Performance Assessment of the Irrigation System using the ePAKSI Application and the Analytic Hierarchy Process (AHP) Method in The Tanah Miring Swamp Irrigation Area (SIA), Merauke Regency

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Abstract. The swamp irrigation system supplies, regulates, and drains water in agricultural areas within natural basins on flat or concave land, often experiencing permanent or seasonal water stagnation. The Tanah Miring Swamp Irrigation Area (SIA), the largest in Merauke Regency, spans 7,840 hectares. However, suboptimal system performance and infrastructure damage have hindered irrigation effectiveness. This study aims to assess the performance of the irrigation system using the ePAKSI application and determine improvement priorities through the Analytic Hierarchy Process (AHP). The findings are expected to support more effective O&M planning and resource allocation. The performance index of Tanah Miring SIA was 72.18% (Good), with the highest score in physical infrastructure (29.10%). The most critical issue was incomplete supporting facilities (48.00% damage), followed by physical infrastructure damage (35.33%), requiring routine and periodic maintenance. AHP results indicate that physical infrastructure is the top improvement priority, followed by planting productivity, personnel, supporting facilities, P3A institutions, and documentation.

Introduction

The use of water, its sources, and related infrastructure—particularly within irrigation systems—must be protected, maintained, and preserved to ensure functionality. Effective water management depends on adequate infrastructure, as mandated by *Undang-Undang (UU) No. 17 tahun 2019* on Water Resources, which includes swamp irrigation systems [1].

Swamps are naturally waterlogged areas formed by poor drainage, with distinct hydrological, physical, chemical, and biological characteristics. Swamp irrigation systems are designed to regulate water availability for agriculture in such areas, serving as both reservoirs and drainage channels depending on the season [2].

Despite their importance, swamp irrigation areas face distinct management challenges due to seasonal fluctuations, limited water sources, and reliance on rainfall. These factors complicate infrastructure operation and maintenance, particularly under constrained budgets and technical capacity. Although tools like the ePAKSI application have been introduced to assess irrigation performance [3], their implementation in swamp irrigation systems remains limited and underexplored.

The ePAKSI application, developed by the Directorate of Water Resources, supports integrated irrigation asset management and performance evaluation through geospatial technology. Prior studies [4, 5, 6, 7, 8] have applied ePAKSI in technical irrigation systems, often comparing it with manual or fuzzy logic approaches and reporting comparable results. However, its application in swamp irrigation systems has not yet been examined.

To support decision-making after system assessments, structured prioritization methods are essential. The Analytic Hierarchy Process (AHP) is a widely adopted tool for ranking interventions based on multiple criteria. Previous studies [8, 9, 10] have shown its effectiveness in irrigation planning, although its application in swamp irrigation remains limited.

This study evaluates the performance of the Tanah Miring Swamp Irrigation Area using the ePAKSI application and identifies infrastructure improvement priorities through the AHP method. By integrating these tools, it aims to promote more efficient, data-driven management of swamp irrigation systems. The results are expected to support policy implementation, optimize resource allocation, and enhance the long-term sustainability of irrigation infrastructure in lowland areas [8, 9].

Tanah Miring SIA, the largest swamp irrigation area in Merauke Regency, covers 7,840 hectares and depends primarily on rain-fed sources. During the wet season, channels act as drainage, while in the dry season, they function as reservoirs, with farmers using individual pumps for irrigation [11, 12]. Due to its scale and operational complexity, effective and prioritized management is essential to sustain agricultural productivity.

Method

Location of the Study. This study was conducted in the Tanah Miring Swamp Irrigation Area (SIA), Merauke Regency, South Papua Province, located between 140°60'–140°80' E and 7°70'–8°40' S. The SIA spans 7,840 hectares and comprises eight sub-areas: SP 2 Yasa Mulya, SP 3 Sumber Harapan, SP 4 Waninggap Say, SP 5 Waninggap Minaf, SP 6 Isanombias, SP 7 Hidup Baru, SP 8 Amun Kay, and SP 9 Yaba Maru.

