






# The impact of human resource management on irrigation and drainage management in Indonesia

Khalisah Hayatuddin<sup>1)</sup> , Asel Mohmuod<sup>2)</sup> , Ainur O. Ongdash<sup>3)</sup> ,  
Seyed Saeed Asghari Zonouz\*<sup>4)</sup> , Shukur-Ali Ataev<sup>5)</sup> 

<sup>1)</sup> Universitas Muhammadiyah Palembang, Faculty of Law, Jl. Jendral A. Yani. 13 Ulu, Palembang, Sumatera Selatan, 30263, Indonesia

<sup>2)</sup> Islamic University of Najaf, College of Art, 2976+72M, Kufa Street, 54001, Najaf, Iraq

<sup>3)</sup> School of Economics and Management, Narkhoz University, 55, Zhandossov street, 050035, Almaty, Kazakhstan

<sup>4)</sup> University of Urmia, Faculty of Mechanical Engineering, Department of Energy Conversion, 11th km of SERO Blvd., Urmia, 5756151818, West Azarbayjan, Iran

<sup>5)</sup> Tashkent State Pedagogical University, Department of German Language and Literature, 100183, 27, Bunyodkor street, Chilanzor district, Tashkent, Uzbekistan

\* Corresponding author

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**Abstract:** This study investigates the impact of human resource management (HRM) practices on irrigation and drainage system performance in Indonesia. A mixed-methods approach was employed, combining quantitative surveys of 500 irrigation managers and engineers from five major islands with qualitative interviews of 50 selected participants. The research utilised stratified random sampling and conducted data collection from March to August 2023. Multiple regression analyses revealed that HRM practices explained 47.6% of the variance in system performance, with training and development emerging as the strongest predictor ( $\beta = 0.342$ ,  $p < 0.001$ ), followed by employee engagement ( $\beta = 0.295$ ,  $p < 0.001$ ). Significant regional variations were observed, with Java demonstrating consistently higher performance scores compared to other regions. Structural equation modelling indicated that organisational culture ( $\beta = 0.412$ ) and leadership style ( $\beta = 0.376$ ) significantly influenced HRM effectiveness. The legal and regulatory environment moderated the relationship between HRM practices and system performance ( $\beta = 0.187$ ). The findings emphasise the critical role of contextualised training programmes and employee engagement initiatives in enhancing system efficiency. This research provides valuable insights for policymakers and managers in developing targeted strategies to improve irrigation and drainage management across Indonesia's diverse geographical landscape.

**Keywords:** drainage, human resource management, irrigation, law environment, operational efficiency, system maintenance, water management

## INTRODUCTION

Across diverse industries, organisational effectiveness, longevity, and productivity are significantly influenced by human resource management (HRM). In the context of irrigation and drainage systems, particularly in developing countries like Indonesia, effective HRM practices are crucial for ensuring food security, sustainable water management, and agricultural productivity (Gharbi *et al.*, 2022). Indonesia, an archipelagic nation with

a diverse landscape and climate, faces unique challenges in managing its water resources and agricultural systems. To ensure optimal performance, the country's irrigation and drainage infrastructure, which spans thousands of islands and supports millions of farmers, requires skilled management and maintenance (Basuki *et al.*, 2022).

The importance of irrigation and drainage systems in Indonesia cannot be overstated. These systems are fundamental to the country's agricultural sector, which contributes signifi-

cantly to its economy and employs a substantial portion of its workforce (Nawiyanto *et al.*, 2024). Effective management of these systems is essential for enhancing crop yields, alleviating the consequences of climate change, and ensuring sustainable water use in both rural and urban areas (Tirtalistyani, Murtiningrum and Kanwar, 2022). However, the efficiency of these systems largely depends on the human resources responsible for their operation, maintenance, and management.

There has been a rising awareness in recent years of the necessity to modernise and improve the management of irrigation and drainage systems in Indonesia (Adi and Wahyudi, 2020; Hakim, Nasirudin and Maghfiroh, 2022). This modernisation effort extends beyond mere technological upgrades; it encompasses a fundamental shift in how human resources are managed within these systems. Traditional approaches to HRM in the water management sector have often been characterised by bureaucratic structures, limited professional development opportunities, and a lack of emphasis on employee engagement (Andayani *et al.*, 2023). These outdated practices have led to inefficiencies, reduced system performance, and challenges in adapting to emerging environmental and socio-economic pressures.

