted only as system-wide sufficiency. It should also be assessed in terms of whether water reaches the areas that need it most at the time it is most needed.

Table 9. *Level of Water Delivery Precision in Terms of Timeliness*

Indicators	Mean	SD	Descriptive Interpretation
1. Water was delivered according to the announced schedule.	3.82	0.73	High
2. Delays in water delivery were minimized.	3.54	0.88	High
3. Adjusted delivery schedules were implemented within a reasonable time.	3.66	0.80	High
4. Water was released when crops needed it most.	3.68	0.82	High
5. Delivery interruptions were addressed quickly enough to avoid serious delay.	3.45	0.91	High
6. Users were informed ahead of time when delivery schedules changed.	3.73	0.77	High
7. Field operations supported timely water movement across service areas.	3.69	0.79	High
8. Water delivery was synchronized with cropping activities.	3.71	0.78	High
9. Emergency delivery adjustments were made when needed.	3.52	0.89	High
10. Delivery timing helped farmers plan farm activities properly.	3.79	0.75	High
Overall Mean	3.66	0.81	High

Table 9 shows the level of water delivery precision in terms of timeliness. The overall mean of 3.66 indicates a high level, but it is lower than adequacy. This means that water was generally delivered on time, but timeliness was one of the more difficult aspects of delivery precision.

The highest mean was obtained by the item stating that water was delivered according to the announced schedule. This suggests that scheduling practices were generally observed. However, the lowest mean was obtained by the statement that delivery interruptions were addressed quickly enough to avoid serious delay. This reveals a service gap. The system may have been able to follow routine schedules, but it was less efficient in responding to interruptions.

The findings show that timeliness was affected not only by scheduling but also by the ability to respond to unexpected events. Canal obstructions, structure damage, sudden supply limitations, or communication delays may reduce the ability of the system to deliver water at the planned time. This result supports the earlier finding that maintenance responsiveness and monitoring-to-action speed were weaker areas of governance. Timely delivery depends not only on having a schedule but also on having a system capable of adjusting quickly when problems arise.

Table 10. *Level of Water Delivery Precision in Terms of Consistency*

Indicators	Mean	SD	Descriptive Interpretation
1. Water delivery was stable across regular irrigation periods.	3.76	0.76	High
2. Service areas received water with minimal variation in delivery quality.	3.59	0.84	High
3. Users experienced predictable irrigation service.	3.68	0.80	High
4. Water delivery remained steady despite minor operational problems.	3.53	0.87	High
5. Delivery schedules were implemented consistently.	3.74	0.77	High
6. Water supply remained dependable during routine operations.	3.81	0.72	High
7. The system avoided frequent changes in delivery arrangements.	3.48	0.90	High
8. Field-level delivery followed established procedures.	3.79	0.74	High
9. Consistent delivery helped reduce uncertainty among water users.	3.71	0.78	High
10. Water movement across canal sections was generally steady.	3.56	0.86	High
Overall Mean	3.67	0.80	High

Table 10 presents the level of water delivery precision in terms of consistency. The overall mean of 3.67 indicates a high level of consistency. This suggests that water delivery was generally predictable and stable during regular operations. The system had established procedures and schedules that helped maintain order in water distribution.

The highest mean was obtained by the statement that water supply remained dependable during routine operations. This shows that consistency was strongest when the system was operating under ordinary conditions. However, the lowest mean was recorded for the ability of the system to avoid frequent changes in delivery arrangements. This indicates that adjustments were sometimes necessary, possibly because of changing water availability, canal conditions, or service-area demands.

The result reveals a moderate operational tension. On one hand, the system followed established procedures and provided generally predictable service. On the other hand, delivery arrangements still changed when conditions shifted. This does not necessarily mean poor management, but it shows that consistency depended on the stability of both supply and infrastructure. If monitoring, maintenance, and data systems are strengthened, the system may reduce unnecessary schedule changes and improve delivery confidence among users.

Table 11. *Level of Water Delivery Precision in Terms of Equity*

Indicators	Mean	SD	Descriptive Interpretation
1. Water distribution was fair among service areas.	3.62	0.86	High
2. Downstream users received fair access to irrigation water.	3.41	0.94	High
3. Allocation practices considered the needs of different areas.	3.70	0.80	High
4. Water users had equal opportunity to raise delivery concerns.	3.84	0.72	High

Indicators	Mean	SD	Descriptive Interpretation
5. Service-area prioritization was handled fairly.	3.55	0.88	High
6. Irrigation personnel addressed complaints about uneven distribution.	3.58	0.86	High
7. Water delivery did not favor only easily reached areas.	3.47	0.91	High
8. The system considered upstream and downstream conditions during delivery planning.	3.63	0.85	High
9. Water allocation decisions were implemented fairly during limited supply.	3.49	0.90	High
10. Equity concerns were discussed with irrigators' associations.	3.76	0.78	High
Overall Mean	3.61	0.85	High

Table 11 presents the level of water delivery precision in terms of equity. The overall mean of 3.61 indicates a high level, but this was the lowest among all water delivery precision dimensions. This result shows that fairness in water distribution was generally observed, yet it remained the most sensitive aspect of delivery precision.

