

COMPARISON OF IRRIGATION WATER REQUIREMENTS: KP-01 AND CROPWAT 8.0 METHODS APPROACH FOR RENTANG IRRIGATION IN MAJALENGKA REGENCY

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Abstrak

This study aims to compare the results of the calculation of irrigation water requirements between the KP-01 method and Cropwat 8.0 software in the Range Irrigation Area, Majalengka Regency. The research method used is a quantitative approach with a comparative method. The data used includes climate and rainfall data for the last 10 years (2014 - 2023) from Kertajati Meteorological Station, Jatiwangi Meteorological Station, and Ciwaringin Rain Station. The results showed that the irrigation water requirement calculated by the KP-01 method was higher than Cropwat 8.0. In the KP-01 method, the average irrigation requirement reached 0.85 lt/second/ha, with the highest requirement of 2.01 lt/second/ha (November I) and the lowest of 0.00 lt/second/ha. Meanwhile, the Cropwat 8.0 method shows an average water requirement of 0.36 lt/sec/ha, with the highest requirement of 1.14 lt/sec/ha (November) and the lowest of 0.05 lt/sec/ha (July). This difference is due to variations in the calculation methods in both methods.

Kata kunci: irigasi, KP-01, Cropwat 8.0, evapotranspiration, effective rainfall

INTRODUCTION

Irrigation is the provision, regulation, and disposal of irrigation water to support agriculture, including surface irrigation, swamp irrigation, groundwater irrigation, pump irrigation, and fishpond irrigation (Peraturan Menteri Pekerjaan Umum Dan Perumahan Rakyat Republik Indonesia Nomor 14/PRT/M/2015 Tentang Kriteria Dan Penetapan Status Daerah Irigasi, 2015). Irrigation is a key factor in optimizing agricultural production. Accurate determination of irrigation water needs is crucial for efficient water resource management. The irrigation water requirement is the amount of water volume needed to meet evapotranspiration, water loss, and plant water needs, considering natural water input through rainfall and groundwater contribution (Sidharta, 1997). In Indonesia, the KP-01 method has long been the standard for irrigation planning. However, with technological advancements, software like Cropwat 8.0 developed by the FAO offers an alternative approach for calculating irrigation water requirements.

The KP-01 method is a conventional irrigation planning approach that has long been adopted in Indonesia. It is based on empirical calculations using climatic parameters and regional characteristics. This method calculates irrigation water requirements by

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considering evapotranspiration, effective rainfall, crop coefficients, and losses due to percolation and evaporation. While KP-01 is widely used and supported by clear technical guidelines, it has limitations in adapting to the increasing variability of climate and the dynamic nature of agricultural practices.

In contrast, Cropwat 8.0, a software developed by the FAO, introduces a modern and computational approach to estimating irrigation needs. It utilizes the Penman-Monteith method—considered a global standard by FAO for reference evapotranspiration—and incorporates various data inputs such as historical climate data, crop types, soil characteristics, and cropping patterns. Its key advantage lies in its ability to simulate different planting scenarios, enabling planners to explore and optimize irrigation strategies under varying environmental and agronomic conditions.

For the Rentang Irrigation Area in Majalengka Regency, comparing the KP-01 and Cropwat methods is highly relevant. This region experiences considerable variability in rainfall and temperature throughout the year, making efficient and adaptive water management vital for sustaining agricultural productivity. By applying both methods to the same geographic and climatic context, this study seeks to assess whether traditional methods remain valid or if modern tools like Cropwat offer superior accuracy and efficiency in irrigation planning.

Moreover, the comparison not only highlights the quantitative differences in estimated water requirements but also reveals methodological contrasts in computing variables like evapotranspiration and effective rainfall. For instance, the KP-01 method applies fixed coefficients for effective rainfall, while Cropwat uses the FAO/AGLW model, which tends to yield lower effective rainfall values. These differences in assumptions and computational procedures have a significant impact on the final estimation of irrigation water needs.

The deeper analysis of both methods is expected to provide valuable insights for water resource planners and policymakers in selecting appropriate tools for irrigation planning. In an era where water scarcity is becoming more pronounced due to climate change and increasing agricultural demand, choosing the most effective and context-appropriate method is essential to ensure food security and sustainability in water management.