The application of modern HRM practices in irrigation and drainage management offers a promising solution to these challenges. Key HRM practices, such as training and development, performance appraisal, and employee engagement, have been shown to significantly enhance organisational performance across various industries (Abbasi *et al.*, 2021). In the context of irrigation and drainage systems, these practices can potentially enhance the skills and motivation of personnel, improve decision-making processes, and foster an environment of innovation and ongoing improvement (Cabezas Burbano *et al.*, 2024).

Training and development programmes, for instance, can equip irrigation managers and engineers with the latest knowledge and skills in water management techniques, environmental conservation, and technological applications (Rudnick *et al.*, 2020). This is particularly crucial in the face of climate change and increasing water scarcity, which demand adaptive management strategies and innovative solutions. Performance appraisal systems, when designed and implemented effectively, can align individual goals with organisational objectives, leading to improved efficiency and accountability in system operations (Neher and Maley, 2020).

Employee engagement, another critical aspect of modern HRM, has been linked to increased productivity, reduced turnover, and enhanced organisational performance (Tensay and Singh, 2020). In the context of irrigation and drainage management, engaged employees are more likely to take ownership of their responsibilities, proactively identify and solve problems, and contribute to the overall improvement of system performance (Ali, 2020). This is especially important in Indonesia, where the geographical dispersion of irrigation systems often requires decentralised decision-making and local problem-solving.

The legal and regulatory environment in Indonesia adds another layer of complexity to HRM practices in irrigation and drainage management. The country's water resources are governed by a complex web of national and local regulations, which have undergone significant changes in recent years (Supangat *et al.*, 2023). The water resource policy and its

subsequent revisions have emphasised the need for integrated water resources management and greater stakeholder participation (Pertamsari and Munandar, 2020; Suntana, 2021). These legal frameworks have implications for HRM practices, particularly in terms of compliance, training requirements, and adaptability of human resource policies.

Furthermore, the decentralisation of water management responsibilities to local governments in Indonesia has created new challenges and opportunities for HRM in the sector (Setiawan *et al.*, 2022). This shift has necessitated the development of local capacity and expertise, highlighting the importance of targeted training programs and knowledge transfer mechanisms. It has also underscored the need for HRM practices that can foster collaboration and coordination among various stakeholders, including government agencies, water user associations, and local communities (Handayani, Dewi and Septiarani, 2023).

The application of effective HRM practices in irrigation and drainage management has far-reaching implications for Indonesia's sustainable development goals. Improved system performance can lead to increased agricultural productivity, enhanced food security, and more efficient water use (Kovalenko *et al.*, 2021; Rudnicki and Wiśniewski, 2021). This, in turn, can contribute to poverty reduction, rural development, and climate change adaptation efforts. Moreover, by fostering a skilled and motivated workforce in the water management sector, effective HRM can drive innovation and the adoption of sustainable practices, aligning with Indonesia's commitments to environmental conservation and sustainable resource management (Kumar *et al.*, 2020).

Despite the potential benefits, the implementation of modern HRM practices in Indonesia's irrigation and drainage sector faces several challenges. Limited financial resources, entrenched bureaucratic structures, and resistance to change are common obstacles (Alaerts, 2020). Additionally, the diverse geographical and cultural landscape of Indonesia necessitates HRM approaches that are sensitive to local contexts and can be adapted to varying needs across different regions (Widjaja, Irdiana and Jusman, 2021). While this study focuses specifically on government-managed irrigation systems to ensure consistency in policy and management practices, future research could explore HRM practices in privately managed irrigation systems, which may operate under different conditions and constraints.

The current problem that this study aims to address is the absence of in-depth research on the specific impacts of HRM practices on irrigation and drainage system performance in the Indonesian context. While there is a growing body of literature on HRM in public sector organisations and water management in general, there is a dearth of empirical evidence on how specific HRM practices influence the efficiency and sustainability of irrigation and drainage systems in Indonesia (Hatta *et al.*, 2023). This knowledge gap hinders the development of targeted strategies for improving system performance and limits the ability of policymakers and managers to make informed decisions about human resource development in the sector.

