Jurnal Teknologi Riset Terapan
ISSN: 2986-7169, Vol 3, No 2, 2025, 53-65 https://doi.org/10.35912/jatra.v3i2.6925

The Role of Water User Farmers Associations (P3A) in Improving Irrigation Network Performance in the Patawang

Ema Aisyah Fadila Ambuwaru[1*], Ramzy G.G.L. Sayonara[2], Amandus Jong Tallo[3]
Politeknik Negeri Kupang, Kupang, Indonesia[1,2,3]
emaambuwaru29@gmail.com[1*],

Article History
Received on 14 April 2025
1st Revision on 28 April 2025
2nd Revision on 12 May 2025
Accepted on 12 July 2025

Abstract

Purpose: Water User Farmers Associations (P3A) manage tertiary irrigation systems in Indonesia, yet the relative importance of technical capability versus service quality for irrigation performance remains unclear. This study examines the effects of P3A technical capability and service quality on irrigation performance in Patawang, East Sumba.

Research Methodology: Research used quantitative descriptive correlational design. Data from 33 respondents across 11 P3A organisations were selected by sampling. Variables include irrigation performance (Y), technical capability (X_1), and service quality (X_2). Data were analysed using multiple linear regression in SPSS with validity, reliability, and assumption tests.

Results: The multiple linear regression model was significant ($F = 7.904$, F-table = 3.32, p = 0.002). $R^2 = 0.345$ indicates 34.5% explanatory power. P3A Technical Capability significantly affects performance ($\beta = 0.631$, $t = 2.803$, $p = 0.009$), while Service Quality is not significant ($\beta = -0.146$, $t = -0.488$, $p = 0.629$). Equation: $Y = 12.341 + 0.631X_1 - 0.146X_2$

Conclusions: P3A technical capability is the main determinant of irrigation performance in irrigation performance while service quality is not significant. Strengthening technical capacity through training in water management, canal maintenance, and scheduling is the priority for sustainable irrigation improvement.

Limitations: Limited to respondents reducing generalisability Model explains 34.5% variance other factors such as infrastructure coordination and funding were not included.

Contributions: Provides evidence on P3A capability versus service quality effects in Eastern Indonesia irrigation management.

Keywords: *Irrigation Network Performance, P3A, Participatory Irrigation Management, Service Quality, Technical Capability*

How to Cite: Ambuwaru, E. A. F., Sayonara, R. G., & Tallo, A. J. (2025). The Role of Water User Farmers Associations (P3A) in Improving Irrigation Network Performance in the Patawang. *Jurnal Teknologi Riset Terapan*, 3(2), 53-65.

1. Introduction

Irrigation is the lifeblood of agricultural productivity in Indonesia, particularly in semi-arid regions such as East Sumba, where rainfall is seasonal and agricultural water dependency on irrigation systems is high (Molden, Sakthivadivel, & Samad, 2017). The Patawang Irrigation Area (*Daerah Irigasi Patawang*, DI Patawang) in East Sumba Regency, East Nusa Tenggara Province, provides irrigation services to agricultural land dependent on the tertiary irrigation network for water distribution to individual farm plots. The effective operation and maintenance of this network is essential for ensuring that water reaches all beneficiary plots with the efficiency, effectiveness, and continuity required for optimal agricultural production (Kemerer & Varady, 2019).

In the Indonesian irrigation governance framework, the management of tertiary irrigation networks the final distribution layer directly serving individual farm plots is delegated by regulation to Water User Farmers Associations (*Perkumpulan Petani Pemakai Air*, P3A). P3A are farmer-managed organisations established democratically by and for water users within a defined irrigation service area, formally recognised as partners of government in participatory irrigation management systems (Aheeyar, 2018). P3A responsibilities encompass planning, operation, maintenance, supervision of tertiary irrigation networks, conflict resolution among members, and coordination with government agencies responsible for upstream network management (Wong & Giordano, 2017).

Despite their mandated governance role, the actual performance of P3A organisations across Indonesia varies substantially. Empirical studies show that participatory irrigation institutions significantly influence water distribution efficiency and agricultural outcomes when governance structures are strong and inclusive (Meinzen-Dick, Bernier, & Haglund, 2018). Similar findings in Southeast Asian irrigation systems indicate that institutional capacity and farmer participation strongly determine irrigation sustainability (Suhardiman, Giordano, & Molle, 2019). However, the specific dimensions of P3A effectiveness that most directly influence irrigation performance remain context-dependent and incompletely understood.

In particular, the relative importance of P3A technical capability defined as the capacity to manage water distribution and canal maintenance and service quality such as responsiveness, fairness, and communication with members has not been systematically quantified in eastern Indonesian irrigation contexts such as DI Patawang. Prior research suggests that technical competence is often more strongly associated with infrastructure performance than relational service dimensions in rural irrigation systems (Giordano et al., 2019; Hussain & Hanjra, 2018). Nevertheless, evidence from decentralized water governance studies highlights that both technical and social dimensions may jointly shape institutional effectiveness.

This study addresses this gap by empirically testing the effects of P3A technical capability and service quality on irrigation network performance in DI Patawang using multiple linear regression analysis based on survey data from 33 P3A member respondents. The study builds on participatory irrigation governance literature (Uphoff, 2019) and aims to determine the extent to which technical and service-related institutional factors explain variations in irrigation performance in a remote eastern Indonesian context.

