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Regional Case Study

Analysis of Irrigation Water Balance in Garum and Jatisari Irrigation Area, Ngajum, Malang Regency

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Abstract
The irrigation water requirement must be balanced with the available water to support plant growth and increase agricultural production. Therefore, information regarding the amount of water needed and its availability is essential for irrigation activities. This research analyzed the water flow availability at the Garum DAM intake using the Weibull method, irrigation water requirement in the Garum and Jatisari irrigation areas using Cropwat 8.0 software (Penman-Monteith Method), and water balance between water availability and the irrigation water requirement of the Garum and Jatisari irrigation areas using a comparative method. The data used included intake flow, climate, rainfall, soil, and plant data. The results of this study show that the water flow available at the Garum DAM intake tends to be high in the rainy season and will tend to be lower in the dry season. Furthermore, the water requirement in the Garum and Jatisari irrigation areas tends to be high during the dry season and decreases during the rainy season. The water balance shows that the water available at the Garum DAM intake cannot fulfill the irrigation water requirement of the Garum and Jatisari irrigation areas. This is because of the lack of a water deficit in certain months.

Keywords: Water balance; Garum Irrigation area; Jatisari Irrigation area

1. Introduction

The agricultural sector influences food availability. Agriculture depends on water resources. The potential of water resources varies between regions and in quantity, causing water shortages in certain areas and not maximizing agricultural production. Providing water that meets the agricultural needs of rice fields is a factor that influences increased agricultural yields (Anisarida and Hafudiansyah, 2022). The agricultural water requirement is the amount of water needed by plants in a rice field area to support plant growth so that plants can grow well and provide satisfactory results (Sabilau et al., 2021). Agricultural water is required by plants during the growth process to fulfill the crop water requirement due to the water loss process, either due to evapotranspiration, seepage, or leaks along the canals (Purba, 2011). Agricultural water needs can be fulfilled by precipitation or river water, which is streamed through irrigation canals to rice fields. Providing water for Agricultural water requirements can be met by building an irrigation system (Faishal, 2013).

Water management for agricultural land is essential. Water that enters agricultural land can originate from dammed river water. The regulation of water entering agricultural land must be adjusted to meet agricultural water needs. In addition to maintaining the agricultural water balance, this will also help maintain water flow continuity, so the river can continue to be sustainable. Irrigation is the distribution of water to cultivated land through irrigation canals, which is carried out systematically to meet plant needs (Tampubolon and Suprayogi, 2017). The purpose of irrigation is to wet the soil to support the water percentage and air contained between the soil grains, which will influence plant growth, thereby increasing agricultural production (Tria et al., 2014). Therefore, irrigation is a watering effort, including the provision, distribution, management, and water regulation, which is carried out to support water needs (water supply) for agriculture.

Good irrigation is based on a balance between the amount of water available and that needed for agriculture (Permana and Gunawan, 2022). The impact that can occur when streaming water for agriculture without considering the need for irrigation water can result in the amount of water needed being greater than the water availability, resulting in a water shortage that can affect the decline in agricultural production (Tampubolon and Suprayogi, 2017). The availability of sufficient groundwater is essential for fulfilling the water needs of plants (Felania, 2017). Plants that lack water experience physiological disruption of the inhibition of CO_2 gas exchange, resulting in decreased photosynthetic activity (Gulo and Nurhayati, 2022).

Malang Regency is one of the regions in East Java that has extensive agricultural land: 46,465 ha divided into ±741 irrigation areas of different sizes (Dinas Pekerjaan Umum Sumber Daya Air Kabupaten Malang, 2018). According to the Directorate General of Irrigation (1986), an irrigation area is a unified area consisting of agricultural land that receives water from an irrigation network. The Garum and Jatisari irrigation areas are located in Ngajum Village, Ngajum, Malang Regency. Both irrigation areas are agricultural lands that rely on surface irrigation networks to provide water for plants. An irrigation network is part of irrigation, which includes buildings, canals, and complementary buildings that form a single unit that is needed for the provision, collection, allocation, and distribution of irrigation water (Peraturan Pemerintah RI, 2006).

The irrigation officer and farmers at the Jatisari irrigation area explained that there is a problem currently occurring at Jatisari; Jatisari's irrigation network was damaged because of landslides in 2021. The damage to the irrigation network caused the water supply to the agricultural land in Jatisari to stop completely. Efforts made by farmers to continue providing water supplies or Jatisari are by streaming water from Garum irregularly, and the water allocation is not regulated directly by the irrigation department. Water allocation is carried out directly in quaternary canals that stream to agricultural plots in Jatisari. Until now, Garum has had to support water availability in Jatisari.

