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Analysis Of Water Use Efficiency in Antokan Irrigation

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ABSTRACT

Water plays a crucial role in agricultural productivity and food security, particularly in irrigated rice farming systems. However, seasonal water shortages and inefficient water management often reduce crop yields in several irrigation areas. This study aimed to evaluate irrigation water use efficiency in the Antokan Irrigation Area, Nagari Manggopoh, Agam Regency, West Sumatra, to support more effective water management strategies. The evaluation was conducted through field measurements of irrigation discharge and channel efficiency, combined with calculations of irrigation water requirements based on consumptive use, land preparation needs, percolation losses, and effective rainfall. Water balance analysis was also applied to assess the adequacy of water supply. The results showed that water availability in the Namuang Saiyo irrigation channel reached 0.061 m³/s, while the total irrigation water requirement was 0.051 m³/s. The irrigation channel efficiency was 94.81%, indicating good hydraulic performance and minimal conveyance losses. The overall irrigation water use efficiency reached 83.29%, classified as efficient. These findings indicate that the Antokan irrigation system is capable of meeting crop water requirements optimally and can serve as a reference for improving irrigation management in similar agricultural areas.

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1. Introduction

Water plays a highly vital role in farming communities in efforts to improve food security and agricultural productivity [1]. One of the most important strategies to support food availability is the development of irrigation infrastructure, as irrigation ensures a reliable and continuous water supply for agricultural land, even when fields are located far

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from surface water sources such as rivers. To guarantee efficient and equitable water distribution, the construction of permanent irrigation channels is essential. Permanent channels enable better monitoring and control of water flow, allowing appropriate volumes of water to be delivered to paddy fields while preventing both excess supply and water shortages, thereby ensuring that crop water requirements are adequately met [2].

The performance of an irrigation system can be evaluated using water use efficiency (WUE), which represents the ratio between the amount of water effectively utilized by crops and the total volume of water supplied through the irrigation network [6]. Low irrigation water use efficiency is commonly associated with high conveyance losses, uneven water distribution, and inadequate irrigation management, conditions that may ultimately reduce agricultural productivity [7]. As pressure on water resources continues to increase due to population growth, climate change, and rising agricultural water demand, improving irrigation efficiency has become increasingly important [8]. Previous studies have shown that the application of appropriate irrigation methods combined with improved management practices can significantly enhance both water use efficiency and crop yields [9,10].

Irrigation efficiency is a key element of sustainable water resource management and is generally defined as the ratio between the amount of water effectively used by crops and the amount of water supplied to agricultural fields. Improving irrigation efficiency is essential for minimizing water losses, increasing crop productivity, and reducing environmental impacts associated with irrigation runoff. Several factors influence irrigation efficiency, including irrigation system design and management, crop water requirements, soil characteristics, and climatic conditions. Consequently, these factors must be carefully considered when evaluating irrigation performance and formulating strategies for improvement. Irrigation efficiency can be divided into conveyance efficiency, which relates to the main canal network, and field efficiency, which includes secondary and tertiary canals as well as water distribution structures up to the paddy plots [3].

The concept of irrigation efficiency is based on the recognition that water losses occur both along irrigation channels and within agricultural fields. Water losses may take place at the primary, secondary, and tertiary canal levels, depending on factors such as canal length, wetted perimeter, surface area, and groundwater conditions [4]. These losses generally result from seepage, percolation, and evaporation. While some

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losses due to evaporation and seepage are unavoidable, excessive water use caused by inefficient irrigation practices can lead to substantially greater losses. Therefore, improving irrigation infrastructure and conducting regular monitoring are essential to ensure that available water discharge is utilized optimally to enhance agricultural productivity.

The Antokan Irrigation Scheme, located in Agam Regency, West Sumatra Province, utilizes water from the Batang Antokan River as its primary source for agricultural irrigation. This irrigation system plays a crucial role in supporting local food security, particularly for irrigated rice fields in the region [11]. The Antokan Irrigation System in Nagari Manggopoh, Tilatang Kamang District, is recognized as one of the top five rice-producing areas in West Sumatra [12]. Ideally, such a productive irrigation area should have sufficient and reliable water availability. However, in practice, water shortages still occur during certain periods and at specific locations, resulting in suboptimal rice yields.