Required Data and Information. This study utilizes secondary data from relevant institutions (e.g., irrigation schemes, P3A, O&M structure, productivity, and facilities) and primary data from field surveys using the ePAKSI app to inventory irrigation assets.

Research Stages. The research stages include: case study, literature review, data collection, performance evaluation, improvement and handling recommendations, prioritization, and conclusion.

Irrigation System Performance Index Assessment (ISPIA) Criteria. The Irrigation System Performance Index Assessment (ISPIA) was conducted using the ePAKSI app, based on criteria aligned with *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat (PUPR) No. 12/PRT/M/2015* on irrigation network operation and maintenance. The six performance indicators and their categories are shown in **Table 1** and **Table 2**. **Fig. 1** shows the location of Tanah Miring SIA [13].

Table 1. ISPIA Component/Indicator.

No.	Component/Indicator	Weight of
1	Physical Infrastructure	45
2	Planting Productivity	15
3	Supporting Facilities	10
4	Personnel Organization	15
5	Documentation	5
6	P3A Institution	10
	Total	100

Table 2. ISPIA Category.

No.	Performance Category	Mark
1	Very good	80-100
2	Good	70-<80
3	Lacking and Needing Attention	55-<70
4	Poor and Needs Attention	<55

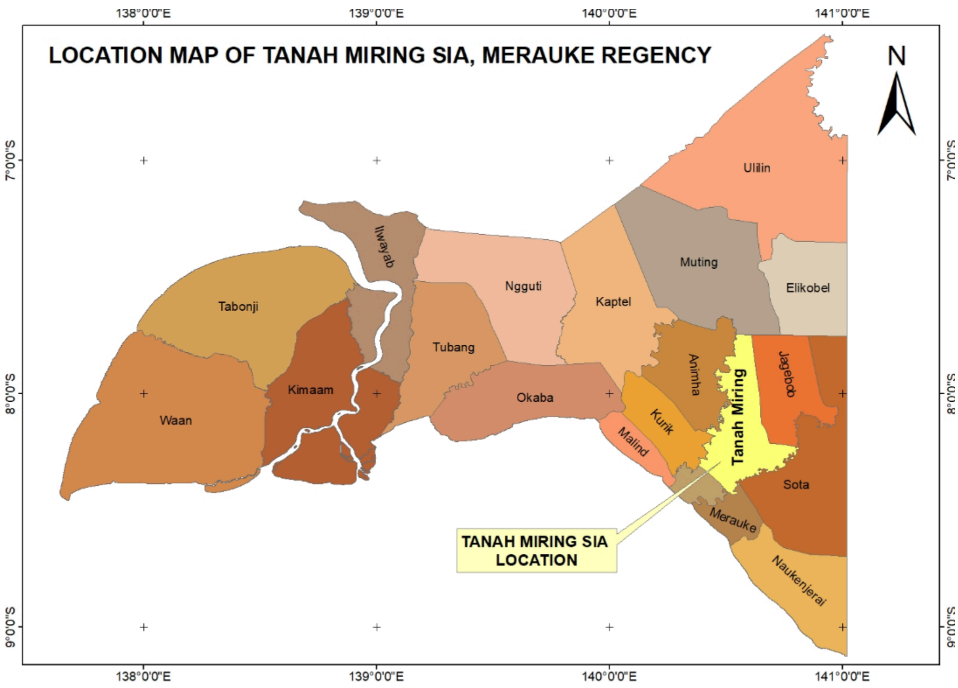

Fig. 1. Location Map of Tanah Miring SIA, Merauke Regency.

Priority Scale Determination for Irrigation System Management Using AHP. To determine the priority scale for irrigation system improvement in Tanah Miring SIA, the Analytic Hierarchy Process (AHP) was applied. The AHP hierarchy, illustrated in **Fig. 2**, consists of the goal at the top and performance index components as alternatives at the bottom. The performance index value serves as the criterion. A pairwise comparison matrix was developed to assign weights based on the relative importance of each component, derived from differences in condition values. The assessment combines results from the ePAKSI evaluation with standard weight references for each component.