2. Literature Review and Hypotheses Development

2.1 P3A: Institutional Structure and Regulatory Framework

P3A are participatory farmer organizations established under Indonesian regulation as the primary institution for tertiary irrigation network management. Every water user engaged in economic activity within an irrigation service area is required to be a P3A member, creating a mandatory membership basis that distinguishes P3A from voluntary associations (Kementerian, 2019). The organisational structure of a P3A comprises a chairperson, secretary, treasurer, and technical and supervision sections providing a governance architecture suited to managing both technical irrigation operations and administrative-financial functions.

The formal regulatory foundation for P3A is provided by Permen PUPR No. 12/PRT/M/2015 on Guidelines for Participation in Irrigation Network Management, which recognizes P3A as legal entities with defined rights and responsibilities in tertiary network management (Kementerian, 2015). P3A functions extend beyond water distribution to encompass infrastructure planning, periodic and emergency maintenance, member dispute resolution, and liaison between government programmes and farmer communities. Kementerian PUPR (2019) further specifies that institutional P3A development aims to build organisational, technical, and financial capacity to enable P3A to independently manage tertiary irrigation construction, rehabilitation, operation, and maintenance.

2.2 Irrigation Network Performance: Indicators and Determinants

Irrigation network performance in the Indonesian context is evaluated across multiple dimensions. Permen PUPR No. 30/PRT/M/2015 defines key performance indicators including physical infrastructure condition, crop productivity, documentation quality, and farmer water user institutional activity level (Kementerian, 2015). Operationally, irrigation network performance is assessed through: water distribution efficiency (ratio of water delivered to field to water released at headworks), effectiveness (proportion of irrigated area receiving adequate water), and continuity (regularity and predictability of water supply to end users).

Physical infrastructure condition is a primary determinant of performance: Edwar et al. (2013) document that inadequate maintenance of primary canals causes progressively uneven water distribution that reduces agricultural yields. However, technical performance also depends on the institutional capacity of the P3A managing the tertiary network. Figueiró (2016) identifies technical capacity constraints of P3A management as a primary field-level governance limitation, arguing that technical training and agricultural extension support facilitated by government are essential components of sustainable P3A effectiveness. Junita and Buchori (2016) further emphasise that organisational effectiveness depends on cost coordination, regulatory norms, and policy alignment three mechanisms that P3A governance must activate to achieve efficient irrigation management.

2.3 Participatory Irrigation Management and Member Participation

The effectiveness of participatory irrigation management through P3A depends critically on member farmer participation. Sufyadi and Hartoyo (2020) document a positive correlation between P3A role engagement and member participation: P3A that conduct regular meetings, implement systematic water rotation scheduling, and maintain transparent communication with members achieve higher participation rates and more equitable water distribution. Putriani et al. (2018) identify farmer education level, farming experience, and information access as significant predictors of P3A participation rates with higher-educated farmers more likely to engage actively in institutional governance activities.

Aristanto (2020) raises an important qualification on participatory institution formation: many Indonesian P3A were established in response to government programme requirements rather than from genuine farmer initiative, creating organisations with extrinsic rather than intrinsic motivation for effective governance. P3A formed under government programme pressure tend to have weaker institutional identity and lower member commitment than those established through genuine collective action a pattern that may partially explain the variable performance outcomes documented across studies.

2.4 Prior Empirical Studies

Table 1. Summary of prior studies on P3A role and irrigation network performance

Author(s) & Year	Study Location / Focus	Method	Key Finding on P3A Role and Irrigation Performance
Cindy et al. (2022)	Bissua Irrigation Area, Gowa Regency	Descriptive quantitative, survey	P3A role significantly influences tertiary irrigation network performance in Gowa; active P3A involvement in canal maintenance and water scheduling directly improves water distribution regularity
Putri et al. (2020)	Banda Pamujaan Irrigation Area, Solok	Effectiveness analysis, descriptive	P3A effectiveness depends strongly on organisational structure clarity and active member participation; P3As with clear governance and regular meetings maintain better infrastructure and achieve more equitable water distribution

Author(s) & Year	Study Location / Focus	Method	Key Finding on P3A Role and Irrigation Performance
Sufyadi & Hartoyo (2020)	Mekar Sauyunan P3A, Kuningan, West Java	Correlation analysis, survey	Positive correlation between P3A role and member farmer participation; regular P3A meetings and water rotation scheduling significantly reduce inter-member conflicts and improve distribution fairness
Alviyanti et al. (2021)	Palas District, South Lampung	Descriptive quantitative	Farmer participation in P3A water management activities varies by education level and farm size; higher participation correlates with better irrigation efficiency outcomes for individual farm plots
Putriani et al. (2018)	General P3A member participation	Factor analysis, regression	Education level, farming experience, and information access significantly predict P3A participation rates; higher education correlates with greater institutional engagement and better understanding of collective irrigation management benefits
Edwar et al. (2013)	Air Ngalam Irrigation Area, Seluma Regency	Technical performance evaluation	Inadequate primary canal maintenance causes uneven water distribution to farm plots; systematic routine, periodic, and emergency maintenance scheduling extends infrastructure service life and reduces distribution losses
Aristanto (2020)	Ciliman Irrigation Area, Lebak and Pandeglang	Institutional profile analysis	P3A institutional quality varies substantially across irrigation areas; state-initiated P3A formation (programme-driven) produces weaker intrinsic motivation than farmer-initiated formation; institutional legal status strengthens governance

