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Evaluation of the Performance of Sustainable Irrigation Systems in Tertiary Networks in the Lamasi Kanan Irrigation Area, Luwu Regency

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Abstract: Sustainable irrigation management plays a crucial role in supporting efficient and environmentally friendly agriculture. This study aims to identify the existing condition of the irrigation network, analyze the performance index of the tertiary irrigation system, and explain the concept of sustainable irrigation management in the Lamasi Irrigation Area. The study was conducted at Lamasi Dam, Batusitanduk Village, Walenrang Sub-district, Luwu Regency, using a quantitative descriptive approach. Secondary data were obtained from maps and irrigation network schemes of the Public Works Department of South Sulawesi Province, while primary data were collected through field surveys related to the physical condition of irrigation channels and structures. Performance analysis used irrigation performance index indicators and the ePAKSI application. The results showed a reliable discharge of 10 m³/second with 78 water user farmer associations. Irrigation performance was classified as good with a value of 84.83%, while the tertiary irrigation network condition index was 73.30% (moderate category) as found in this study, with a damage level of 21–40% requiring regular maintenance. The conclusion indicates the need for improved network maintenance and strengthening collaboration between stakeholders based on information technology.

Keywords: ePAKSI; Irrigation area; System performance; Tertiary network; Sustainable

Introduction

Sustainable irrigation management is essential to support efficient and environmentally friendly agricultural production (Marzuki et al., 2023; Pratama et al., 2025). Irrigation plays a critical role in ensuring reliable water availability for agriculture; however, its sustainability is increasingly challenged by declining water resources, infrastructure degradation, and changes in the socio-economic conditions of farmers (Fulazzaky, 2017; Karim et al., 2022).

In Luwu Regency, agriculture constitutes a vital economic sector supported by favorable geographic and climatic conditions, which necessitate a well-managed and reliable irrigation system (Mohsen et al., 2013; Santoso et al., 2025). The Lamasi Dam, located in Batusitanduk Village, Walenrang Sub-District, functions as both a raw water source and an irrigation supply connected to the Lamasi Kanan irrigation network. Management of this system involves water user farmer associations (WUFA), which are responsible for water distribution, infrastructure maintenance, and regulation of water use among farmers (Sato et al., 2011; Pambudi, 2021).

Despite their strategic role, WUFAs face persistent managerial and technical challenges that often result in inefficient water use and declining irrigation infrastructure performance (Kustiani & Scott, 2014; Ariyanti, 2023). Consequently, systematic evaluation of irrigation system performance is crucial to identify existing conditions and management weaknesses (Frija et al., 2017; Rondhi et al., 2020). Recent advances in

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information technology, particularly the ePAKSI application, provide a data-driven approach for assessing irrigation network conditions and performance in a more efficient and integrated manner (Makbul & Desi, 2021).

However, previous studies have largely focused on partial technical evaluations or have not fully integrated physical infrastructure, operational performance, and institutional aspects of WUFA using digital-based assessment tools, particularly at the tertiary irrigation network level. Therefore, the novelty of this study lies in a comprehensive evaluation of tertiary irrigation system performance in the Lamasi Kanan Irrigation Area using the ePAKSI application, integrating physical, operational, and institutional dimensions to support sustainable irrigation management and evidence-based policy formulation.

Method

This research was conducted in the Lamasi Kanan Irrigation Area, Luwu Regency, South Sulawesi Province. The study area was selected using purposive sampling, based on the consideration that the Lamasi Kanan Irrigation Area is directly supplied by the Lamasi Dam and represents an area where agriculture is highly dependent on irrigation systems and managed by water user farmer associations (WUFA). This approach is appropriate for in-depth evaluation of irrigation system performance at the tertiary network level (Loureiro et al., 2023).

The unit of analysis in this study is the tertiary irrigation network. Six tertiary plots were purposively selected to represent variations in physical condition, service coverage, and management characteristics, namely: (1) L.1 Ki, (2) B.8 Ki.2, (3) B.St.1 Ka, (4) L.14 Ki, (5) P5 Ki.1, and (6) PP.6 Ka.