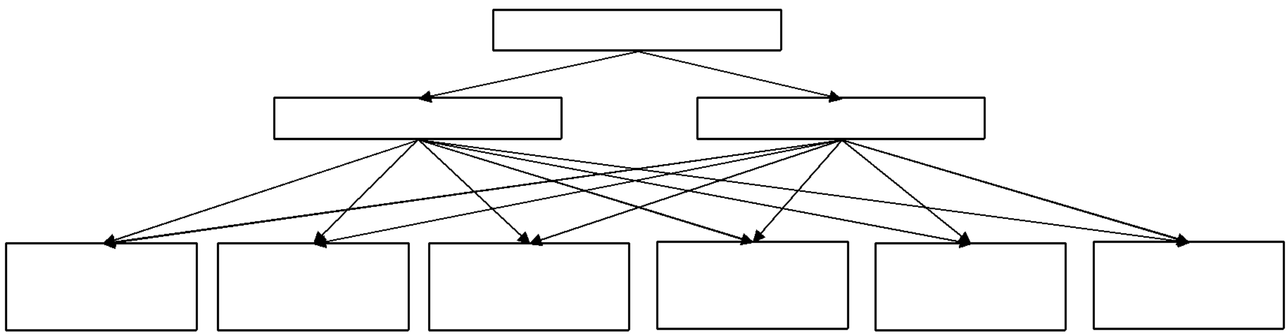

Fig. 2. AHP Method Network Structure [8].

Results and Discussion

Data for the Tanam Miring SIA. This subsection presents data on the Land Area and Planting Productivity, O&M Support Facilities, Personnel Organization, Documentation, and P3A Institution of the Tanah Miring SIA.

Land Area and Planting Productivity. Since 2015, the land area of Tanah Miring SIA has expanded from 7,840 to 8,474 hectares—an increase of 634 hectares (8.09%). The potential area has also grown by 1,204 hectares (15.36%), reaching 9,044 hectares. Rice productivity averages 4.43 tons/ha, 7% higher than the national average for tidal swamp rice (4.14 tons/ha). In contrast, chili productivity remains low at 6.36 tons/ha, 40.60% below the national average of 10.71 tons/ha [14].

Support Facilities. The Operations and Maintenance (O&M) support facilities at the Tanah Miring SIA include basic equipment such as grass cutters, meters, measuring tanks, printers, fans, and dispensers. However, several components still require improvement, including the provision of personal protective equipment (PPE), flashlights, raincoats, and machetes for each officer. Transportation facilities are unavailable; while bicycles are recommended, fuel allowances may be more appropriate due to the challenging terrain. Office support needs to be enhanced with additional items like stationery, whiteboards, desks, and chairs. Communication infrastructure is also lacking, indicating the need for telephones and internet access.

Personnel Organization. The current condition of the Tanah Miring SIA personnel organization, compared to the recommendations of *Peraturan Menteri PUPR No. 5/PRT/M/2010* presented in **Table 3**.

Table 3. Personnel Organization Conditions of the Tanah Miring SIA.

No.	Recommendation of *Peraturan Menteri PUPR No. 5/PRT/M/2010*		Current Number of Officers
	Serving area / Water gate	Number of Officers	
1	3,000– 25,000 ha	1 Observer + 3 Staff	1 Observer + 1 Staff
2	1,000– 2,000 ha	4 Irrigation Officers	4 Irrigation Officers
3	4 Water Gates	8 Water Gate Officers	8 Water Gate Officers

Based on the data, Tanah Miring SIA—with a standard area of 7,840 ha—currently employs only one observer, below the recommended three personnel for service areas between 3,000 and 25,000 ha [15]. An increase in observer staff is therefore recommended to enhance operational efficiency. The number of irrigation officers (four) aligns with the standard; however, the number of water gate operators (eight) exceeds the recommended five. This increase is justified by the considerable distances between gates and limited road access, particularly during the rainy season.