These shortages are often linked to excessive and inefficient water use, such as continuous flooding practices that significantly increase overall water demand. In contrast, rice irrigation can be managed using intermittent irrigation methods, which are known to reduce water consumption while promoting better root aeration and deeper root development. Therefore, an analysis of water use efficiency in the Antokan Irrigation Scheme is essential to assess the effectiveness of water utilization from the water source to the agricultural fields. The results of this evaluation are expected to provide a scientific basis for developing strategies to improve irrigation performance through better water distribution management, reduced conveyance losses, and more efficient and equitable water use among farmers [9,10].

2. Materials and Method

The research stages involved field data collection, irrigation evaluation data analysis, and result processing. The main tools used included ArcGIS software, Microsoft Excel, Microsoft Word, and supporting instruments such as smartphones and questionnaires. The research procedure involved the collection of secondary data, which were obtained from indirect sources such as government agencies. These data included information on the administrative boundaries of Nagari Koto Tangah,

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Tilatang Kamang District, Agam Regency, the Antokan Irrigation Area map, and climatological data from Nagari Manggopoh.

3. Result

Site Description

The Antokan Irrigation Area is geographically located at 0°18′56.9″ South Latitude and 100°06′37.3″ East Longitude, within Nagari Manggopoh, Lubuk Basung District, Agam Regency, West Sumatra Province. The Antokan Irrigation System supplies water to approximately 70 ha of irrigated rice fields, while detailed field measurements in this study were conducted over an area of 24.4 ha.

Nagari Manggopoh covers an area of about 45.85 km² and consists of nine *jorong* (sub-villages), namely Kubu Anau, Anak Aia Dadok, Pasar Durian, Batu Hampar, Balai Satu, Sago, Padang Tongga, Padang Mardani, and Kajai Pisik. The study area is situated at an elevation of approximately 420 m above sea level, with average air temperatures ranging from 25 to 30 °C. Annual rainfall reaches around 2,000 mm, supporting dominant agricultural activities such as rice cultivation, maize, and horticultural crops.

Irrigation Water Requirement

The irrigation water requirement is calculated by taking into account factors such as consumptive water needs, land preparation, percolation, effective rainfall, and irrigation channel efficiency. Based on the calculations, the total irrigation water requirement is 0.051 m^3/s.

Land Preparation

The paddy fields are cultivated twice a year using tractors. Based on the Water Balance method, the water requirement for land preparation is 11 mm/day, as obtained from the Antokan Irrigation Station.

Consumptive Water Requirement (ETc)

The measurement of consumptive water needs was conducted for three growth phases of rice:

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- Vegetative phase (0–30 DAS): 5.262 mm/day
- Active growth phase (31–60 DAS): 9.233 mm/day
- Maturation phase (61–90 DAS): 5.551 mm/day

Percolation

The soil, classified as sandy clay, has a percolation rate of 6 mm/day.

Table 1. Percolation Observation Results

Time (minutes)	Water Loss (mm)
5	3,5
10	1
15	0,5
20	0,5
25	0,5
35	0
45	0
55	0
Total	**6**

Effective Rainfall

The effective rainfall available for rice crops is 0.047 mm/day, based on data from the AWS and the Antokan Irrigation Agricultural Station.

Irrigation Channel Efficiency

The irrigation channel efficiency is 94.81%, calculated from the ratio of inflow to outflow in a 150-meter-long channel.

Table 2. Irrigation Channel Efficiency in the Antokan Irrigation System

Location	Efficiency (%)				Average
	1	2	3	4	
Upstream	98,2	97,5	98,2	97,9	97,95
Middle	97,6	97,4	97,4	97,3	97,4

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Downstream	87,4	88,9	91,2	89,00	89,1
Total					**94,81**

Water Balance Analysis

The water availability during the land preparation stage reached 1.764 m^3/s over 21 days (averaging 0.084 m^3/s per day). Meanwhile, the average water availability during the rice growth period (0–90 DAS) was 0.046 m^3/s. The total water requirement during the planting period was 0.592 m^3/s, which is lower than the available water, indicating that the irrigation system is functioning optimally.