The accurate calculation of irrigation water requirements is critical in sustaining agricultural productivity and efficient water use. However, discrepancies in estimation results between conventional methods like KP-01 and modern tools such as Cropwat 8.0 often lead to confusion in selecting the most suitable approach for a specific region, especially in areas with fluctuating climatic conditions like the Rentang Irrigation Area in Majalengka. This poses a challenge in determining which method yields more reliable data for irrigation planning.

As climate change increasingly affects rainfall patterns and evapotranspiration rates, the urgency to adapt irrigation planning methods becomes more pronounced. Traditional systems, while proven historically, may no longer be adequate to respond to

rapidly changing environmental conditions. Simultaneously, water scarcity has become a pressing issue, urging the need for precision in water allocation for agriculture.

Furthermore, the government's commitment to modernizing irrigation infrastructure demands the integration of advanced tools and decision-support systems into agricultural water management. By assessing the performance of both KP-01 and Cropwat 8.0, this study contributes to the national agenda of developing sustainable irrigation policies and technological innovations in agronomy.

Previous research has explored this topic. Susilowati et al. optimized planting schedules and irrigation in the Ciliman Irrigation Area, increasing the Planting Index (IP) from 199.7% to 213.7% with 100% reliability (Susilowati et al., 2020). Anggraeni and Kalsim (2013) compared rice irrigation needs between the KP-01 method and Cropwat 8.0, finding that the KP-01 method provided higher water estimates (Anggraeni & Kalsim, 2013). Laurentia and Arlensietami (2022) applied Cropwat 8.0 to optimize planting patterns in Gunungpati District, showing that changing cropping patterns can significantly reduce water requirements (Laurentia & Arlensietami, 2022).

Despite existing studies comparing irrigation models, there remains a lack of localized evaluations in the Rentang Irrigation Area of Majalengka, where climatic and agronomic conditions may influence the effectiveness of both KP-01 and Cropwat 8.0 methods. Few studies have provided a month-by-month comparison of irrigation requirements using real multi-year data, especially focusing on deviations between evapotranspiration and effective rainfall estimation techniques.

This research provides a unique contribution by directly comparing KP-01 and Cropwat 8.0 over a 10-year climatic dataset specific to the Rentang area. It includes detailed monthly analyses, incorporates both rice and secondary crop cycles, and highlights the computational differences in evapotranspiration and rainfall processing, offering practical implications for region-specific irrigation policy.

Based on these studies, there is a need for further research comparing the KP-01 and Cropwat 8.0 methods in specific contexts. This study aims to compare the irrigation water requirement calculations between the KP-01 and Cropwat 8.0 methods in the Rentang Irrigation Area, Majalengka Regency, and identify factors causing differences in the results between the two methods. The findings of this study are expected to provide new insights into choosing the appropriate method for irrigation planning in the study area and other regions with similar characteristics.

Methodology

This research uses a quantitative approach with a comparative method. The study location is the Rentang Irrigation Area in Majalengka Regency. The data used includes climate data (average temperature, humidity, wind speed, and sunshine duration) and rainfall data from the past 10 years (2014–2023) from the Kertajati Meteorological Station, Jatiwangi Meteorological Station, and Ciwaringin Rainfall Station.

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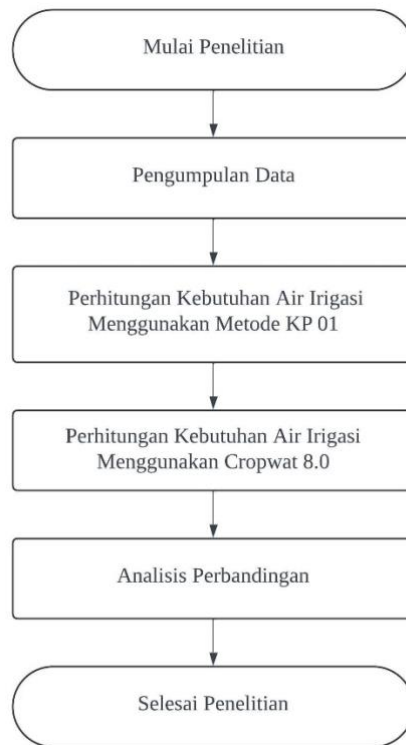