Data Types and Sources

This study utilized primary and secondary data. Secondary data consisted of irrigation network maps, irrigation building schemes, and irrigation channel layouts obtained from the Public Works and Spatial Planning Office of South Sulawesi Province. Primary data included the physical condition of irrigation channels and structures, the spatial position of assets, and photographic documentation collected through direct field surveys.

Primary data collection was conducted using the irrigation network tracing method, starting from the main structure (Lamasi Dam) to the selected tertiary irrigation plots. Data collection employed the ePAKSI application, which allows systematic recording of irrigation asset conditions, coordinates, photos, and supporting attributes. In addition, semi-structured interviews were conducted with irrigation operation and maintenance officers, irrigation observers, and representatives of water user farmer associations to support technical and institutional analysis.

Data Analysis

Data analysis was conducted in a structured sequence as follows:

1. Data preparation and verification

Field survey data were compiled, checked, and standardized according to the ePAKSI data format.

2. Spatial data processing

GPS data collected during field surveys were downloaded and processed using Garmin MapSource software to support spatial referencing and mapping of irrigation assets.

3. Irrigation performance assessment

The processed data were analyzed using the ePAKSI application to evaluate the condition and performance of irrigation assets, including physical infrastructure, operational aspects, and supporting institutional indicators.

4. Interpretation and Synthesis

The results of the ePAKSI assessment were interpreted to determine the irrigation performance index and to identify key issues affecting the sustainability of the tertiary irrigation system.

Justification of Methodological Consistency

In this study, purposive sampling is applied consistently for both site selection and unit analysis, as the research focuses on specific irrigation networks with defined technical and institutional characteristics. Therefore, the use of quota sampling is not applicable and has been excluded to maintain methodological clarity and coherence.

Result and Discussion

Existing Network Conditions

The Lamasi Kanan Irrigation Area is located in Luwu Regency at coordinates 2.844922° S and 120.118656° E, covering a potential irrigated area of 11,506 ha, of which 9,567 ha are currently functional. This indicates that approximately 83.1% of the potential area is actively served by irrigation, reflecting relatively good service coverage but also indicating untapped capacity.

The irrigation system is supported by two main dams and two auxiliary dams, which serve as the primary water sources. The canal network consists of 32.56 km of main canals, 93.35 km of secondary canals, 1.41 km of supplementary canals, and 0.34 km of drainage canals, distributing water through 49.53 km of

tertiary canals and 18.61 km of quaternary canals. Supporting infrastructure includes 232 regulating structures and 480 ancillary structures, such as siphons, flumes, and culverts, as well as two offices and twelve housing units. A summary of the existing conditions is presented in Table 1.

Table 1. Existing Condition of Lamasi Kanan Irrigation Area

Item	Volume	Unit
Irrigation Area (Potential)	11,506	Ha
Irrigation Area (Functional)	9,567	Ha
Main Dam	2	Unit
Suppression Dam	2	Unit
Main Canal	32.56	Km
Secondary Canal	93.35	Km
Supplement Canal	1.41	Km
Drainage Channel	0.34	Km
Flood Diversion Channel	0.00	Km
Carrying Channel	0.00	Km
Tertiary Channel	49.53	Km
Quarter Channel	18.61	Km
Tertiary Drainage Channel	0.10	Km
Pumps	0	Unit
Sludge Bags	2	Unit
Regulation Structures	232	Unit
Ancillary Buildings	480	Unit
Offices	2	Unit
Housing	12	Unit
Warehouses	0	Unit

The study focused on six tertiary canals, representing variations in physical dimensions, discharge capacity, and service area (Table 2). Canal lengths ranged from 364.65 m to 607.00 m, with measured discharges varying between 0.0361 and 0.1354 $m^3\ s^{-1}$. These differences reflect both hydraulic conditions and seasonal water demand, as the irrigation area practices two cropping seasons per year.