Documentation. Documentation data provides comprehensive information on the physical, technical, and administrative aspects of the irrigation area, supporting planning, management, evaluation, and operational control. In Tanah Miring SIA, as managed by the River Basin Organization (RBO) for Papua Merauke, documentation includes the Irrigation Area Data Book—containing the Water Allocation Report, Operation Manual, Performance Assessment Report, and Actual O&M Requirements—and a collection of maps and images, such as Office Wall Data (Irrigation Area Map, Work Area Map, Organizational Structure Map), Implementation Drawings (As-Built Drawings, Maintenance Maps, Building Plans), and Network Schemes (Execution and Structural Components). However, the Office Wall Data remains incomplete.

P3A Institution. The Water Users Farmers Association (P3A) functions as a community-based irrigation management institution in the Tanah Miring SIA, formed democratically by water users in collaboration with the RBO for Papua Merauke. Twenty legally recognized P3A groups operate across eight sub-work areas, all participating in the P3TGAI program. While not individually analyzed, these groups collectively support irrigation performance in the region. The largest service area is managed by P3A Hidup Air Rawa in SP 6 Isanombias (961 ha), while SP 8 Amun Kay hosts the highest number of P3A groups (4 groups managing 897 ha in total).

Evaluation of the Use of the ePAKSI Application. This subsection presents the Physical Infrastructure Inventory, the Irrigation System Performance Index Assessment (ISPIA), and the Results of Determining the Priority Scale for Handling the Tanah Miring SIA using AHP.

Physical Infrastructure Inventory. An inventory of physical infrastructure at Tanah Miring SIA was conducted through field surveys using the ePAKSI application, with results compared to the existing Network Map. While both sources report the same number of water gates (28 units), discrepancies were found in the total lengths of primary and secondary channels, where the Network Map figures are higher due to rounding adjustments by the RBO for Papua Merauke OP officer—ranging from 107.5–579.9 meters for primary channels and 13.5–243.2 meters for secondary channels. The ePAKSI-derived data are considered more accurate, reflecting actual field conditions. Notably, bridge and culvert data are missing from the Network Map, whereas the ePAKSI inventory records 89 bridges and 58 culverts. A more accurate and updated network map is currently in development. The inventory of physical infrastructure components at Tanah Miring SIA is presented in **Table 4**.

Table 4. Inventory of Physical Infrastructure Components at Tanah Miring SIA

No.	**Physical Infrastructure Components**	**Total Length/Number of Assets**	
		Network Map of Tanah Miring SIA	**ePAKSI Inventory Result Data**
1	Primary Channel	173,823 m	157,530 m
2	Secondary Channel	385,745 m	349,240 m
3	Sluice	28 Unit	28 Unit
4	Bridge	-	86 Unit
5	Culvert	-	58 Unit

Irrigation System Performance Index Assessment (ISPIA). The summary of the ISPIA assessment results for the Tanah Miring SIA using the ePAKSI application is presented in **Table 5**.

Table 5. Recapitulation of ISPIA Assessment Results for the Tanah Miring SIA.