Figure 1
Methodology

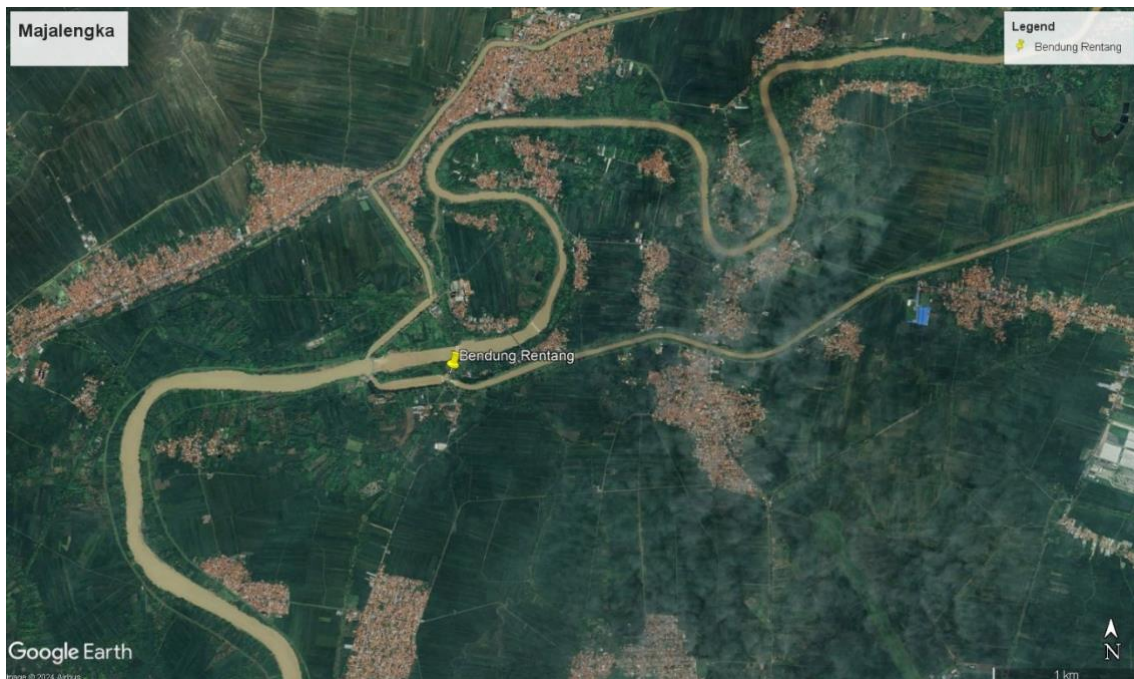


Figure 2
Research Location

The irrigation water requirements were calculated using two methods:

1. KP-01 Method: This includes calculations for water needs during land preparation, consumptive use, percolation, water layer replacement, and effective rainfall (Kementerian Pekerjaan Umum, 2013).
2. Cropwat 8.0 Method: Cropwat is a decision support system developed by FAO's Land and Water Development Division based on the Penman-Monteith method to plan and manage irrigation (Katarina Manik et al., n.d.). In the Cropwat 8.0 software, climate data is needed for evapotranspiration, effective rainfall, crop data, soil data, and cropping patterns.

In the KP-01 Method, crop coefficients were taken from the Irrigation Planning Criteria standards (Kementerian Pekerjaan Umum, 2013):

Table 1 Rice Crop Coefficients

Month	Nedeco / Prosida		FAO	
	Regular Variety	High Yield Variety	Regular Variety	High Yield Variety
0,5	1,20	1,20	1,10	1,10
1,0	1,20	1,27	1,10	1,10
1,5	1,32	1,33	1,10	1,05
2,0	1,40	1,30	1,10	1,05
2,5	1,35	1,30	1,10	0,95
3,0	1,24	0	1,05	0
3,5	1,12		0,95	
4,0	0		0	

Source: Kementerian Pekerjaan Umum, Kriteria Perencanaan 01, 2013

Table 2 Nilai Koefisien untuk Tanaman Palawija

Crop	Growth Period (days)	½ Month No.	Koeffisien					
			1	2	3	4	5	6
Maize	80		0,5	0,59	0,96	1,05	1,02	0,95

Source: Kementerian Pekerjaan Umum, Kriteria Perencanaan 01, 2013

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Meanwhile, in Cropwat 8.0, crop coefficients are determined according to FAO Irrigation and Drainage Paper No. 24. (Doorenbos & Pruitt, 1977)

RICE DATA
(File: C:\ProgramData\CROPWAT\data\crops\FAO\PADDY.CRO)