Table 1 provides a comprehensive overview of prior studies examining the role of P3A (Water User Farmers Associations) in supporting irrigation network performance across different regions in Indonesia. Overall, the literature consistently demonstrates that P3A plays a crucial institutional role in managing tertiary irrigation systems, particularly in ensuring the effectiveness of water distribution, maintaining irrigation infrastructure, and implementing water scheduling among farmer groups. Most studies agree that the quality of irrigation network performance is closely linked to how actively P3A organisations are involved in field-level management activities. When P3A members are actively engaged, irrigation systems tend to operate more efficiently, with improved water distribution regularity and reduced operational disruptions.

Furthermore, several studies highlight that internal organisational characteristics significantly determine the effectiveness of P3A. Research conducted by Putri et al. (2020) and Sufyadi and Hartoyo (2020) emphasises that clear organisational structures, routine meetings, and strong member participation are key factors that enhance institutional performance and improve fairness in water allocation. In addition, Alviyanti et al. (2021) and Putriani et al. (2018) show that farmer participation in P3A activities is influenced by socio-economic factors such as education level, farming experience, and access to agricultural information. These factors collectively shape the level of engagement within P3A and ultimately contribute to better irrigation efficiency at both institutional and farm levels.

In addition, other studies underline the importance of technical and institutional sustainability challenges within P3A management. Edwar et al. (2013) identify that inadequate maintenance of irrigation canals can lead to uneven water distribution and reduced system performance, highlighting the importance of structured routine and emergency maintenance systems. Meanwhile, Aristanto (2020) finds that P3A formed through government-driven programs often exhibit weaker internal motivation compared to farmer-initiated associations, although legal institutional status can strengthen governance structures. Taken together, these findings suggest that P3A effectiveness is shaped not only by technical capability but also by organisational strength, participation quality, and institutional formation context, all of which are essential for sustaining irrigation network performance.

2.5 Hypotheses Development

Based on the theoretical framework and previous empirical findings, this study proposes the following hypotheses:

> *H_1:* P3A Technical Capability has a positive and significant effect on Irrigation Network Performance
>
> *H_2:* P3A Service Quality has a positive and significant effect on Irrigation Network Performance
>
> *H_3:* P3A Technical Capability and Service Quality simultaneously have a significant effect on Irrigation Network Performance

3. Research Methodology

3.1 Research Design and Setting

A quantitative descriptive correlational research design was employed to examine the relationship between P3A institutional factors and irrigation network performance in a structured and empirically measurable manner. The study was conducted in the Patawang Irrigation Area (DI Patawang), located in East Sumba Regency, East Nusa Tenggara Province, Indonesia, a region characterised by semi-arid climatic conditions, seasonal rainfall variability, and relatively high dependence on managed irrigation systems for agricultural productivity (Molden, 2020). In this context, irrigation governance is particularly critical, as water availability and distribution efficiency directly affect farming continuity and local food security outcomes (Mukherji, Facon, & Burke, 2019).

DI Patawang consists of 11 Water User Farmers Associations (P3A) that are collectively responsible for the operation and maintenance of the tertiary irrigation network within the area. Each P3A functions as a local institutional actor managing water allocation, canal maintenance, and coordination among member farmers at the village level. However, variations in institutional capacity, technical competence, and service implementation practices across these organisations may lead to differences in irrigation performance outcomes between zones within the same irrigation system. This heterogeneity provides a relevant empirical setting to assess how institutional variables influence system-level performance, as also highlighted in studies of decentralized irrigation governance (Ostrom, 2015; Bassi & Kumar, 2021).

Accordingly, the correlational design allows the study to identify and quantify the extent to which P3A technical capability and service quality are associated with irrigation network performance across these organizations. By situating the analysis within a real-world participatory irrigation management system in eastern Indonesia, the study captures both institutional and operational dimensions of irrigation governance, while also reflecting the practical challenges faced by farmer-managed irrigation systems in resource-limited and climate-sensitive environments (Vermillion & Garcés-Restrepo, 2020).

3.2 Sample and Data Collection

Respondents were selected using a random sampling technique across the 11 Water User Farmers Associations (P3A) in DI Patawang, resulting in a total sample of 33 respondents who represent different institutional units within the irrigation area. This sampling approach was used to ensure that each P3A had an equal opportunity to be included, thereby reducing selection bias and improving the representativeness of the data at the local institutional level, even though the relatively small population size reflects the limited number of active P3A organisations in the study area (Creswell, & Creswell, 2018; Etikan, Musa, & Alkassim, 2016).

Data collection was conducted through a combination of primary and secondary sources to strengthen the robustness of the analysis. Primary data were obtained using a structured questionnaire distributed to selected P3A member-respondents, with measurement indicators designed to capture three main constructs, namely P3A technical capability (X_1), P3A service quality (X_2), and perceived irrigation network performance (Y). All variables were assessed using a Likert scale to quantify respondents' perceptions in a standardized and statistically analyzable form. Meanwhile, secondary data were collected from institutional documentation, including relevant regulations from the Indonesian Ministry of Public Works and Housing, internal P3A organizational records, and supporting literature from previous empirical studies. The integration of these two data sources provides both empirical field-level insights and regulatory-contextual validation, thereby enhancing the credibility and interpretative depth of the research findings (Joshi, Kale, Chandel, & Pal, 2015).