	Description	**Final Score [%]**	**Value [%]**	**Condition Index**	
				Which is [%]	**Max 100%**
I.	**Physical Infrastructure**	**29.10**	**100**	**64.67**	**45**
1	Channel	9.17	100	61.12	15
a	*Wetted Cross-Section*	*6.07*	*100*	*67.47*	*9*
b	*Berm*	*0.04*	*100*	*4.05*	*1*
c	*Embankment*	*3.06*	*100*	*61.10*	*5*
2	Building	8.37	100	83.69	10
a	*Main Building (Doors: sliding, valve, balk, etc.)*	*6.56*	*100*	*87.46*	*7.5*
b	*Supporting buildings (garbage filters, handrails, culverts, pierscails, bridges, etc.)*	*1.81*	*100*	*72.38*	*2.5*
3	Protective Dike	9.17	100	61.10	15
4	Office, Housing, and Warehouse	2.40	100	48.00	5
a	*Office*	*1.70*	*100*	*85.00*	*2*
b	*Housing area*	*-*	*100*	*-*	*2*
c	*Warehouse*	*0.70*	*100*	*70.00*	*1*
II.	**Planting Productivity**	**12.37**	**100**	**82.49**	**15**
1	Planting Realization / IP	2.81	100	93.70	3
2	Rice Productivity	6.00	100	100.00	6
3	Horticultural Productivity (Dominant)	3.56	100	59.38	6
III.	**Supporting Facilities**	**5.20**	**100**	**52.00**	**10**
1	O&M Equipment	3.50	100	87.50	4
2	Transportation	-	100	-	2
3	Office Supplies	1.70	100	85.00	2
4	Communication tool	-	100	-	2
IV.	**Personnel organization**	**13.50**	**100**	**90.00**	**15**

Description		Final Score [%]	Value [%]	Condition Index	
				Which is [%]	Max 100%
1	The O&M organization has been structured with clear boundaries of responsibility and duties.	4.75	100	95.00	5
2	Personnel	8.75	100	87.50	10
V.	**Documentation**	**3.80**	**100**	**77.50**	**5**
1	DI data book	1.70	100	85.00	2
2	Maps and pictures	2.10	100	70.00	3
VI.	**Water Users Farmers Association (GP3A/IP3A)**	**8.20**	**100**	**82.00**	**10**
1	GP3A/IP3A has legal status	1.43	100	95.00	1.5
2	Institutional conditions of GP3A/IP3A	0.43	100	85.00	0.5
3	Meeting of Village Leaders/P3A/GP3A/IP3A with Branches/Observers/UPTD	1.70	100	85.00	2
4	GP3A/IP3A actively participates in network surveys/tracing	0.85	100	85.00	1
5	Participation of GP3A/IP3A members in network repair and handling of natural disasters	1.70	100	85.00	2
6	GP3A/IP3A contribution for participation in the main network repairs	1.40	100	70.00	2
7	GP3A/IP3A Participation in Planting Planning and Water Allocation	0.70	100	70.00	1
	Total	**72.18**			**100**

The performance assessment of the Tanah Miring SIA irrigation system yielded a final ISPIA score of 72.18%, which falls under the "Good" category. Among all components, *Physical Infrastructure* contributed the highest weighting (29.10%), while *Documentation* had the lowest (3.80%). These findings are consistent with previous studies [5, 7], which also identified *Physical Infrastructure* as the most influential factor in irrigation system performance.

Despite the varying field conditions across irrigation areas, the results highlight a consistent tendency in ePaksi assessments, where *Physical Infrastructure* tends to dominate the overall weighting. Interestingly, although the *Physical Infrastructure* scores in all three studies were relatively similar—ranging from 28.53% to 29.10%—they led to different overall performance categories. Both Tanah Miring SIA and the study by Inadhi et al. (2022) in the Ketapang Barat Irrigation Area achieved "Good" ratings with ISPIA scores of 72.18% and 71.91%, respectively. In contrast, the study by Kresnanto et al. (2022) in the Amandit Irrigation Area resulted in an ISPIA score of 64.39%, placing it in the "Lacking and Needing Attention" category. This variation indicates that while *Physical Infrastructure* is indeed the most influential component, other components also make significant contributions to the total performance score of an irrigation system. A comparison of the ISPIA scores between Tanah Miring SIA and previous studies is presented in **Fig. 3**.