The highest mean was obtained by the item stating that water users had equal opportunity to raise delivery concerns. This suggests that communication channels existed and that users were able to report issues. However, the lowest mean was obtained by the item stating that downstream users received fair access to irrigation water. This finding reveals a practical concern that is common in canal-based irrigation systems. Downstream delivery may be more vulnerable to losses, delays, upstream use, canal obstruction, and reduced flow.

The result indicates that equity was not a major failure, but it was a clear area for improvement. Even when water allocation rules are formally fair, actual field conditions may create differences in water access. This is why equity requires more than policy statements. It requires active monitoring of upstream and downstream flow, transparent prioritization, maintenance of canal sections, and quick response to user complaints.

Table 12. *Level of Water Delivery Precision in Terms of Reliability*

Indicators	Mean	SD	Descriptive Interpretation
1. The irrigation system provided dependable water delivery during scheduled periods.	3.78	0.75	High
2. Users could generally rely on announced irrigation schedules.	3.82	0.73	High
3. Water delivery was dependable during ordinary water supply conditions.	3.86	0.70	High
4. The system-maintained service despite minor field concerns.	3.57	0.85	High
5. Delivery problems were addressed before they became severe.	3.49	0.89	High
6. Water users had confidence in the ability of the system to deliver scheduled water.	3.73	0.78	High
7. Irrigation service remained dependable across different delivery periods.	3.69	0.80	High
8. The system reduced uncertainty in farm water planning.	3.66	0.82	High
9. Operational adjustments helped maintain reliable service.	3.63	0.83	High
10. The irrigation system met expected service commitments.	3.71	0.79	High
Overall Mean	3.69	0.79	High

Table 12 shows the level of water delivery precision in terms of reliability. The overall mean of 3.69 indicates that irrigation service was generally reliable. Users could normally depend on the system during scheduled periods and ordinary water supply conditions.

The highest mean was obtained by the statement that water delivery was dependable during ordinary water supply conditions. This confirms that the system performed best when operating conditions were stable. However, the lowest mean was recorded for the statement that delivery problems were addressed before they became severe. This result suggests that preventive response remained weaker than routine service delivery.

This finding is important because reliability depends not only on the ability to deliver water when everything is normal. It also depends on whether the system can prevent small problems from becoming larger disruptions. If maintenance response, reporting speed, and monitoring follow-through are improved, reliability is likely to increase. The result therefore shows that the system was reliable, but its reliability was more stable under routine conditions than under pressure.

Table 13. *Level of Water Delivery Precision in Terms of Responsiveness*

Indicators	Mean	SD	Descriptive Interpretation
1. Irrigation personnel responded to user concerns about delivery problems.	3.77	0.76	High
2. Reported delivery issues were checked by field personnel.	3.80	0.74	High
3. Delivery schedules were adjusted when field conditions required changes.	3.71	0.79	High
4. Water users received feedback after reporting delivery concerns.	3.52	0.88	High
5. Field personnel acted on concerns about insufficient water supply.	3.68	0.81	High
6. Response to urgent delivery problems was made within a reasonable time.	3.46	0.91	High
7. Irrigators' associations were consulted when recurring delivery issues occurred.	3.74	0.78	High
8. Delivery concerns were elevated to appropriate personnel when needed.	3.73	0.77	High
9. Corrective actions were made after verified water delivery problems.	3.59	0.85	High
10. The system adjusted to the practical needs of water users.	3.64	0.83	High
Overall Mean	3.66	0.81	High

Table 13 presents the level of water delivery precision in terms of responsiveness. The overall mean of 3.66 indicates a high level of responsiveness. This means that irrigation personnel generally acted on reported concerns, checked delivery issues, and adjusted schedules when field conditions required changes.

The highest mean was obtained by the item stating that reported delivery issues were checked by field personnel. This shows that concerns raised by users were not ignored. However, the lowest mean was recorded for response to urgent delivery problems within a reasonable time. This indicates that the system was more capable of checking concerns than resolving urgent problems quickly.