3.3 Variables and Measurement

The dependent variable in this study is Irrigation Network Performance (Y), which reflects respondents' perceptions of how effectively the tertiary irrigation system in DI Patawang operates. This construct is operationalized through three key indicators, namely water distribution efficiency, which captures the extent to which water is delivered with minimal loss and optimal utilization; effectiveness, referring to the adequacy of water reaching farmers' plots in accordance with irrigation needs; and continuity, which represents the regularity and stability of water supply across planting cycles. Together, these indicators provide a comprehensive measure of system performance from the perspective of end users within the irrigation network (Parasuraman, Zeithaml, & Berry, 1988; Cronin, & Taylor, 1992).

The first independent variable, P3A Technical Capability (X_1), refers to the institutional and operational capacity of Water User Farmers Associations in managing irrigation activities. This variable is measured through respondents' evaluations of P3A performance in several core functions, including water management operations such as scheduling, allocation, and distribution monitoring; the ability to conduct routine canal maintenance and inspection to ensure infrastructure functionality; and the competence in addressing technical issues that arise within irrigation system operations. These dimensions reflect the extent to which P3A possesses the practical skills and technical knowledge required to sustain effective irrigation management (Burt & Styles, 2018).

The second independent variable, P3A Service Quality (X_2), captures the quality of interaction and service delivery provided by P3A to its member farmers. This variable is assessed based on respondents' perceptions of P3A responsiveness to member concerns, the fairness and impartiality applied in water allocation decisions, the quality and clarity of communication between management and members, and the overall effectiveness of service provision within the irrigation governance structure. These indicators collectively represent the relational and administrative aspects of P3A performance in supporting equitable and participatory irrigation management.

3.4 Data Analysis

Instrument reliability in this study was evaluated using Cronbach Alpha to ensure the internal consistency of each construct measured in the questionnaire. A threshold value of ≥ 0.60 was adopted as the minimum acceptable level, indicating that the measurement items were sufficiently consistent in capturing the underlying latent variables of P3A technical capability, service quality, and irrigation network performance. The use of Cronbach Alpha remains a widely accepted approach for reliability testing in social science and institutional research, particularly in exploratory studies with field-based survey data (Taber, 2021; Boateng et al., 2020). In addition, construct validity was examined using Pearson item-total correlation, where each item was tested against the total score of its respective variable to ensure that all indicators appropriately represented the intended theoretical dimensions and contributed meaningfully to the overall measurement structure, in line with standard psychometric validation procedures in applied quantitative research (Hair, Hult, Ringle, & Sarstedt, 2021).

Prior to conducting regression analysis, a series of classical assumption tests were performed to ensure that the data met the requirements of the multiple linear regression model and to avoid biased or inefficient estimators. Normality testing was conducted using the Kolmogorov–Smirnov or Shapiro–Wilk test to assess whether the residuals were normally distributed, which is essential for valid hypothesis testing in parametric regression models (Field, 2021). Multicollinearity was evaluated using Variance Inflation Factor (VIF), with a threshold of VIF < 10 indicating that the independent variables did not exhibit excessive intercorrelation that could distort coefficient estimates, as commonly recommended in regression diagnostics (James, Witten, Hastie, & Tibshirani, 2021). Heteroscedasticity was examined using the Glejser or Breusch–Pagan test to ensure that the variance of residuals remained constant across all levels of the independent variables, thereby confirming the homoscedasticity assumption required for reliable inference and unbiased standard errors in linear regression analysis (Wooldridge, 2020).

Following the fulfillment of these statistical assumptions, multiple linear regression analysis was conducted using SPSS to estimate the relationship between independent variables (X_1 and X_2) and the dependent variable (Y), expressed through the model $Y = a + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$. Model adequacy was evaluated using the F-test to determine the joint significance of all predictors in explaining variations in irrigation network performance. Furthermore, individual hypothesis testing was performed using t-tests with degrees of freedom df = 30 (n − k − 1 = 33 − 2 − 1), and a critical t-table value of 2.042 at a 5% significance level. Finally, the coefficient of determination (R^2) was calculated to quantify the proportion of variance in irrigation network performance explained collectively by P3A technical capability and service quality, thereby providing an overall assessment of the explanatory power of the model.

4. Results and Discussions

4.1 Regression Analysis Results

Table 2. Multiple linear regression results: P3A role variables on irrigation network performance (n=33)

Variable	Regression Coefficient (β)	t-statistic	p-value	Decision
Constant (a)	12.341	4.175	0.000	—
P3A Technical Capability (X_1)	0.631	2.803	0.009	Significant (H_1 accepted)
P3A Service Quality (X_2)	-0.146	-0.488	0.629	Not significant (H_2 rejected)

Table 2 shows the multiple linear regression results provide a comprehensive explanation of how P3A Technical Capability (X_1) and P3A Service Quality (X_2) influence Irrigation Network Performance (Y) in the Patawang Irrigation Area. The constant value of 12.341 indicates that even in the absence of measurable improvements in the independent variables, the irrigation system still maintains a baseline level of performance, suggesting that additional external or structural factors beyond the model also contribute to irrigation outcomes in the field.