Crop Name: PADDY		Transplanting date: 0112/19/94				Harvest: 23/02/1995		
Stage	nursery	landprep		initial	growth stage		total	
		total	puddling		develop	mid		late
Length (days)	30	20	5	20	25	20	20	115
Kc dry	0,70		0,30	0,50	-->	1,05	0,70	
Kc wet	1,20		1,05	1,10	-->	1,20	1,05	
Rooting depth (m)				0,10	-->	0,60	0,60	
Puddling depth (m)			0,40					
Nursery area (%)	10							
Critical depletion	0,20			0,20	-->	0,20	0,20	
Yield response f.				1,00	1,09	1,09	1,09	1,09
Cropheight (m)						1,00		

Figure 3
Rice Crop Coefficient Values in Cropwat 8.0

DRY CROP DATA
(File: C:\ProgramData\CROPWAT\data\crops\FAO\MAIZE.CRO)

Crop Name: MAIZE (Grain)		Planting date: 17/06			Harvest: 19/10	
Stage	initial	develop	mid	late	total	
Length (days)	20	35	40	30	125	
Kc Values	0,30	-->	1,20	0,35		
Rooting depth (m)	0,30	-->	1,00	1,00		
Critical depletion	0,55	-->	0,55	0,80		
Yield response f.	0,40	0,40	1,30	0,50	1,25	
Cropheight (m)			2,00			

Figure 4
Secondary Crop Coefficient Values in Cropwat 8.0

Results and Discussion

Reference Evapotranspiration (ET₀)

Reference evapotranspiration is the evapotranspiration of a reference crop, namely short grass. ET₀ reflects evaporation under meteorological conditions such as temperature, solar radiation, humidity, and wind (Kementerian Pekerjaan Umum, 2013).

The results show that the ET₀ value in the KP-01 method is on average 18% higher than in Cropwat 8.0. This difference is due to the use of different methods, where KP-01 employs the Modified Penman method, while Cropwat 8.0 uses the Penman-Monteith

method. The latter provides a more accurate estimation, which is why FAO recommends it for estimating standard evapotranspiration rates (Shalsabillah et al., 2019).

The KP-01 method uses the following Modified Penman equation: (Doorenbos & Pruitt, 1977)

$$ET_0 = c[W \cdot R_n + (1 - W) \cdot f(u) \cdot (ea - ed)]$$

where,

ET_0 : Reference crop evapotranspiration in mm/day

W : Temperature-related weighting factor

R_n : Net radiation in equivalent evaporation in mm/day

$f(u)$: Wind-related function

$(ea - ed)$: Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar

c : Adjustment factor to compensate for the effect of day and night weather conditions

Meanwhile, Cropwat 8.0 uses the Penman-Monteith equation:

$$ET_0 = \frac{0,408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0,34U_2)}$$

di mana,

ET_0 : Reference evapotranspiration (mm/day)

R_n : Net radiation at the crop surface (MJ/m²/day)

G : Soil heat flux density (MJ/m²/day)

T : Air temperature at 2 meters height (°C)

U_2 : Wind speed at 2 meters height (m/s)

e_s : Saturation vapor pressure (kPa)

e_a : Actual vapor pressure (kPa)

Δ : Slope vapor pressure curve (kPa/°C)

γ : Psychrometric constant (kPa/°C)

Table 3
Comparison of ET0 Values in Cropwat 8.0 and KP-01

Month	CROPWAT (mm/day)	KP-01 (mm/day)
January	3,33	4,16
February	3,09	3,87
March	3,47	3,90
April	3,53	3,60
May	3,50	3,57
June	3,26	3,41
July	3,65	3,91

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August	4,16	4,98
September	4,58	6,08
October	4,56	5,97
November	3,92	4,96
December	3,50	4,34

Effective Rainfall

The rainfall needed for planning water usage and flood control is the average rainfall across the entire region, not just at specific points. This regional rainfall is expressed in millimeters (Sosrodarsono & Takeda, 2003). One common method for calculating regional rainfall is the Thiessen Polygon Method, which takes into account the weight of each station representing the surrounding area. In this method, rainfall recorded at a station represents the area around it, making it suitable when rainfall stations are not evenly distributed. Average rainfall calculations are done by considering the area influenced by each station (Triatmodjo, 2019).