Given the critical importance of irrigation and drainage systems to Indonesia's agricultural sector and overall development, addressing this knowledge gap is of paramount importance. Analysing the association between HRM practices and system performance can provide valuable insights for policymakers, water resource managers, and HR professionals working in the

sector. It can inform the design of more effective training programmes, performance management systems, and employee engagement strategies tailored to the unique needs of irrigation and drainage management in Indonesia (Mahmud *et al.*, 2020).

Therefore, the goal of the current research is to investigate the impact of specific HRM practices, including training and development, performance appraisal, and employee engagement, on the management, maintenance, and operation of irrigation and drainage systems in Indonesia. By examining these relationships within the context of Indonesia's legal and regulatory environment, this research aims to provide a comprehensive understanding of how HRM practices can be leveraged to improve the performance and sustainability of irrigation and drainage systems across the country.

This research seeks to further the existing knowledge on HRM in water resource management and to provide practical recommendations for enhancing the efficiency and effectiveness of irrigation and drainage systems in Indonesia. By addressing these critical issues, the research has the potential to inform policy decisions, improve resource allocation, and ultimately contribute to the effective management of water resources sustainably and the improvement of agricultural productivity in Indonesia.

## MATERIALS AND METHODS

### TYPE OF STUDY AND METHOD

A mixed-methods approach was adopted in this research, merging quantitative and qualitative methodologies to thoroughly explore the influence of HRM practices on irrigation and drainage systems in Indonesia. The primary design was a cross-sectional study, supplemented by semi-structured interviews for in-depth insights. This approach allowed for the collection of both broad, generalisable data and rich, contextual information (Kumar *et al.*, 2020).

### TIME OF DATA COLLECTION

Data collection was conducted over a six-month period from March to August 2023. This timeframe was chosen to coincide with both wet and dry seasons in Indonesia, allowing for a more comprehensive assessment of irrigation and drainage system management across varying environmental conditions (Adi and Wahyudi, 2020).

The period from March to May represented the transition from wet to dry season, while June to August covered the peak dry season, allowing researchers to observe system operations under different environmental conditions. Data collection was structured in three phases:

- 1 (March–April 2023): initial survey distribution and preliminary interviews during the late wet season, capturing management practices during high water availability conditions;
- 2 (May–June 2023): core data collection period during the transitional season, focusing on system adaptation practices as water availability began to decrease;
- 3 (July–August 2023): final data collection during the dry season, examining management strategies under water scarcity conditions and peak irrigation demand.

The timing also aligned with the agricultural calendar, covering both primary and secondary growing seasons, which enabled comprehensive assessment of HRM practices during periods of varying operational intensity. This temporal distribution helped ensure that the collected data reflected the full spectrum of challenges faced by irrigation and drainage system managers throughout the year.

### PLACE OF RESEARCH

The study was conducted across five major islands of Indonesia: Java, Sumatra, Kalimantan, Sulawesi, and Bali. These islands were selected to represent the geographical diversity of Indonesia and to capture a range of irrigation and drainage system types and management practices (Supangat *et al.*, 2023).

In Java, primary research sites included the Citarum River Basin in West Java, the Serayu-Bogowonto River Basin in Central Java, and the Brantas River Basin in East Java. These areas were characterised by intensive rice cultivation and well-developed irrigation infrastructure, featuring both large-scale technical irrigation systems (>3,000 ha) and medium-scale systems (1,000–3,000 ha). The high population density and urbanisation pressures in Java significantly impacted water management practices and strategies.

The Sumatran research locations focused on North Sumatra's Deli-Serdang region and South Sumatra's Komering River Basin, representing areas with mixed agricultural practices including rice, palm oil, and horticultural crops. These sites included both tidal irrigation systems in coastal areas and conventional irrigation in inland regions, presenting unique challenges related to peat soil management. In Kalimantan, study locations concentrated on the Kapuas River Basin in West Kalimantan and the Barito River Basin in South Kalimantan, characterised by tidal swamp irrigation systems and newer irrigation development areas. These sites faced distinct challenges related to acid sulphate soils and water quality management.