From an analytical perspective, the uneven discharge among tertiary canals suggests inequitable water distribution, which can potentially affect crop productivity and farmer satisfaction. This finding emphasizes the importance of regulating tertiary-level flows, where inefficiencies are most likely to occur but often least monitored.

The study area covers 9,806.38 hectares of land served by 78 registered water user farmer associations. The six tertiary canal sections focused on in the study vary in length and dimensions. Discharge data indicate differences in flow capacity across each canal section, as the study area has two growing seasons per year. The existing conditions used in assessing the performance of the irrigation system were based on field survey results and Minister of Public Works and Public Housing Regulation No. 12/PRT/M/2015.

Table 2. Research Location Survey

Tertiary Channel Name	Channel Length (M)	Debit (m3/ det)	Channel Dimensions Li (M)	b (M)	La (M)	H (M)
BL 1-L1 Ki	607	0.1176	0.30	2.4	0.30	0.8
BB 8 Ki-B 8Ki2	400	0.0361	0.30	0.70	0.30	0.8
ST.1 Ka	547	94.05	0.25	0.40	0.25	0.7
L 14 Ki	364.65	135.43	0.20	0.50	0.20	1
BP 5 – P 5 Kil	485.11	127.66	0.30	1.30	0.30	1
BPP 6 Ka-PP 6 Ka	529.04	127.59	0.26	1	0.26	1

Six aspects of irrigation system performance were assigned evaluation indicators and weighted assessments. Physical infrastructure performance received a weighting of 14.93%, and crop productivity received a weighting of 12.95%. Operational and maintenance conditions received a weighting of 13%, and water distribution officers received a weighting of 8.7%. Documentation received a weighting of 1.50%, and water user farmer associations received a weighting of 14.76%. The total weighting of each aspect was 65.84%, indicating that the irrigation system's performance fell into the moderate category.

Tertiary Irrigation System Performance Index Value

The performance index value of the left tertiary channel irrigation network system BL1-L1 Ki, nomenclature BL 1- L1 Ki, upstream building BL 1, downstream building L1 Ki, channel length 607 meters, channel service area 94.09 Ha. Good asset condition, value 85%, section 2 performance index value of the tertiary channel irrigation network system BB 8 Ki-B 8 Ki2.

Nomenclature: BB 8 Ki-B 8 Ki2, upstream building BB 8, downstream building T1, channel length 400 meters, channel service area 2,885 Ha. Good asset condition, value 85%, section 3 performance index value of the tertiary channel irrigation network system ST.1 Ka. Nomenclature st. 1 Ka, upstream building T1, downstream building ST 1 Ka, channel length 547 meters, channel service area 57 Ha.

Good asset condition, value 85%, section 4 performance index value of the tertiary channel irrigation network system L.14 Ki. Nomenclature L.14 Ki, upstream building T1, downstream building T2, channel length 364.65 meters. Channel service area 82.08 Ha, good asset condition, value 85%, segment 5 performance index value of tertiary channel irrigation network system BP 5 – P 5 Ki1.

Nomenclature BP 5 – P 5 Ki1, upstream building BP 5, downstream building P 5 Ki1, channel length 485.11 meters. Channel service area 77.37 Ha, good asset condition, value 84%, segment 6 performance index value of tertiary channel irrigation network system BPP

6 Ka-PP 6 Ka. Nomenclature BPP 6 Ka-PP 6 Ka, upstream building BPP 6, downstream building T1, channel length 529.04 meters, channel service area 77.33 Ha. Good asset condition, value 85%, irrigation system performance index value of the water user farmer association at the research location.

Assessment of physical infrastructure is carried out through field observation by tracing the irrigation network from upstream to downstream. Field conditions are evaluated for the performance assessment of the Tertiary irrigation system by the Regulation of the Minister of PUPR No. 12 / PRT / M / 2015. In the Lamasi Kanan Irrigation Area, the performance index value of the tertiary irrigation system in the physical infrastructure aspect is 30.47% of the maximum weight of 25%.