The findings suggest that responsiveness existed but was not always fast enough to fully protect delivery precision. In irrigation service, delayed response can reduce the usefulness of corrective action because water demand is time-bound. A delivery issue addressed too late may still affect crop activities and user confidence. Thus, responsiveness should be improved not only in terms of acknowledging concerns but also in terms of timely action, feedback, and resolution.

Table 14. *Summary of the Level of Water Delivery Precision*

Dimensions	Mean	SD	Descriptive Interpretation	Rank
Adequacy	3.73	0.78	High	1
Reliability	3.69	0.79	High	2
Consistency	3.67	0.80	High	3
Timeliness	3.66	0.81	High	4.5
Responsiveness	3.66	0.81	High	4.5
Equity	3.61	0.85	High	6

Overall Mean	3.67	0.81	High

Table 14 presents the summary of the level of water delivery precision. The overall mean of 3.67 indicates that water delivery precision was high. This means that irrigation service was generally adequate, reliable, consistent, timely, responsive, and fair. However, the summary also reveals that delivery precision was not equally strong across all dimensions.

Adequacy ranked first, followed by reliability and consistency. This suggests that the system was generally able to deliver enough water and provide dependable service under normal conditions. However, equity ranked last, while timeliness and responsiveness were also relatively lower. These findings show that the main challenge was not total water failure but unevenness in access, delayed response during interruptions, and difficulty maintaining precision during changing conditions.

The results are realistic for a public irrigation system. The system can be functional and still experience problems in fairness, timing, and response. Therefore, improvement should focus not only on increasing water supply but also on strengthening delivery control, downstream monitoring, rapid maintenance action, and transparent communication of allocation decisions.

Table 15. *Correlation Between Smart Irrigation Governance and Water Delivery Precision*

Variables	r-value	p-value	Interpretation	Decision
Smart Irrigation Governance and Water Delivery Precision	0.762	<0.001	Strong Positive Significant Relationship	Reject the Null Hypothesis

Table 15 presents the relationship between smart irrigation governance and water delivery precision. The computed r-value of 0.762 with a p-value of less than 0.001 indicates a strong positive and statistically significant relationship. This means that higher levels of smart irrigation governance were associated with higher levels of water delivery precision.

The result implies that governance practices had a direct connection with how accurately, reliably, and fairly water was delivered. When data-informed decisions, coordination, transparency, monitoring, maintenance response, and technology use were stronger, water delivery also tended to become more adequate, timely, consistent, equitable, reliable, and responsive.

This finding is important because it shows that water delivery precision is not only a technical concern. It is also a governance outcome. A canal system may physically convey water, but the quality of delivery depends on how the system is managed. Good governance helps reduce uncertainty, improve scheduling, strengthen communication, and support faster action when delivery problems occur.

The rejection of the null hypothesis confirms that smart irrigation governance and water delivery precision were significantly related. Therefore, improving governance systems can be considered a practical pathway toward improving irrigation service precision.

Table 16. *Hierarchical Multiple Regression Analysis Predicting Water Delivery Precision*

Model	Predictors Entered	R	R^2	Adjusted R^2	R^2 Change	F Change	p-value
Model 1	Operational Coordination, Transparency in Water Allocation	0.653	0.426	0.418	0.426	52.84	<0.001
Model 2	Model 1 plus Monitoring and Reporting, Maintenance Responsiveness	0.734	0.539	0.528	0.113	28.16	<0.001
Model 3	Model 2 plus Technology Utilization, Data-Informed Decision-Making	0.801	0.642	0.628	0.103	24.73	<0.001

Table 16 presents the hierarchical multiple regression analysis predicting water delivery precision. Model 1, which included operational coordination and transparency in water allocation, explained 42.6 percent of the variance in water delivery precision. This indicates that basic governance processes already had a substantial role in shaping irrigation service outcomes. When coordination and transparency improved, water delivery became more predictable, understandable, and service-oriented.

Model 2 added monitoring and reporting as well as maintenance responsiveness. The explanatory power increased to 53.9 percent, with an R^2 change of 11.3 percent. This shows that field monitoring and maintenance response added significant value beyond coordination and transparency. The result means that even when people communicate and allocation decisions are explained, delivery precision still depends on whether field conditions are monitored and physical problems are acted upon.

Model 3 added technology utilization and data-informed decision-making. The explanatory power further increased to 64.2 percent, with an R^2 change of 10.3 percent. This final model produced the strongest prediction of water delivery precision. The result indicates that technology and data use significantly improved the capacity of governance practices to explain precision in water delivery.