Sulawesi's research areas encompassed the Sadang River Basin in South Sulawesi and the Palu River Basin in Central Sulawesi, featuring medium-scale irrigation systems (500–1,000 ha). These locations represented areas with distinct dry season challenges and systems adapting to climate change impacts. The Bali study sites focused on the Subak traditional irrigation systems in central and southern regions, representing UNESCO World Heritage irrigation systems that demonstrated unique socio-cultural aspects of water management and the successful integration of traditional and modern management practices.

### POPULATION, SAMPLE SIZE, AND SAMPLING METHOD

The target population consisted of irrigation managers and engineers working in government-managed irrigation and drainage systems across Indonesia. A sample size of 500 participants was determined using power analysis ( $\alpha = 0.05$ ,  $\beta = 0.20$ , effect size = 0.25), which provided sufficient statistical power for the planned analyses (Nawiyanto *et al.*, 2024). A multi-stage stratified random sampling method was employed to ensure representation across different regions and system types. In the first stage, irrigation and drainage systems were stratified by island and system size (small, medium, large). In the second stage,

individual participants were randomly selected from each stratum. This method ensured a diverse and representative sample of the target population (Ojha and Schofield, 2022). While representing a small fraction of Indonesia's total irrigation management workforce, this sample size provides statistically reliable results through careful stratification and random sampling procedures across different regions.

### RESEARCH SETTING

The research was conducted in collaboration with the Indonesian Ministry of Public Works and Housing, which oversees the management of irrigation and drainage systems nationwide. Surveys and interviews were carried out at local irrigation offices, water user association meetings, and field sites to capture a comprehensive view of HRM practices and their impacts (Hakim *et al.*, 2022).

### DATA COLLECTION TOOL, VALIDITY, AND RELIABILITY

The study employed a structured questionnaire as the primary data collection tool, developed based on established HRM and water management literature. The questionnaire consisted of five sections: demographic information, HRM practices (employee engagement, performance appraisal, training and development), irrigation and drainage system performance metrics, organisational factors, and legal and regulatory environment. Originally drafted in English, the questionnaire was subsequently converted into Bahasa Indonesia using a forward-backward translation method to ensure linguistic and cultural equivalence (Basuki *et al.*, 2022). Content validity was established through expert review by a panel of five professionals, including HRM specialists, irrigation engineers, and academic researchers. The content validity index (CVI) was calculated, with items scoring below 0.78 being revised or removed (Pertamsari and Munandar, 2020). To ensure reliability, a pilot study was conducted with 50 participants not included in the final sample. Cronbach's alpha was calculated for each subscale, with values ranging from 0.82 to 0.91, indicating good to excellent internal consistency. For the qualitative component, a semi-structured interview guide was developed based on the research objectives and initial survey findings. The guide was reviewed by experts and pilot-tested to ensure clarity and relevance of questions. To mitigate potential self-reporting bias, data triangulation was employed through the mixed-methods approach, where quantitative survey responses were validated and contextualised through qualitative interviews.

### DATA COLLECTION METHOD

Quantitative data were collected through self-administered questionnaires distributed both online (via a secure web platform) and in paper format to accommodate varying levels of internet access across regions. Participants were given two weeks to complete the questionnaire, with reminder emails or phone calls made after one week to encourage participation. Qualitative data were collected through semi-structured interviews with a subset of 50 participants, selected using maximum variation sampling to ensure diverse perspectives. Interviews were conducted in person or via video conferencing, depending on logistical constraints. Each interview lasted approximately 60–90 min and was audio-

recorded with the participant's consent. To ensure data quality, all researchers involved in data collection underwent standardised training on survey administration and interview techniques. Continuous quality assessments were performed during data collection to quickly identify and tackle any issues.

### DATA ANALYSIS METHOD

IBM SPSS Statistics version 27.0 and STATA version 17.0 were used to perform quantitative data analysis. The combination of SPSS and STATA was chosen to leverage their complementary strengths – SPSS for its user-friendly interface and basic analyses, while STATA was utilised for its advanced econometric capabilities, particularly in handling complex panel data structures.