The results of the physical infrastructure assessment are produced from the carrier channel component of 9.97% of the maximum weight of 14%, and the building on the carrier channel of 4.96% of the maximum weight of 8%. In the physical infrastructure, several illegal tapping points and leaks were found, which affected the channel capacity, and in the lining channel, there was peeling/cracking/breaking of less than 20%.

The irrigation system performance index value for the aspect of crop productivity was 12.95% of the maximum weight of 15%. The results of the crop productivity assessment were generated from the water requirement fulfillment component of 8.68% of the maximum weight of 9%, the realization of the planted area of 2.27% of the maximum weight of 4%, and rice productivity of 1.99% of the maximum weight of 2%.

The assessment of the maintenance operation condition aspect obtained a value of 13% of the maximum weight of 20%. The results of the assessment of bobol (illegal taking) from tertiary channels were 4.20% of the maximum weight of 6%, Turns for water distribution during low discharge times were 3.40% of the maximum weight of 4%, tertiary channel cleaners were 4.20% of the maximum weight of 6%, and support equipment were 1.2% of the maximum weight of 4%.

The assessment for the personnel organization aspect obtained a value of 8.70% of the maximum weight of 15%. The results of the assessment of technical officers of the farmer user association of water are available 4.20% of the maximum weight of 6%, technical officers of the farmer user association of water have been trained 1.35% of the maximum weight of 4.5%, and technical officers of the farmer user association of water communicate with farmers and interpreters 3.15% of the maximum weight of 4.5%.

The assessment of the water user farmer association aspect obtained a value of 14.76% of the maximum weight of 20%. The results of the assessment of the water user farmer association were generated from the component of the water user farmer association already having a legal entity, amounting to 1.52% of the maximum weight of 2%. The institutional condition of the water user farmer association amounts to 2.21% of the maximum weight of 3%. Meetings of the water user farmer association with observers or agricultural extension officers' amount to 1.47% of the maximum weight of 2%.

The water user farmer association actively participated in surveys or network tracing, amounting to 2.21% of the maximum weight of 3%. The participation of the water user farmer association in network repair and natural disaster management amounts to 2.21% of the maximum weight of 3%. The water user farmer association contribution used for network repair amounts to 1.47% of the maximum weight of 2%. The participation of the water user farmer association in cropping planning and water allocation amounts to 2.21%. The maximum weight is 3% and the involvement of water user farmer associations, monitoring, and evaluation is 1.47% of the maximum weight of 2%.

Table 3. Irrigation System Performance Index Assessment

Tertiary Irrigation System

Component	Existing Condition Index	Maximum Weight	Total Value
Infrastructure	14.93	45	30.47
Plant Productivity	12.95	15	13.34
Operation Conditions	13.00	10	7.07
Water Distribution Officers	8.70	15	10.95
Documentation	1.5	5	3.58
Water User Farmers Association	14.76	10	7.89
Total	65.84	100	73.30

The Concept of a Sustainable Irrigation Network

Sustainable irrigation is water management focused on the efficient use of water resources to meet agricultural needs without disrupting the balance of the ecosystem. This ensures that agriculture does not damage the environment and maintains yields.

Irrigation is considered sustainable when it maintains water availability and minimizes the risk of water waste. Reliable water availability, with a reliable discharge of 10 m^3/second, indicates a sufficient water source to meet irrigation needs.

The number of farmer water user associations in 78 locations indicates a strong organizational structure for irrigation water management at the farmer level. The irrigation system performance score of 73.30% (moderate performance) based on Minister of Public Works and Public Housing Regulation No. 12/PRT/M/2015 indicates that the irrigation system is functioning well.

Physical infrastructure performance requires regular maintenance and improvements to maintain infrastructure condition. Plant productivity needs to be optimized to increase yields. Maintenance operations need to be maintained and efficiency improved. Water distribution officers need training and capacity building. Documentation needs to be improved to facilitate management and evaluation. P3A (Public Work Unit) needs continued support and empowerment.