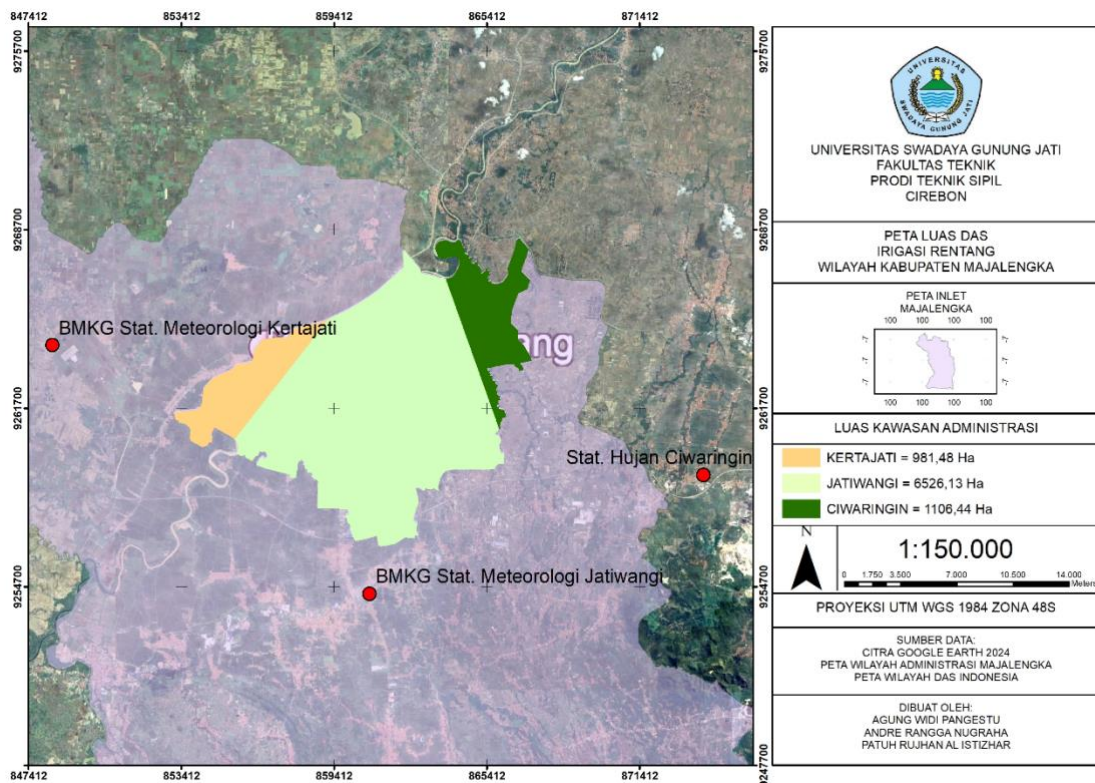


Figure 5
Map of the Watershed Area in the Rentang Irrigation Area

To calculate effective rainfall for irrigation, the R80 reliable rainfall is used, which is the rainfall that can be exceeded 80% of the time (Nurdiyanto, 2019). In the KP-01 method, this reliable rainfall is multiplied by a factor of 70% for rice and 50% for secondary crops. Meanwhile, in Cropwat 8.0, the FAO/AGLW formula is recommended

for estimating effective rainfall to avoid water shortages. This is because the method provides smaller effective rainfall values compared to other methods in Cropwat (Bokke & Shoro, 2020).

In the KP-01 method, effective rainfall is calculated as follows:

$$Re\ rice = 70\% \times R80$$

$$Re\ secondary\ crop = 50\% \times R80$$

In Cropwat 8.0, the FAO/AGLW method uses the following formula:

$$P_{eff} = 0,6 \times P - 10\ \text{untuk}\ P \leq 70\ \text{mm}$$

$$P_{eff} = 0,8 \times P - 24\ \text{untuk}\ P > 70\ \text{mm}$$

Table 4 Comparison of Effective Rainfall

Month		KP-01 (mm/month)	Cropwat 8.0 (mm/month)
Jan	1	95,47	47,1
	2	155,17	
Feb	1	79,50	66,6
	2	28,00	
Mar	1	178,05	125,1
	2	189,92	
Apr	1	89,36	76,0
	2	139,36	
May	1	86,26	36,2
	2	145,34	
Jun	1	78,61	41,9
	2	30,00	
Jul	1	29,33	59,8
	2	36,92	
Aug	1	71,67	0,0
	2	83,61	
Sep	1	92,98	0,0
	2	86,60	
Oct	1	0,00	0,0
	2	0,00	
Nov	1	189,10	27,2
	2	189,10	
Dec	1	101,63	33,6
	2	161,74	