To date, no research has specifically examined the water balance in the Garum and Jatisari Irrigation Areas, especially after damage to the irrigation network in the Jatisari Irrigation Area, which resulted in the Jatisari Irrigation Area's water supply being dependent on water availability in the Garum DAM. This can increase the irrigation water requirement, which is not proportional to the amount of water available, and can affect agricultural production results (Tampubolon and Suprayogi, 2017).

In connection with the problem that has been described, it is necessary to carry out an analysis of the water balance in Garum and Jatisari irrigation areas, which aims to determine the water flow availability at Garum intake and irrigation water requirement in Garum and Jatisari irrigation area, as well as to determine the water balance between water availability and irrigation water requirement of Garum and Jatisari irrigation area, so that from the results of this analysis it can be known the condition of water availability and irrigation water requirements in Garum and Jatisari irrigation areas. and provide information regarding whether the amount of water available from Garum intake is sufficient to fulfill the irrigation water requirements in the two irrigation areas. It is hoped that this information can help local farmers to adjust agricultural patterns, both types of crops and planting patterns used at the research location, so that they can provide good results for agricultural production.

2. Methods

2.1 Research Location

This research was conducted in the Garum and Jatisari irrigation areas. Administratively, the Garum and Jatisari irrigation areas are located in Ngajum Village, Ngajum District, Malang Regency. Astronomically, Garum irrigation area is located at 112°32'08.86" East Longitude and 8°06'33.77" South Latitude, while Jatisari irrigation area is located at 112°32'16.68" East Longitude and 8°5'48.69" South Latitude. The area of Garum irrigation area is 97 Ha and the area of Jatisari irrigation area is 33 Ha. The research location map is shown in Figure 1.

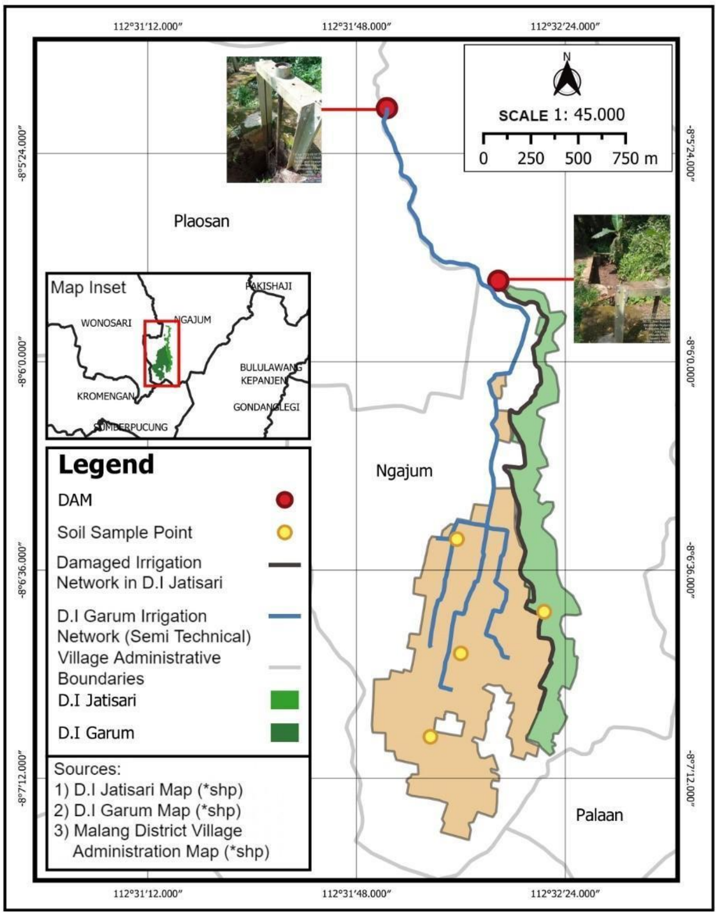


Figure 1. Research location map

2.2 Data Collection

The data types and sources are listed in (Table 1).