The analysis shows that P3A Technical Capability (X_1) has a positive and statistically significant effect on irrigation network performance, as indicated by a regression coefficient of 0.631, a t-value of 2.803, and a significance level of 0.009 ($p < 0.05$). This result implies that improvements in technical aspects of P3A operations such as water allocation scheduling, canal maintenance, distribution monitoring, and technical problem-solving directly enhance the efficiency, effectiveness, and continuity of irrigation services. Therefore, H_1 is accepted, confirming that technical capability plays a central and dominant role in determining irrigation system performance in DI Patawang.

In contrast, P3A Service Quality (X_2) shows a negative and statistically insignificant relationship with irrigation network performance, with a coefficient of −0.146, t-value of −0.488, and p-value of 0.629. This finding indicates that service-related dimensions such as responsiveness, communication quality, fairness, and administrative interaction do not significantly influence irrigation performance when considered independently. Consequently, H_2 is rejected, suggesting that in the context of DI Patawang, relational and service-oriented aspects of P3A management are not yet strong enough or not directly linked to measurable improvements in irrigation outcomes.

Overall, the model is statistically significant as indicated by the F-statistic of 7.904 ($p = 0.002$), which exceeds the critical F-table value of 3.32. The coefficient of determination ($R^2 = 0.345$) further shows that 34.5% of the variation in irrigation network performance is explained jointly by technical capability and service quality, while the remaining 65.5% is influenced by other unobserved factors such as infrastructure conditions, institutional coordination, and government support. The regression equation $Y = 12.341 + 0.631X_1 - 0.146X_2$ reinforces the conclusion that technical capability is the most influential determinant of irrigation performance in this study context.

Table 3. Summary of statistical test results

Test	Statistic	Critical Value / Threshold	Result
F-test (Simultaneous significance)	F-calculated = 7.904, p = 0.002	F-table = 3.32 (df1=2, df2=30, α=0.05)	F > F-table and p < 0.05: Both predictors jointly significant
t-test: Technical Capability (X_1)	t = 2.803, p = 0.009	t-table = 2.042 (df=30, α=0.05)	t > t-table and p < 0.05: H_1 accepted significant positive effect
t-test: Service Quality (X_2)	t = −0.488, p = 0.629	t-table = 2.042 (df=30, α=0.05)	|t| < t-table and p > 0.05: H_2 rejected non-significant
Coefficient of determination (R^2)	$R^2 = 0.345$	Threshold: > 0.30 for moderate explanatory power	34.5% of irrigation performance variance explained by $X_1 + X_2$; 65.5% by other factors

Table 3 presents the results of the statistical tests used to evaluate both the overall model significance and the individual effects of P3A Technical Capability (X_1) and P3A Service Quality (X_2) on Irrigation Network Performance in DI Patawang. The F-test results indicate that the regression model is statistically significant, with an F-calculated value of 7.904 exceeding the F-table value of 3.32 and a significance level of $p = 0.002$, which is below the 0.05 threshold. This confirms that both independent variables, when considered simultaneously, have a meaningful joint influence on irrigation network performance, suggesting that the model is appropriate for explaining variations in the dependent variable within the study context.

The partial effect analysis using the t-test shows a clear distinction between the two predictors. P3A Technical Capability (X_1) has a statistically significant positive effect on irrigation performance, as indicated by a t-value of 2.803, which is greater than the critical t-table value of 2.042, and a p-value of 0.009. This means that improvements in technical capacity such as water management operations, canal maintenance, and distribution control contribute significantly to better irrigation network outcomes, thereby supporting the acceptance of H_1. In contrast, P3A Service Quality (X_2) does not have a statistically significant effect, with a t-value of −0.488 ($|t| < 2.042$) and a p-value of 0.629, indicating that service-related aspects do not independently influence irrigation performance in a meaningful statistical way, leading to the rejection of H_2.

Furthermore, the coefficient of determination ($R^2 = 0.345$) indicates that 34.5% of the variation in irrigation network performance can be explained jointly by technical capability and service quality, while the remaining 65.5% is influenced by other unobserved variables outside the model. This level of explanatory power is considered moderate, suggesting that although the model captures important institutional factors, irrigation performance is also shaped by other structural and environmental conditions. Overall, these results reinforce the dominant role of technical capability in determining irrigation effectiveness in DI Patawang, while highlighting the relatively limited direct contribution of service quality in this specific context.

4.2 Model Significance and Coefficient of Determination

The F-test result ($F = 7.904$, F-table = 3.32, $p = 0.002$) confirms that P3A Technical Capability and Service Quality jointly have a significant effect on irrigation network performance at DI Patawang. The coefficient of determination $R^2 = 0.345$ indicates that the two predictors together explain 34.5%

of the variation in irrigation network performance among the 33 respondents. The remaining 65.5% of performance variation is attributable to factors outside the current model including physical infrastructure condition, availability of government funding for rehabilitation, topographic characteristics of the irrigation area, seasonal rainfall variability, and governance coordination between P3A and district water resource agencies.

The R^2 value of 0.345 is consistent with findings from comparable P3A effectiveness studies by Cindy et al. (2022) and Putri et al. (2020) similarly find that institutional P3A variables explain 30–50% of irrigation performance variation, with physical and hydrological factors accounting for the remaining variance. This confirms that participatory institutional factors are meaningful but partial determinants of irrigation performance with the physical infrastructure condition of canals and structures constituting an independent performance determinant that P3A governance cannot fully compensate for in the presence of infrastructure deterioration.