The analysis proceeded in several stages, including descriptive statistics, reliability analysis, factor analysis, correlation analysis, multiple regression analysis, structural equation modelling, moderation analysis, and analysis of variance. Descriptive statistics provided an overview of the sample characteristics and distribution of responses. Reliability analysis confirmed internal consistency of scales using the full sample data. Exploratory and confirmatory factor analyses were conducted to verify and validate the underlying structure of HRM practices and system performance measures. Correlation analysis examined bivariate relationships between key variables, while hierarchical multiple regression assessed the impact of HRM practices on system performance while controlling for demographic and organisational factors. Structural equation modelling was used to develop and test a comprehensive model examining the relationships between HRM practices, organisational factors, and system performance. Additionally, moderation analysis was conducted to assess the moderating effects of organisational factors and the legal regulations. One-way ANOVA examined differences in HRM practices and system performance across different regions and system types, with post-hoc comparisons using the Bonferroni correction.

For the qualitative data analysis, thematic analysis was conducted using NVivo version 12 software. The analysis process involved transcription and translation of interview recordings, independent coding by two researchers using both deductive and inductive approaches, theme development through an iterative process of discussion and refinement, and validation through member checking and peer debriefing. Integration of quantitative and qualitative findings was performed using a convergent parallel design, where both datasets were analysed separately and then merged for interpretation. This integration allowed for a more comprehensive understanding of the research questions, with qualitative data providing context and depth to the quantitative results (Hatta *et al.*, 2023). Throughout the analysis process, careful attention was paid to potential confounding factors and alternative explanations for observed relationships. Sensitivity analyses were conducted to assess the robustness of findings to different analytical approaches and assumptions. By employing this comprehensive methodological approach, the study aimed to provide a rigorous and nuanced understanding of the impact of HRM practices on irrigation and drainage system performance in Indonesia, while accounting for the complex organisational and regulatory context in which these systems operate.

## RESULTS AND DISCUSSION

### GENERAL INFORMATION

The analysis of data, collected from 500 irrigation managers and engineers across five major islands of Indonesia, yielded significant insights into the impact of HRM practices on irrigation and drainage system performance. The results are presented in the following sections, organised according to the study’s main objectives.

### DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Demographic information for those involved in the research can be found in Table 1.

**Table 1.** Demographic characteristics of participants (*N* = 500)

Characteristic	Category	Frequency	Percentage
Gender	male	375	75.0
	female	125	25.0
Age	20–30 years	85	17.0
	31–40 years	195	39.0
	41–50 years	150	30.0
	>50 years	70	14.0
Education level	bachelor’s degree	320	64.0
	master’s degree	165	33.0
	doctoral degree	15	3.0
Years of experience	1–5 years	95	19.0
	6–10 years	175	35.0
	11–15 years	130	26.0
	>15 years	100	20.0

Explanation: *N* = sample size.  
Source: own study.

The sample was predominantly male (75.0%), reflecting the gender distribution in the irrigation and drainage management sector in Indonesia. The majority of participants were between 31–50 years old (69.0%), held a bachelor’s degree (64.0%), and had 6–15 years of experience (61.0%) in the field.

### HUMAN RESOURCE MANAGEMENT PRACTICES IN IRRIGATION AND DRAINAGE SYSTEMS

The prevalence and perceived effectiveness of key HRM practices across the sampled irrigation and drainage systems is summarised in Table 2.

Training and development programmes were widely implemented (92.0%) and perceived as relatively effective (3.78 ±0.87). Employee engagement initiatives, though less prevalent (76.0%), were rated as the most effective HRM practice (3.89 ±0.79). Performance appraisal systems were common (88.0%) but perceived as less effective (3.45 ±0.92) compared to other practices.

**Table 2.** Prevalence and perceived effectiveness of human resources management (HRM) practices (*N* = 500)

HRM practice	Prevalence (%)	Perceived effectiveness (mean ±SD)
Training and development	92.0	3.78 ±0.87
Performance appraisal	88.0	3.45 ±0.92
Employee engagement	76.0	3.89 ±0.79
Career development	68.0	3.32 ±1.05
Compensation and benefits	95.0	3.56 ±0.88

Note: perceived effectiveness was measured on a 5-point Likert scale (1 = not at all effective, 5 = extremely effective).