Net Field Requirement

In KP-01, the calculation of irrigation water requirements for rice crops is determined by the formula:

$$NFR = ET_C + P - Re + WLR$$

where,

NFR : Net Field Requirement (mm/day)

ET_C : Crop evapotranspiration (mm/day)

P : Percolation (mm/day)

Re : Effective rainfall (mm/day)

WLR : Water Layer Replacement (mm/day)

For irrigation water requirements during land preparation, the following formula is used:

$$NFR = IR - Re$$

where,

NFR : Net Field Requirement (mm/day)

IR : Water requirement during preparation (mm/day)

Re : Effective rainfall (mm/day)

The water requirement for land preparation itself is calculated using a formula developed by Van de Goor and Zijlstra (Goor & Zijlstra, 1982):

$$IR = M e^k / (e^k - 1)$$

IR : Irrigation water requirement at field level, mm/day

M : Water requirement to replace/compensate for water loss due to evaporation and percolation in saturated rice fields $M = E_0 + P$, mm/day

E_0 : Open water evaporation taken as $1.1 \cdot ET_0$ during land preparation, mm/day

P : Percolation

K : MT/S

T : Land preparation time, (days)

S : Water requirement for saturation plus a 50 mm water layer.

Meanwhile, the water requirement for secondary crops is determined by the formula:

$$NFR = ET_C - Re$$

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NFR : Net Field Requirement (mm/day)

ET_C : Crop evapotranspiration (mm/day)

Re : Effective rainfall (mm/day)

Diversion Requirement (DR)

To determine the Diversion Requirement (DR), the total water requirement in the rice field is divided by the irrigation efficiency. The unit is converted to liters/second/hectare by dividing the DR value by 8.64. The Diversion Requirement can be calculated using the following formula: (Srijayanti & Anwar, 2017)

$$DR = \frac{NFR}{E \times 8,64}$$

where,

DR : Diversion Requirement (liters/second/hectare)

NFR : Net Field Requirement (mm/day)

E : Irrigation efficiency (0,65)

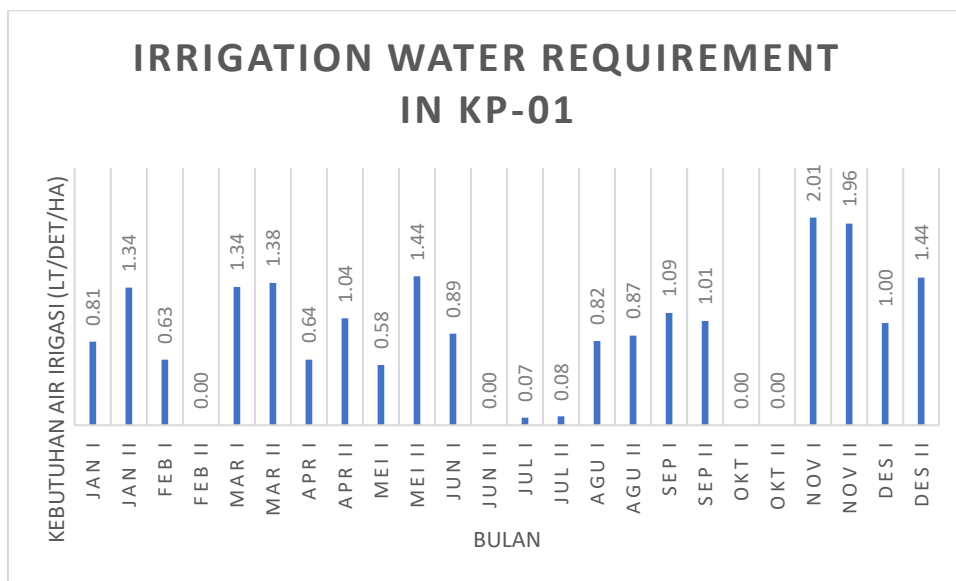


Figure 6
Irrigation Water Requirement in KP-01

for conservative water planning or regions with abundant water supply, Cropwat 8.0 is better suited to areas facing water constraints, as it supports more efficient resource allocation. In line with this, future studies should consider validating these results across different agro-ecological zones, integrating real-time meteorological data, and exploring hybrid approaches that combine empirical and model-based methods. Such developments can contribute to the advancement of precision irrigation planning and sustainable agricultural water use amid increasing climatic uncertainties.

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