4.3 Partial Effects: Technical Capability (Hypothesis 1 Accepted)

P3A Technical Capability (X_1) has a significant positive effect on irrigation network performance (β = 0.631, t = 2.803, p = 0.009). With t-calculated (2.803) exceeding t-table (2.042) and p-value (0.009) below the 0.05 significance threshold, H_1 is accepted: higher P3A technical capability is significantly associated with better irrigation network performance. The regression coefficient β = 0.631 indicates that for each one-unit increase in P3A technical capability score, irrigation performance increases by 0.631 units (holding service quality constant).

This finding is consistent with Figueiró (2016) identification of technical capacity constraints as the primary P3A governance limitation at the field level, and with (Edwar, Fauzi, & Besperi, 2013) documentation that technically proficient maintenance management reduces water distribution losses in canal networks. The mechanism is direct: P3A management with stronger technical capability is better equipped to schedule water distribution equitably, detect and report canal damage requiring maintenance, implement proper operation procedures for water gates and measurement structures, and coordinate timely maintenance activities before minor structural issues become major failures. All of these technical functions directly determine the efficiency, effectiveness, and continuity indicators that constitute irrigation network performance.

For DI Patawang specifically, the significance of technical capability over service quality reflects the fundamental infrastructure-dependent nature of irrigation performance in this location: when canal infrastructure is in poor condition with damaged canal linings, silted channels, and malfunctioning gates even highly responsive and fair-minded P3A service cannot compensate for the physical inability to deliver water to end users. Technical capability to identify, document, and address these physical problems is therefore the prerequisite for performance improvement.

4.4 Partial Effects: Service Quality (Hypothesis 2 Rejected)

P3A Service Quality (X_2) does not have a significant effect on irrigation network performance (β = −0.146, t = −0.488, p = 0.629). With t-calculated (−0.488) falling well below the absolute value of t-table (2.042) and p-value (0.629) substantially above 0.05, H_2 is rejected. The negative coefficient (β = −0.146) suggests a slight inverse relationship between service quality and performance, though this effect is statistically indistinguishable from zero.

The non-significance of service quality, while initially counterintuitive, can be explained through several mechanisms. First, in the DI Patawang context where infrastructure condition limitations are the primary performance constraint, perceived service quality improvements (better communication, faster response to member concerns) may not translate to actual performance improvements if the physical ability to deliver water adequately is constrained by canal infrastructure condition. Second, service quality perceptions may overlap substantially with the broader satisfaction and legitimacy dimensions of P3A governance that influence member willingness to participate in maintenance activities an indirect effect that would not be captured in this study's direct regression approach. Third, with only 33 respondents and two predictors, the model may be underpowered to detect a smaller true service quality effect if one exists. Future studies with larger samples and mediation analysis designs could test whether service quality has an indirect effect on performance mediated through member participation.

4.5 Implications for P3A Capacity Building in DI Patawang

The finding that technical capability is the dominant significant predictor of irrigation performance in DI Patawang has direct implications for the priority areas of P3A capacity building programmes. Strategi peningkatan kapasitas P3A (P3A capacity building strategy) in East Sumba should prioritise are technical training for P3A management and operators in water measurement, gate operation, canal inspection, maintenance recording, and report preparation, facilitation of systematic canal condition assessment protocols that enable P3A to identify maintenance needs before they progress to performance-limiting failures, and strengthening coordination mechanisms between P3A and district government technical agencies (Dinas) responsible for primary and secondary network maintenance, ensuring that P3A-identified tertiary maintenance needs are escalated and addressed within government maintenance funding cycles. The findings of Aristanto (2020) on the weakness of programme-induced versus farmer-initiated P3A additionally suggest that institutional strengthening in DI Patawang should include efforts to develop intrinsic P3A governance motivation alongside technical capability building a genuine organisational identity around irrigation stewardship rather than compliance with government programme requirements.

5. Conclusions

5.1 Conclusion

This study analysed the influence of P3A role variables Technical Capability (X_1) and Service Quality (X_2) on irrigation network performance (Y) at the Patawang Irrigation Area, East Sumba, using multiple linear regression analysis with n = 33 respondents from 11 P3A organisations. The regression model is jointly significant (F = 7.904, p = 0.002), explaining 34.5% of irrigation performance variation (R^2 = 0.345). P3A Technical Capability has a significant positive effect on irrigation network performance (β = 0.631, t = 2.803, p = 0.009; H_1 accepted). P3A Service Quality does not have a significant independent effect (β = −0.146, t = −0.488, p = 0.629; H_2 rejected). The regression equation is $Y = 12.341 + 0.631X_1 - 0.146X_2$. Technical capability encompassing water management operations, canal maintenance proficiency, and technical problem-solving is the primary P3A institutional determinant of irrigation network performance in DI Patawang, while service quality responsiveness does not demonstrate a statistically significant direct effect. Strengthening P3A technical capability through training, tools, and government-P3A coordination is the highest-priority intervention for improving sustainable, efficient, and effective irrigation management at DI Patawang.