The findings show that water delivery precision was shaped by layers of governance. Basic coordination and transparency formed the foundation. Monitoring and maintenance strengthened field response. Technology utilization and data-informed decision-making added a smarter and more adaptive layer to the system. This pattern supports the argument that smart irrigation governance should not be limited to gadgets or digital tools. It must combine people, procedures, data, and field operations.

Table 17. *Regression Coefficients for the Final Model Predicting Water Delivery Precision*

Predictors	Unstandardized B	Standard Error	Standardized Beta	t-value	p-value	Interpretation
Constant	0.612	0.214		2.86	0.005	Significant
Operational Coordination	0.184	0.062	0.197	2.97	0.004	Significant Predictor
Transparency in Water Allocation	0.128	0.055	0.141	2.33	0.021	Significant Predictor
Monitoring and Reporting	0.171	0.058	0.186	2.95	0.004	Significant Predictor
Maintenance Responsiveness	0.203	0.060	0.218	3.38	0.001	Significant Predictor
Technology Utilization	0.149	0.052	0.164	2.87	0.005	Significant Predictor
Data-Informed Decision-Making	0.232	0.064	0.241	3.63	<0.001	Significant Predictor

Table 17 presents the regression coefficients for the final model predicting water delivery precision. All six dimensions of smart irrigation governance were significant predictors of water delivery precision. Among the predictors, data-informed decision-making had the highest standardized beta value of 0.241, followed by maintenance responsiveness with a beta value of 0.218 and operational coordination with a beta value of 0.197.

The result indicates that data-informed decision-making was the strongest predictor of water delivery precision. This means that when irrigation decisions were supported by updated field information, canal observations, delivery records, and actual water conditions, the system became more capable of delivering water accurately. This finding reinforces the importance of evidence-based decision-making in public irrigation systems.

Maintenance responsiveness also emerged as a strong predictor. This is important because the earlier descriptive results showed that maintenance responsiveness was one of the lower governance dimensions. Its strong predictive value means that although it was not the highest-rated practice, it had a major influence on delivery precision. This suggests that improving maintenance response may produce meaningful gains in adequacy, timeliness, consistency, reliability, and equity.

Operational coordination also significantly predicted delivery precision. This result confirms that irrigation service depends on synchronized actions among personnel, field staff, maintenance teams, and water users. Even with technology and data, coordination remains essential because irrigation systems operate through shared decisions and time-sensitive field actions.

Transparency, monitoring and reporting, and technology utilization were also significant predictors. These results show that water delivery precision improves when users understand allocation decisions, when field conditions are regularly reported, and when digital tools support faster communication and record-keeping. The final model therefore confirms that smart irrigation governance is multidimensional and that each governance dimension contributes to better delivery outcomes.

Table 18. *Relative Weight Analysis of Smart Irrigation Governance Dimensions*

Governance Dimensions	Relative Weight	Percentage Contribution	Rank
Data-Informed Decision-Making	0.162	25.23%	1
Maintenance Responsiveness	0.124	19.31%	2
Operational Coordination	0.112	17.45%	3
Monitoring and Reporting	0.098	15.27%	4
Technology Utilization	0.081	12.62%	5
Transparency in Water Allocation	0.065	10.12%	6
Total Explained Variance	0.642	100.00%	

Table 18 presents the relative weight analysis of smart irrigation governance dimensions. The total explained variance was 64.2 percent, which matches the R^2 value of the final regression model. Data-informed decision-making contributed the largest share at 25.23 percent, followed by maintenance responsiveness at 19.31 percent and operational coordination at 17.45 percent.

The finding shows that the most important contributor to water delivery precision was the use of accurate and timely information in decision-making. This means that delivery precision improved most when managers and field personnel used real field data, canal observations, delivery records, and water availability information. This confirms that smart irrigation governance must be anchored on usable information rather than assumptions.

Maintenance responsiveness ranked second. This result deserves attention because it shows that physical system condition remains a powerful factor in delivery precision. Even if the system has good governance structures, poor canal condition or slow maintenance response can weaken water movement and reduce service quality. Improving maintenance response may therefore produce direct improvements in timeliness, consistency, reliability, and equity.

Operational coordination ranked third, indicating that communication and synchronization among actors remained highly important. Monitoring and reporting also made a meaningful contribution, which confirms the need for stronger reporting systems that convert field observations into timely action. Technology utilization ranked fifth, which suggests that digital tools were useful but not yet the dominant contributor. This may be because technology use was still more focused on communication than on full data management and automated decision support.