The principles of sustainable irrigation, including efficient water use with a large, reliable flow rate, are essential for continuously improving water use efficiency through appropriate irrigation methods and sound management. Water resources management: The abundant availability of water must be maintained sustainably through prudent management, including water conservation and water catchment management. Environmental protection: irrigation systems must ensure they do not cause negative environmental impacts, such as erosion, salinization, or water pollution. Economic sustainability: irrigation must provide sustainable economic benefits to farmers by increasing their productivity and income. Social justice: all farmers must have equitable access to irrigation water, regardless of social or economic status.

Development measures include capacity building for water-using farmer associations and capacity building for farmers in irrigation management, including technical training, financial management, and decision-making. Infrastructure maintenance: routine maintenance and repair of irrigation infrastructure to ensure optimal performance. Technology utilization: the application of modern, more efficient, and environmentally friendly irrigation technologies. Monitoring and evaluation: regular monitoring and evaluation of irrigation system performance to identify problems and find solutions. Community involvement is involved in irrigation management, including decision-making and monitoring.

The availability of a reliable discharge of 10 $m^3\ s^{-1}$ and the presence of 78 registered WUFAs demonstrate favorable conditions for sustainable irrigation. However, sustainability requires more than water abundance. It depends on efficient use, environmental protection, economic viability, and social equity.

Key improvement priorities include:

1) Routine maintenance and sediment control to maintain channel capacity;
2) Strengthening operational management, particularly during low-discharge periods;
3) Capacity building for water distribution officers and WUFAs; and
4) Improving documentation and monitoring systems to support evidence-based decision-making.

Beyond its technical implications, this study offers strong potential as a contextual learning resource for natural sciences, particularly in topics related to environmental science and water resources. The Lamasi Kanan irrigation system can be used as a concrete example to illustrate: (a) Hydrological concepts, such as discharge, flow continuity, and sedimentation; (b) Environmental interactions, including erosion, water conservation, and ecosystem balance; (c) Human-environment systems, demonstrating how management practices affect natural resources; and (d) Scientific inquiry and systems thinking, by connecting field observations, data analysis, and sustainability principles.

Integrating local irrigation systems into natural science learning can enhance students' understanding of abstract scientific concepts by grounding them in observable environmental phenomena, thereby enhancing scientific literacy and environmental awareness.

Conclusion

The existing condition of the irrigation network system from the assessment results has a moderate performance with a value of 65.84%, based on the Regulation of the Minister of PUPR No.12/PRT/M/2015 if the existing condition value ≥ 60%, periodic maintenance is carried out in a remedial manner, every 5 years. The irrigation system performance index value at the research location, after using e-Paksi, is in the moderate category.

The tertiary irrigation network condition index value is 73.30%, included in the condition category (60% – 80%). Periodic maintenance is carried out in a remedial manner, every 5 years. The concept of the right-sided tertiary irrigation network system is stated to be sustainable if the water discharge relied on is 10 m3/second, continues to flow constantly for 5 years. The existing condition of the irrigation network system is as assessed results has a moderate performance. The

irrigation system performance index value at the research location.

After using e-Paksi, it is also in the moderate category. So that the association of water-using farmers located in 78 locations can have a planting season twice a year over 5 years. This gives farmers' organizations the potential to support optimal irrigation system management and sustainable agriculture by providing long-term benefits to farmers and the community.

The Lamasi Kanan irrigation area has significant potential to increase agricultural productivity in Luwu Regency. Existing infrastructure is generally adequate. However, several aspects require greater attention to achieve more efficient and sustainable irrigation management. The irrigation system performance index assessment shows that overall irrigation system performance is in the moderate category.

Several aspects require greater attention to improve the efficiency and sustainability of the irrigation system. This proposed sustainable irrigation network concept provides a comprehensive framework for improving irrigation management by water-using farmer associations. This concept emphasizes the importance of active participation by water-using farmer associations, the use of information technology, good governance, and multi-stakeholder involvement.

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Conflicts of Interest

The author declares that there is no conflict of interest with any party.

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