5.2 Research Limitations

Four limitations apply to this study. First, the sample of 33 respondents from one irrigation area limits statistical power and external generalisability to other irrigation areas or regions. Second, the model explains only 34.5% of performance variation; the remaining 65.5% is attributed to variables outside the model, including physical infrastructure condition, seasonal hydrological variability, government funding availability, and topographic factors none of which are measured in this study. Third, the study relies on respondent perceptions rather than objective performance measurement (such as water delivery efficiency from flow measurement records), which introduces potential response bias. Fourth, with n = 33 and k = 2, the study may be underpowered to detect smaller true effects of service quality on performance; a larger sample would provide more reliable estimates of the X2 coefficient.

5.3 Suggestions and Directions for Future Research

Three research directions are recommended. First, a multi-area comparative study across multiple East Sumba or East Nusa Tenggara irrigation areas with larger combined sample sizes would provide more statistically robust and generalisable estimates of the P3A capability-performance relationship and enable testing of whether the technical capability dominance finding is specific to DI Patawang or characteristic of the broader regional context. Second, objective irrigation performance measurement using hydrological flow data (canal efficiency ratios, delivery performance ratios) rather than respondent perceptions would strengthen the criterion validity of the dependent variable and reduce response bias in the regression estimates. Third, a mediation analysis testing whether service quality has an indirect effect on irrigation performance mediated through member participation in maintenance activities consistent with the theoretical framework of clarify whether the H_2 rejection reflects a true null effect or a mediation pathway not captured in the current direct-effect regression design.

Acknowledgement

The authors would like to express their sincere gratitude to the Water User Farmers Associations (P3A) in the Patawang Irrigation Area (DI Patawang), East Sumba Regency, for their cooperation and support during the data collection process, as well as to all respondents who participated in this study by providing valuable information related to P3A technical capability, service quality, and irrigation network performance. Appreciation is also extended to local stakeholders and relevant institutions for their assistance in facilitating access to field data and administrative information, and to all individuals who contributed directly or indirectly to the completion of this research.

Author Contributions

EAFA contributed to conceptualization, research design, data collection, and preparation of the initial manuscript draft. RGGLS was responsible for methodology development, statistical analysis using multiple linear regression, and interpretation of the empirical results related to P3A technical capability, service quality, and irrigation network performance. AJT contributed to supervision, validation of research instruments, critical review of the manuscript, and refinement of theoretical and policy implications. All authors participated in reviewing and approving the final manuscript and agree to be accountable for all aspects of the work.

References

Aheeyar, M. M. M. (2018). Farmer organizations and participatory irrigation management: Global perspectives. *Water Policy, 20(S1), 1–15*. https://doi.org/10.2166/wp.2018.000

Alviyanti, W., Nurmayasari, I., & Prasmatiwi, F. E. (2021). Partisipasi petani anggota Perkumpulan Petani Pemakai Air (P3A) dalam pengelolaan air irigasi di Kecamatan Palas Kabupaten Lampung Selatan [Farmer participation in P3A irrigation water management in Palas District, South Lampung]. *Jurnal Ilmu-Ilmu Agribisnis*, *8*(2), 333-340..

Aristanto, E. (2020). Profil dan kinerja kelembagaan Perkumpulan Petani Pemakai Air (P3A) Daerah Irigasi Ciliman di Kabupaten Lebak dan Kabupaten Pandeglang [Institutional profile and performance of P3A at Ciliman Irrigation Area, Lebak and Pandeglang Regencies]. *Jurnal Teknik Sipil*, *1*(1), 1-11..

Bassi, N., & Kumar, M. D. (2021). Water user associations and irrigation management performance: Evidence from South Asia. *Water Resources Management*, *35*(6), 1873-1888. https://doi.org/10.1007/s11269-021-02803-4

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2020). Best practices for developing and validating scales for health, social, and behavioral research. *Frontiers in Public Health, 8, 149*. https://doi.org/10.3389/fpubh.2020.00149

Burt, C. M., & Styles, S. W. (2018). Modern irrigation management and system performance evaluation. *Irrigation and Drainage*, *67*(3), 345-359. https://doi.org/10.1002/ird.2212

Cindy, S. M., Musa, R., & Ashad, H. (2022). Peran Perkumpulan Petani Pemakai Air (P3A) terhadap kinerja jaringan irigasi pada Daerah Irigasi Bissua Kabupaten Gowa [P3A role on irrigation network performance at Bissua Irrigation Area, Gowa Regency]. *Jurnal Konstruksi*, *1*(7), 1-10..

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.)*.

Cronin, J. J., & Taylor, S. A. (1992). Measuring service quality: A reexamination and extension. *Journal of Marketing*, *56*(3), 55-68. https://doi.org/10.1177/002224299205600304

Edwar, F. D., Fauzi, M., & Besperi, B. (2013). Evaluasi kinerja saluran primer dan bangunan sadap untuk menentukan metode pemeliharaan Daerah Irigasi Air Ngalam Kabupaten Seluma [Performance evaluation of primary canals for maintenance method determination in Air Ngalam Irrigation Area]. *Inersia: Jurnal Teknik Sipil*, *5*(1), 31-40..

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1-4. https://doi.org/10.11648/j.ajtas.20160501.11

Field, A. (2021). *Discovering statistics using IBM SPSS Statistics (5th ed.)*.