Irrigation Water Requirement Analysis

- Land preparation: 0.677 m^3/s (0.032 m^3/s daily)
- Vegetative phase: 0.096 m^3/s (0.003 m^3/s daily)
- Generative phase: 0.495 m^3/s (0.015 m^3/s daily)
- Overall total: 0.051 m^3/s

Evaluation of Irrigation Water Use Efficiency

Table 3. Evaluation of Irrigation Water Use Efficiency in the Antokan Irrigation System

No	Description	Area (Ha)	Requirement (m^3/s)	Water Availability (m^3/s)	Efficiency (%)
1	Land Preparation	13,1	0,032	0,061	52,311
2	Generative Phase	9,8	0,015		25,92
3	Vegetative Phase	1,5	0,003		5,05

The total efficiency of irrigation water use reached 83.29%, which is considered good [13].

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4. Discussion

The results of this study indicate that water availability in the Antokan Irrigation Area is generally sufficient to meet irrigation requirements throughout the rice growing period. The high irrigation channel efficiency reflects favorable physical conditions of the canal network and effective water conveyance management. The measured channel efficiency exceeds the standard efficiency range for primary irrigation canals (87.5–92.5%) as defined by the Directorate General of Irrigation (1986), suggesting that conveyance losses due to seepage and leakage are relatively minimal in this system. Similar findings have been reported in previous studies, which emphasize that well-maintained irrigation infrastructure plays a critical role in improving overall irrigation performance and water use efficiency [7,3].

Variations in irrigation water requirements across rice growth stages observed in this study are consistent with crop physiological characteristics. Higher water demand during the generative phase is associated with increased metabolic activity during panicle initiation, flowering, and grain filling. This pattern aligns with findings from earlier studies, which reported that water stress during the generative stage can significantly reduce rice yield and water productivity [9,10]. Therefore, prioritizing water allocation during this critical growth stage is essential for maintaining crop productivity.

The percolation rate observed in the study area reflects the influence of sandy clay soil texture, which allows relatively high infiltration compared to heavier soils. Similar percolation rates have been reported in other irrigated rice fields with comparable soil characteristics [4]. While percolation losses cannot be entirely avoided, inefficient irrigation practices, such as prolonged continuous flooding, may exacerbate water losses. This highlights the importance of improved irrigation scheduling and the potential application of intermittent irrigation techniques to reduce unnecessary water use while maintaining favorable soil moisture conditions.

The low effective rainfall recorded during the study period indicates that irrigation water supply from the canal system remains the dominant source of water for rice cultivation in the Antokan Irrigation Area. Under such conditions, efficient management of canal water distribution becomes increasingly important. The overall irrigation water use efficiency achieved in this study demonstrates that the system is

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capable of utilizing available water effectively, comparable to efficiency levels reported in other irrigation schemes in Indonesia with well-functioning canal networks [6,8].

From a practical perspective, the findings suggest several implications for irrigation management in the field. Regular maintenance of downstream canal sections is necessary to prevent efficiency decline and ensure equitable water distribution among farmers. In addition, optimizing irrigation scheduling based on crop growth stages and promoting water-saving irrigation practices could further enhance water use efficiency. The presence of surplus water availability also indicates opportunities to increase planting intensity or expand irrigated areas, provided that water distribution is managed carefully to avoid conflicts among water users.

Overall, this study confirms that the Antokan irrigation system exhibits good hydraulic performance and efficient water use, supporting sustainable rice production and local food security. These results provide valuable insights for irrigation managers and policymakers in developing effective water management strategies for similar irrigation systems facing increasing pressure on water resources.

5. Conclusions

Based on the study results, water availability in the Antokan Irrigation System was recorded at 0.061 m^3/s, while the water requirement reached 0.051 m^3/s. The irrigation channel efficiency was 94.837%, and the overall water use efficiency during the study period was 83.288%. These results indicate that the Antokan irrigation channels are still functioning well, as they are able to meet irrigation water needs optimally. This is evidenced by the fact that water availability exceeds irrigation demand. The system can serve as a model for effective water management in other regions with similar conditions.

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