Explanation: *N* = sample size, *SD* = standard deviation.

Source: own study.

### IMPACT OF HUMAN RESOURCE MANAGEMENT PRACTICES ON SYSTEM PERFORMANCE

To assess the impact of HRM practices on irrigation and drainage system performance, multiple regression analysis was conducted (Tab. 3).

**Table 3.** Multiple regression analysis – impact of human resources management (HRM) practices on system performance (*N* = 500)

HRM practice	$\beta$	SE	<i>t</i>	<i>p</i> -value
Training and development	0.342	0.041	8.341	<0.001
Performance appraisal	0.187	0.038	4.921	<0.001
Employee engagement	0.295	0.043	6.860	<0.001
Career development	0.156	0.036	4.333	<0.001
Compensation and benefits	0.203	0.039	5.205	<0.001

Note:  $R^2 = 0.476$ , adjusted  $R^2 = 0.471$ ,  $F(5, 494) = 89.73$ ,  $p < 0.001$ .

Explanations: *N* = sample size,  $\beta$  = beta coefficient (standardised regression coefficient that indicates the strength and direction of relationship between each HRM practice and system performance; higher absolute values indicate stronger relationships), *SE* = standard error, *t* = *t*-statistic, *p* = probability,  $R^2$  = determination coefficient, *F* = *F*-statistic.  
Source: own study.

The regression model explained 47.6% of the variance in system performance ( $R^2 = 0.476$ ,  $F(5, 494) = 89.73$ ,  $p < 0.001$ ). All HRM practices were significant predictors of system performance ( $p < 0.001$ ). Training and development emerged as the strongest predictor ( $\beta = 0.342$ ,  $p < 0.001$ ), followed by employee engagement ( $\beta = 0.295$ ,  $p < 0.001$ ) and compensation and benefits ( $\beta = 0.203$ ,  $p < 0.001$ ).

### REGIONAL VARIATIONS IN HUMAN RESOURCE MANAGEMENT PRACTICES AND SYSTEM PERFORMANCE

One-way ANOVA was conducted to examine regional differences in HRM practices and system performance across the five studied islands (Tab. 4).

Significant regional variations were observed in all HRM practices and system performance ( $p < 0.05$ ). Post-hoc

**Table 4.** Regional variations in human resources management (HRM) practices and system performance ( $N = 500$ )

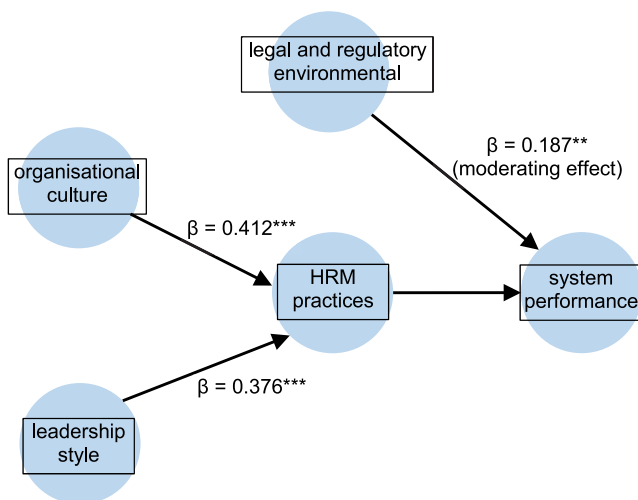
Variable	Value for island					F	p-value
	Java	Sumatra	Kalimantan	Sulawesi	Bali		
Training and development	3.92 ±0.76	3.75 ±0.89	3.58 ±0.95	3.69 ±0.83	3.86 ±0.79	3.754	0.005
Performance appraisal	3.61 ±0.87	3.42 ±0.94	3.29 ±0.98	3.35 ±0.91	3.53 ±0.88	2.985	0.019
Employee engagement	4.05 ±0.72	3.87 ±0.81	3.71 ±0.85	3.79 ±0.78	3.98 ±0.75	4.217	0.002
System performance	4.18 ±0.68	3.95 ±0.75	3.82 ±0.79	3.89 ±0.73	4.07 ±0.70	5.136	<0.001