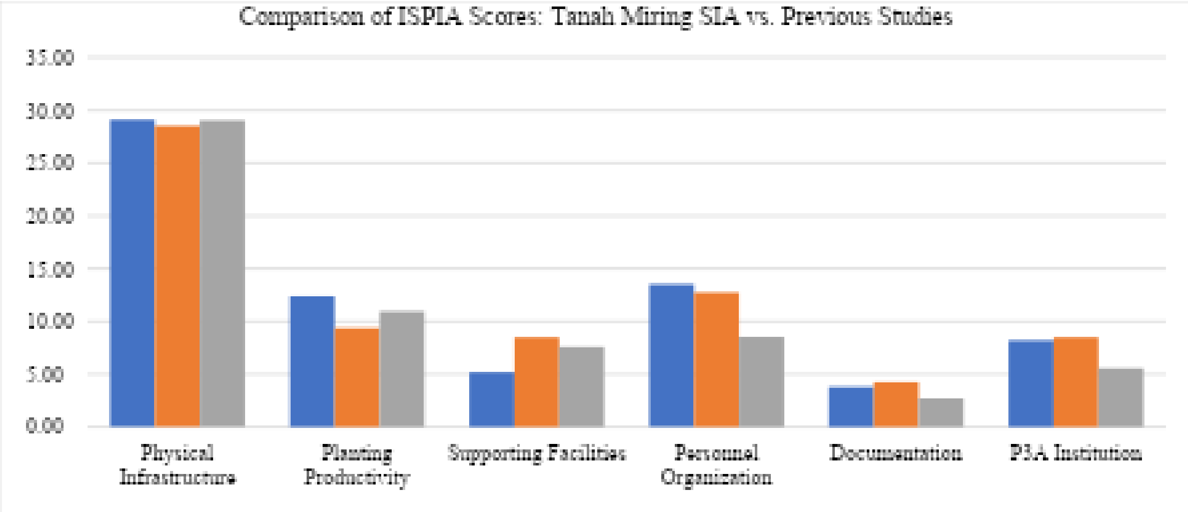

Fig. 3. Comparison of ISPIA Scores: Tanah Miring SIA vs. Previous Studies

This result illustrates an important aspect of the ISPIA scoring mechanism, where the final performance category is determined not only by the absolute value of individual components but also by the weighted contributions assigned to each one. Although the Tanah Miring SIA and Ketapang Barat Irrigation Area both achieved a "Good" rating, the composition of their component scores may differ significantly. This is possible because the ISPIA framework assigns the highest weight (45%) to Physical Infrastructure, while other components such as Documentation and P3A institutions contribute relatively small weights (5–10%). Thus, even when certain components show moderate or high levels of damage—such as Supporting Facilities (48.00%) or Physical Infrastructure (35.33%) in this study—the strong performance in other components with moderate or high weightings, such as Personnel Organization or Planting Productivity, can compensate and help maintain a higher overall score.

Conversely, a study like that of the Amandit Irrigation Area, despite having a similar score in Physical Infrastructure, produced a lower ISPIA score of 64.39%, categorized as "Lacking and Needs Attention." This discrepancy occurred because other components in the Amandit area scored lower, thereby reducing the cumulative weighted score. Therefore, a high score in one component is insufficient unless supported by adequate performance in others, especially those with significant weightings in the ISPIA calculation.

It is important to note that the assessment of sub-components under Physical Infrastructure differs between swamp and surface irrigation areas. These differences arise from variations in the types of assets or physical infrastructure sub-components present in each type of irrigation system, which in turn require distinct weighting factors. **Table 6** outlines the differences in physical infrastructure sub-components along with the corresponding ePAKSI assessment weightings for both surface and swamp irrigation areas. These structural differences have the potential to influence the typical scoring patterns for the Physical Infrastructure component in each irrigation system type, although the assessment criteria for other components remain consistent.