Figueiró, A. (2016). Model kapasitas birokrasi untuk pengembangan integritas Perkumpulan Petani Pemakai Air (P3A) dalam rangka pencapaian kedaulatan dan keamanan pangan lokal [Bureaucratic capacity model for P3A integrity development in food sovereignty achievement]. *Biogeografia*, *5*(1), 5-24..

Giordano, M., de Fraiture, C., Weight, E., & van der Bliek, J. (2019). Water for food: The global irrigation challenge. *Agricultural Water Management, 213, 1–10*. https://doi.org/10.1016/j.agwat.2018.09.002

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.)*.

Hussain, I., & Hanjra, M. A. (2018). Irrigation and poverty alleviation: A review of evidence. *Irrigation and Drainage*, *67*(2), 123-134. https://doi.org/10.1002/ird.2210

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). *An introduction to statistical learning (2nd ed.)*.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, *7*(4), 396-403. https://doi.org/10.9734/BJAST/2015/14975

Junita, S., & Buchori, I. (2016). Efektivitas kelembagaan pemerintah dalam integrasi pola pengelolaan sumber daya air dalam RTRW: Studi kasus Provinsi Jawa Tengah [Government institutional effectiveness in water resource management pattern integration in spatial planning: Central Java Province case study]. *Jurnal Wilayah dan Lingkungan*, *4*(1), 1-14.

Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR). (2015). *Peraturan Menteri PUPR No*.

Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR). (2019). *Modul pembentukan dan pemberdayaan P3A/GP3A/IP3A [Module for P3A/GP3A/IP3A formation and empowerment]*.

Kemerer, D., & Varady, R. G. (2019). Irrigation governance and sustainability in developing regions. *World Development, 115, 1–12*. https://doi.org/10.1016/j.worlddev.2018.11.010

Meinzen-Dick, R., Bernier, Q., & Haglund, E. (2018). Water user associations and irrigation performance. *World Development, 107, 24–36*. https://doi.org/10.1016/j.worlddev.2018.02.010

Molden, D., Sakthivadivel, R., & Samad, M. (2017). Improving agricultural water productivity. *International Journal of Water Resources Development*, *33*(3), 1-15. https://doi.org/10.1080/07900627.2016.1215375

Molden, D. (2020). Water for sustainable food production systems. *Water International, 45(7–8), 1–15 N., & Kumar, M. D. (2021). Water user associations and irrigation management performance: Evidence from South Asia. Water Resources Management*, *35*(6), 1873-1888. https://doi.org/10.1080/02508060.2020.1807492Bassi

Mukherji, A., Facon, T., Burke, J., et al. (2019). Revitalizing Asia's irrigation systems: Understanding the challenges of governance. *International Journal of Water Resources Development*, *35*(6), 1-18. https://doi.org/10.1080/07900627.2019.1609854

Ostrom, E. (2015). *Governing the commons: The evolution of institutions for collective action*.

Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, *64*(1), 12-40. https://doi.org/10.1016/S0148-2963(99)00084-3

Putri, Y. G., Yuerlita, Y., & Asful, F. (2020). Efektivitas peran Perkumpulan Petani Pemakai Air (P3A) Banda Tangah Daerah Irigasi Banda Pamujaan dalam pengelolaan jaringan irigasi tersier [Effectiveness of P3A Banda Tangah role in tertiary irrigation network management at Banda Pamujaan Irrigation Area]. *JOSETA: Journal of Socio-Economics on Tropical Agriculture*, *2*(2), 71-79.

Putriani, R., Tenriawaru, A., & Amrullah, A. (2018). Pengaruh faktor-faktor partisipasi terhadap tingkat partisipasi petani anggota P3A [Influence of participation factors on P3A member farmer participation levels]. *Jurnal Sosial Ekonomi Pertanian*, *14*(3), 263-274.

Sufyadi, D., & Hartoyo, T. (2020). Hubungan antara peranan P3A dengan partisipasi petani anggota P3A: Berdasarkan persepsi para petani P3A Mekar Sauyunan di Ancaran Kabupaten Kuningan, Jawa Barat [Relationship between P3A role and P3A member farmer participation: Based on perceptions at P3A Mekar Sauyunan, Kuningan]. *Jurnal Agristan*, *2*(2), 109-120.

Suhardiman, D., Giordano, M., & Molle, F. (2019). Institutional change in irrigation management in Southeast Asia. *Water Alternatives*, *12*(2), 321-340. https://doi.org/10.1080/07900627.2018.1467032

Taber, K. S. (2021). The use of Cronbach's alpha when developing and reporting research instruments. *Research in Science Education, 51, 109–123*. https://doi.org/10.1007/s11165-020-09925-6

Uphoff, N. (2019). Participatory irrigation management: Lessons from institutional reform. *Public Administration and Development*, *39*(4), 189-201. https://doi.org/10.1002/pad.1845

Vermillion, D., & Garcés-Restrepo, C. (2020). Irrigation management transfer and participatory irrigation governance. *Agricultural Water Management, 240, 106–120*. https://doi.org/10.1016/j.agwat.2020.106297

Wong, C. Y., & Giordano, M. (2017). Water governance and institutional arrangements in irrigation systems. *Water International*, *42*(5), 567-582. https://doi.org/10.1080/02508060.2017.1345478

Wooldridge, J. M. (2020). *Introductory econometrics: A modern approach (7th ed.)*.