Note: values represent mean ±SD. System performance was measured on a 5-point Likert scale (1 = very poor, 5 = excellent). Explanations:  $N$  = sample size,  $F$  =  $F$ -statistic,  $p$  = probability,  $SD$  = standard deviation.

comparisons using the Bonferroni correction revealed that Java consistently scored higher in all categories compared to other regions, particularly Kalimantan ( $p < 0.01$  for all comparisons).

### RELATIONSHIP BETWEEN ORGANISATIONAL FACTORS AND HUMAN RESOURCE MANAGEMENT EFFECTIVENESS

Structural equation modelling (SEM) was used to examine the relationships between organisational factors, HRM practices, and system performance. The final model demonstrated good fit ( $\chi^2/df = 2.34$ ,  $CFI = 0.953$ ,  $TLI = 0.947$ ,  $RMSEA = 0.052$ ). Figure 1 presents the path diagram of the SEM results.



**Fig. 1.** Path diagram of structural equation model results; HRM = human resources management,  $\beta$  = standardised path coefficient (showing the strength and direction of relationships between variables),  $** = p < 0.01$ ,  $*** = p < 0.001$ ; source: own study

The SEM results indicated that organisational culture ( $\beta = 0.412$ ,  $p < 0.001$ ) and leadership style ( $\beta = 0.376$ ,  $p < 0.001$ ) had significant direct effects on the effectiveness of HRM practices. Additionally, the legal and regulatory environment had a direct positive effect on system performance ( $\beta = 0.187$ ,  $p < 0.01$ ), indicating that a supportive legal and regulatory framework contributes to better irrigation and drainage system outcomes.

### QUALITATIVE INSIGHTS ON HRM PRACTICES AND SYSTEM PERFORMANCE

Thematic analysis of the semi-structured interviews ( $N = 50$ ) revealed several key themes that provided context to the following quantitative findings.

1. Importance of contextual training: participants emphasised the need for training programmes tailored to local environmental and social conditions. One manager stated, “Generic training often fails to address the unique challenges we face in our region’s irrigation systems.”
2. Challenges in performance appraisal: many interviewees reported difficulties in implementing fair and objective performance appraisal systems. A common sentiment was expressed by an engineer who said, “It’s challenging to quantify performance in our field, especially when external factors like weather play a significant role.”
3. Employee engagement and local community involvement: several participants highlighted the importance of engaging not only employees but also local water user associations. An irrigation manager noted, “When we involve local communities in decision-making, we see better maintenance of the systems and more efficient water use.”
4. Impact of decentralisation: the decentralisation of water management to local governments was frequently mentioned as both an opportunity and a challenge for HRM. One senior manager explained, “Decentralisation allows for more tailored approaches, but it also creates disparities in resources and expertise across regions.”
5. Technology adoption and skill development: many interviewees stressed the need for continuous skill development to keep pace with technological advancements. An engineer commented, “We need ongoing training to effectively use new technologies for water management and system monitoring.”

The results of this study provide compelling evidence for the significant impact of HRM practices on the performance of irrigation and drainage systems in Indonesia. The finding that HRM practices explain 47.6% of the variance in system performance underscores the critical role of effective human resource management in this sector. Notably, training and development emerged as the strongest predictor of system performance, followed closely by employee engagement. This suggests that investing in the skills and motivation of irrigation managers and engineers can yield substantial improvements in system efficiency and effectiveness.

The high prevalence of training and development programmes (92.0%) across the sampled organisations indicates a widespread recognition of their importance. However, the lower prevalence of employee engagement initiatives (76.0%), despite their high perceived effectiveness, suggests an opportunity for organisations to enhance their HRM strategies. The qualitative findings provide context to these results, highlighting the importance of tailoring training programmes to local conditions and the challenges in implementing effective performance appraisal systems in the complex environment of irrigation and drainage management.