Table 6. Physical Infrastructure Sub-Components for Surface vs. Swamp Irrigation Areas

No.	Physical Infrastructure Sub-Components for Surface Irrigation Areas	Weight [%]
1	Main Building	13
2	Carrier Channel	10
3	Buildings on the Carrier Channel	9
4	Drainage Channel and The building	4

No.	Physical Infrastructure Sub-Components for Swamp Irrigation Areas	Weight [%]
1	Channel	15
2	Building	10
3	Protective Dike	15
4	Office, Housing, and Warehouse	5

5	Entry/Inspection	4
6	Office, Housing, and Warehouse	5
	Total Weight	45

Total Weight	45

Despite the overall positive score, several components exhibit varying levels of deterioration based on damage level analysis. Supporting facilities show the highest level of damage at 48.00%, followed by physical infrastructure (35.33%), documentation (24.00%), P3A institution (18.00%), planting productivity (17.51%), and personnel organization (10.00%). These findings highlight the need for targeted improvements, particularly in infrastructure and supporting facilities. Remedial measures have been recommended in accordance with *Peraturan Menteri PUPR No. 05/PRT/M/2010* and field observations to prevent further decline and enhance overall performance.

Proposed interventions are categorized into six components. For infrastructure, regular maintenance (e.g., channel cleaning, gate lubrication, vegetation control) and periodic efforts (e.g., desilting, structure repair, installation of BM/CP markers and signage) are essential, with rehabilitation required for assets with over 50% damage. In planting productivity, priorities include optimizing land use, planning planting schedules, improving yields—especially horticulture—through inputs and extension services. Strengthening personnel organization involves hiring irrigation observers, providing training, and improving staff welfare. Supporting facilities require additional O&M tools, office supplies, and better transport and communication support. Enhancing P3A institutions calls for capacity building and collaboration with managers to ensure water use efficiency. Lastly, documentation efforts should focus on completing and updating technical records, including maps, organizational charts, and maintenance documentation.

Results of Determining Priority Scale for Handling the Tanah Miring SIA with AHP. To determine intervention priorities in the Tanah Miring Swamp Irrigation Area (SIA), an Analytic Hierarchy Process (AHP) analysis was carried out based on six key components outlined in *Peraturan Menteri PUPR No. 12/PRT/M/2015*. The analysis involved expert judgment from five respondents familiar with the local irrigation context, using weightings derived from the ePAKSI evaluation. The results indicated that current system conditions were considered 3.2 times more critical than the standard baseline. The resulting priority scale, presented in **Table 7**, serves as a strategic reference for targeted improvements and resource allocation.

Table 7. Priority Order for Handling the Tanah Miring SIA.

Priority Order	Component	Scale
1	Physical Infrastructure	0.4142
2	Personnel Organization	0.1783
3	Planting Productivity	0.1664
4	P3A Institution	0.1104
5	Supporting Facilities	0.0786
6	Documentation	0.0520

The AHP analysis ranked the components in the following order: Physical Infrastructure as the top priority, followed by Personnel Organization, Planting Productivity, P3A Institutions, Supporting Facilities, and Documentation. These findings are consistent with previous studies [8, 16], which also highlighted the dominant role of Physical Infrastructure in irrigation system performance, as illustrated in **Fig. 4**. This component holds the highest potential weighting—reaching up to 45%—within the performance index framework, sedangkan untuk urutan prioritas pada componen yang lain sangat bervariasi pada masing-masing studi whereas the other components generally contribute between 5% and 15%. However, it is important to recognize that these priority rankings may vary depending on the specific physical, organizational, and operational conditions of each irrigation area.

The AHP analysis ranked the components in the following order: Physical Infrastructure as the top priority, followed by Personnel Organization, Planting Productivity, P3A Institutions, Supporting Facilities, and Documentation. These findings are consistent with previous studies [8, 16], which also highlighted the dominant role of Physical Infrastructure in irrigation system performance.

This component carries the highest potential weighting—up to 45%—within the performance index framework. In contrast, the priority rankings of the remaining components vary significantly across different studies, with their respective weights generally ranging between 5% and 15%. This variation indicates that the prioritization of components is highly context-dependent, influenced by the specific physical, institutional, and operational characteristics of each irrigation area as illustrated in **Fig. 4**. The detailed priority rankings from each study are presented in **Table 8**.