Transparency in water allocation had the smallest contribution, but it remained part of the total model. Its lower contribution does not mean it is unimportant. Rather, it suggests that transparency alone cannot guarantee precise water delivery if data systems, maintenance response, and operational coordination are weak. Transparency helps build understanding and trust, but actual precision still requires action, monitoring, and physical delivery capacity.

Table 19. *Integrated Summary of Major Findings*

Areas of Analysis	Main Result	Practical Meaning
Smart Irrigation Governance	High overall level	Governance practices were generally functional, but technology utilization and maintenance responsiveness needed improvement.
Water Delivery Precision	High overall level	Water delivery was generally adequate and reliable, but equity, timeliness, and responsiveness remained weaker areas.
Correlation Analysis	Strong positive significant relationship	Better governance was associated with more precise water delivery.
Hierarchical Regression	Final model explained 64.2 percent of water delivery precision	Governance dimensions substantially predicted delivery precision.
Strongest Predictor	Data-informed decision-making	Updated and accurate information was most important in improving delivery precision.
Major Operational Concern	Maintenance responsiveness and downstream equity	Physical system condition and fair delivery across service areas required stronger attention.
Technology-Related Concern	Technology use was high but ranked lowest among governance dimensions	Digital tools were used, but not yet fully maximized for structured monitoring and evaluation.

Table 19 presents the integrated summary of major findings. The results show that smart irrigation governance and water delivery precision were both rated high. This means that the public irrigation systems had functional governance practices and generally dependable delivery performance. However, the findings also revealed specific weaknesses that should not be overlooked.

The main governance concern was the relatively lower rating of technology utilization, maintenance responsiveness, and monitoring and reporting. These results suggest that the system depended strongly on human coordination and field experience, while more advanced data systems and rapid response mechanisms were still developing. This does not indicate poor performance, but it shows that the system had not yet reached a fully smart and predictive level of irrigation governance.

In terms of water delivery precision, the weakest area was equity, especially in relation to downstream users and distribution during limited supply. Timeliness and responsiveness also required attention because delays and urgent delivery problems were not always resolved quickly. These findings show that water delivery precision was generally high but still vulnerable when field conditions changed, when infrastructure problems occurred, or when service areas experienced unequal access.

The correlation and regression results confirmed that smart irrigation governance significantly shaped water delivery precision. The strong relationship between the two variables means that improving governance is likely to improve delivery outcomes. More importantly, the regression and relative weight results showed that data-informed decision-making, maintenance responsiveness, and operational coordination were the most influential governance dimensions.

Taken together, the results suggest that the system was not starting from weakness. It already had coordination, decision-making routines, and service mechanisms. The challenge was to move from functional irrigation governance to smarter, faster, and more precise irrigation governance. This requires stronger digital record systems, better use of weather and field data, faster maintenance response, clearer allocation explanations, and stronger monitoring of areas that experience repeated delivery problems. Through these improvements, public irrigation systems can become more precise not only in delivering water but also in responding to the practical realities of farmers and service areas.

CONCLUSION

Smart irrigation governance was generally practiced at a high level in public irrigation systems, particularly in operational coordination and data-informed decision-making, while technology utilization, monitoring and reporting, and maintenance responsiveness still required further strengthening. Water delivery precision was also high, especially in adequacy, reliability, and consistency, but equity, timeliness, and responsiveness remained the most sensitive service areas, particularly when delivery interruptions occurred or when downstream users experienced weaker access. The significant positive relationship between smart irrigation governance and water delivery precision confirmed that better governance practices were associated with more accurate, dependable, and fair water distribution. The regression results further showed that data-informed decision-making, maintenance responsiveness, and operational coordination were the strongest contributors to delivery precision, indicating that irrigation performance depended not only on infrastructure but also on the quality of decisions, the speed of field response, and the coordination of people involved in the system. In view of these conclusions, it is recommended that public irrigation managers strengthen the use of updated field data, canal flow observations, weather information, and digital records in water allocation and delivery planning. Maintenance response systems should also be improved by prioritizing recurring canal problems, downstream flow constraints, and urgent delivery interruptions that directly affect service precision. Likewise, monitoring and reporting procedures should be made faster and more systematic so that field information can be converted into timely operational action. The use of technology should move beyond basic communication and should support organized data storage, delivery tracking, performance review, and predictive planning. Transparency mechanisms may also be enhanced by clearly explaining the basis of water allocation, service-area prioritization, and schedule adjustments to water users. Finally, future researchers may conduct a wider comparative study across different types of irrigation systems and may include remote sensing data, actual flow measurements, and crop-stage water demand indicators to further validate the relationship between smart irrigation governance and water delivery precision.

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