These findings align with previous research in other sectors that have demonstrated the positive impact of HRM practices on organisational performance (Andayani *et al.*, 2023). However, the specific context of irrigation and drainage systems in Indonesia presents unique challenges and opportunities. For instance, the strong emphasis on training and development in this study contrasts with some studies in other developing countries that found limited investment in employee training in public sector organisations (Widjaja, Irdiana, and Jusman, 2021). This difference may reflect the technical nature of irrigation and drainage management and the recognised need for continuous skill development in the face of environmental and technological changes.

The identified regional variations in HRM practices and system performance are consistent with studies that have highlighted the uneven distribution of resources and expertise across different parts of Indonesia (Oketch, Kilika and Kinyua, 2020). The superior performance of systems in Java may be attributed to better infrastructure, more resources, and possibly more advanced HRM practices. This finding underscores the need for targeted interventions to address regional disparities in water management capabilities.

The moderating effect of the legal and regulatory environment on the relationship between HRM practices and system performance aligns with institutional theory, which posits that organisational practices are shaped by the broader institutional context (Gupta and Gupta, 2021). In the case of Indonesia's irrigation and drainage sector, the complex and evolving legal framework appears to influence the effectiveness of HRM practices, highlighting the need for adaptive management approaches.

Despite the comprehensive nature of this research, several limitations should be acknowledged to guide future studies and inform the interpretation of results. The study's primary limitation lies in its cross-sectional design, which captured data at a single point in time, potentially missing long-term trends and seasonal variations in HRM practices and system performance. While the six-month data collection period (March–August 2023) encompassed both wet and dry seasons, a longitudinal study would provide more robust insights into the temporal dynamics of HRM's impact on irrigation system performance.

Sample representation presents another limitation. Although the study included 500 participants across five major islands, this represents a relatively small fraction of Indonesia's total irrigation management workforce. While careful stratification and random sampling procedures were employed to ensure representativeness, the findings may not fully capture the diversity of experiences and practices in smaller, more remote

irrigation systems. Furthermore, the study focused exclusively on government-managed irrigation systems, excluding privately managed systems that might operate under different conditions and constraints.

The reliance on self-reported data through surveys and interviews introduces potential response bias. While data triangulation through mixed methods helped mitigate this limitation, participants might have overstated the effectiveness of their HRM practices or system performance. While being robust, the use of SPSS and STATA for analysis limited the exploration of more complex statistical relationships that might have been possible with more advanced analytical tools. Additionally, the combination of these software packages, chosen for their complementary strengths, may have introduced minor inconsistencies in data handling.

Language and cultural barriers posed additional challenges. Although the questionnaire underwent rigorous translation and back-translation processes, some nuances in participants' responses might have been lost in translation. The study's focus on formal HRM practices may also have overlooked informal management practices that play significant roles in traditional irrigation systems, particularly in areas with strong cultural water management traditions like the Subak system in Bali.

External validity considerations should be noted, as the research was conducted during a period of significant global climate variations and economic challenges. The findings may therefore reflect the unique circumstances of this period rather than typical operational conditions. Additionally, the study's scope did not include detailed economic analysis of HRM interventions, limiting its ability to provide cost-benefit assessments of different management practices.

## CONCLUSIONS

In conclusion, this study provides compelling evidence for the significant impact of HRM practices on the performance of irrigation and drainage systems in Indonesia. The findings highlight the critical role of training and development, employee engagement, and contextually-tailored HRM strategies in enhancing system efficiency and effectiveness. Regional variations in HRM practices and system performance underscore the need for targeted interventions to address disparities across the Indonesian archipelago. The moderating effect of the legal and regulatory environment emphasises the importance of adaptive management approaches in this complex sector. As Indonesia continues to face challenges in water resource management and agricultural productivity, these insights offer valuable guidance for policy-makers and managers. By prioritising effective HRM practices, particularly those focused on skill development and employee engagement, organisations can significantly improve the performance and sustainability of irrigation and drainage systems, contributing to food security and sustainable development goals in Indonesia. While these findings are specific to Indonesia's context, the general principles of effective HRM in irrigation management could be relevant to other developing countries. However, cultural, environmental, and regulatory differences should be carefully considered when applying these insights in different contexts.

## CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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