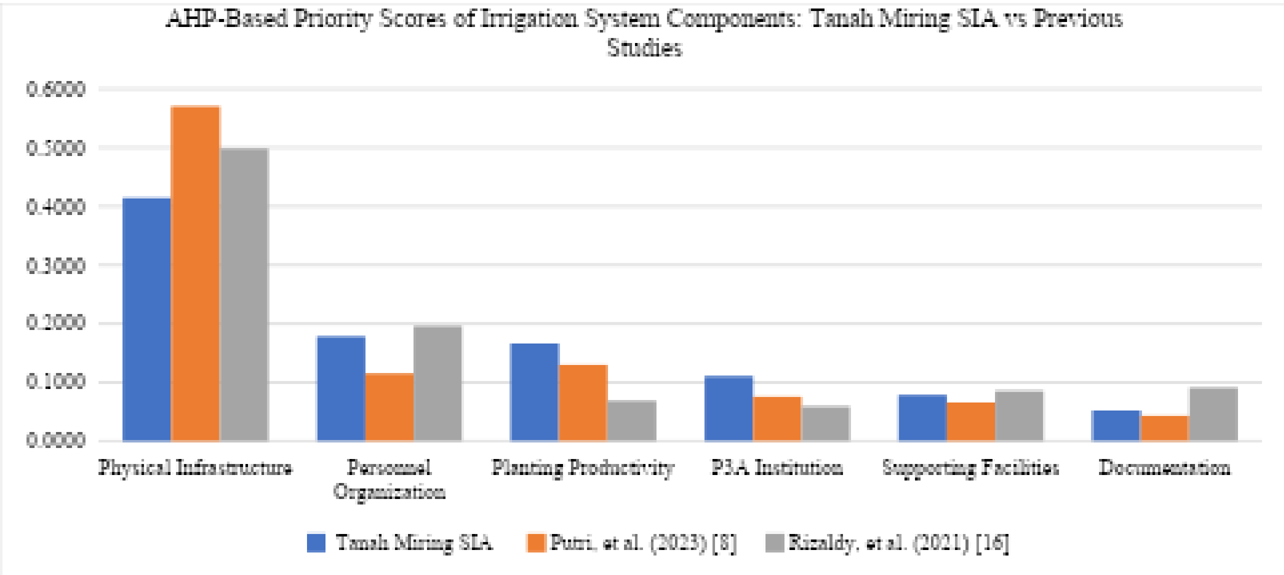

Fig. 4. AHP-Based Priority Scores of Irrigation System Components: Tanah Miring SIA vs Previous Studies

Table 8. AHP-Based Priority Order of Handling

Component	AHP-Based Priority Order of Handling		
	Tanah Miring SIA	Putri, et. al. (2023) [8]	Rizaldy, et. al. (2021) [16]
Physical Infrastructure	1	1	1
Personnel Organization	2	3	2
Planting Productivity	3	2	5
P3A Institution	4	4	6
Supporting Facilities	5	5	4
Documentation	6	6	3

Summary

This study assessed the performance of the Tanah Miring Swamp Irrigation Area (SIA) in Merauke Regency using the ePAKSI application and prioritized improvement measures through the Analytic Hierarchy Process (AHP) method. The performance evaluation resulted in an Irrigation System Performance Index Assessment (ISPIA) score of 72.18%, categorized as Good. Among the six components evaluated, physical infrastructure contributed the highest weight (29.10%), while documentation contributed the least (3.80%). The most severe damage was found in supporting facilities (48.00%), followed by physical infrastructure (35.33%) and documentation (24.00%), indicating the need for targeted maintenance and rehabilitation efforts.

The AHP analysis identified the following priority order for improvement: physical infrastructure, personnel organization, planting productivity, P3A institutions, supporting facilities, and documentation. Recommended interventions include routine and periodic maintenance, infrastructure rehabilitation, strengthening of organizational capacity, provision of operational tools, and enhancement of technical documentation. The integration of ePAKSI and AHP proves effective in facilitating data-driven decision-making for irrigation management. This approach may be replicated in other swamp irrigation areas to support sustainable infrastructure planning and optimize resource allocation.

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