Table 1. Data types and sources

Data Types	Data	Sources
Primary Data	Soil texture	Laboratory analysis
	Inflow-outflow data in the Garum irrigation canal	Direct measurements in the field
Secondary Data	Intake flow data Garum DAM (2013-2022)	Malang Regency Water Resources Public Works Department
	Rainfall data at Ngajum station (2013-2022)	
	RTTG	

Data Types	Data	Sources
	Climate data (duration of sunlight, air humidity, average air temperature, wind speed) from Karangkates climate station (2013-2022)	BMKG Karangkates

2.3 Research Procedure

This research begins with a literature study, identification of problems and objectives, data collection, and data processing. The data processing techniques used included calculating irrigation water availability, irrigation water requirements, and irrigation water balance. The stages of the research activities were as follows:

2.3.1. Water Availability

Water availability in this research is the surface water availability; the intake flow from Garum DAM. Measuring the intake flow at Garum DAM is based on a flow meter in the form of a sluice gate/Romjin. The sluice gate/Romjin is a wide threshold measuring tool used to regulate and measure flow in the irrigation canal network, which is then the data tested and the dependable flow analyzed.

Flow data testing is carried out using trend analysis and uniformity tests. The trend test was carried out using the Spearman rank correlation test. The Spearman method is a non-parametric statistical test that can determine whether there is a trend or not. The use of the Spearman method is carried out to determine whether there is dependence or no dependence between time variables and hydrological variables (Soewarno, 2013). This test can be carried out using Equations (1) and (2) (Soewarno, 2013):

$$KP = 1 - \frac{6\sum(Dt)^2}{N^3 - N} \quad (1)$$

$$t = KP\left[\frac{N-2}{(1-KP^2)}\right]^{\frac{1}{2}} \quad (2)$$

KP represents the Spearman rank correlation coefficient, Dt is Rt – Tt, Rt is ranking of hydrological variables, Tt is time rating, N is number of data, t is distributed value- t at degrees of freedom = dk = N – 2 and a degree of reliability of 95% is accepted or error rate of 5%. The uniformity test was carried out by testing the variance value using the F-test and the average value test using the T-test. The uniformity test aims to test the stability of the average value and variance of two parts of time series flow data (Soewarno, 2013). This test can be done using Equations (3), (4), and (5) (Soewarno, 2013):

$$F = \frac{N_1 \times S_1^2 \times (N_2 - 1)}{N_2 \times S_2^2 \times (N_1 - 1)} \quad (3)$$

$$t = \frac{(\underline{X_1} - \underline{X_2})}{\alpha\left(\frac{1}{N_1} + \frac{1}{N_2}\right)^{0,50}} \quad (4)$$

$$\alpha = \left[\frac{(N_1 \times S_1^2) + (N_2 \times S_2^2)}{(N_1 + N_2 - 2)}\right]^{0,50} \quad (5)$$

N1 is the total data of group.1, N2 is the total data of group.2, S1 is the standard deviation of group.1, S2 is the standard deviation of group.2, $\underline{X_1}$ is the average of group.1, $\underline{X_2}$ is the average of group 2. After testing the intake flow data, and then the dependable flow is decided, this is the minimum river flow for the possibility of fulfilling the predetermined conditions that can be used for irrigation (Direktorat Jendral SDA, 2013). The method used to calculate dependable flow is probability using the Weibull Method (Fanmira and Soebagio, 2024). The dependable flow used for irrigation is determined at 80% (Direktorat Jendral SDA, 2013). Determination of dependable flow is based on Equation (6):

$$Q_{80} = \frac{m}{(n+1)} \times 100\% \quad (6)$$

Q_{80} is the dependable flow at the 80% level (L/s), m is the sequence number of the data, and n is the number of observation years.

2.3.2 Irrigation Water Requirement

The analysis of irrigation water requirement is divided into three categories: crop water requirement (CWR), diversion requirement (DR), and total irrigation water requirement. The amount of irrigation water needed in Garum and Jatisari was determined using Cropwat 8.0 and Microsoft Excel software.

Crop Water Requirement (CWR)

Calculation of crop water requirement (CWR) is carried out using Cropwat 8.0 software which is a Windows-based program. This program is developed by the FAO Land and Water Requirement Division based on the Penman-Monteith method which is used to plan and regulate irrigation (Dasril et al., 2021). Experts recommend using the Penman-Monteith method as a new standard for determining ETo values for calculating irrigation water requirements (Allen et al., 1998). Besides that, Cropwat 8.0 software is used because it is an effective method and has the smallest possibility of human error (Shalsabillah et al., 2018). The calculation of CWR includes potential evapotranspiration (ETo), effective rainfall, planting patterns, and soil type.

(1) Potential Evapotranspiration (ETo)

Evapotranspiration Potential value (ETo) is determined using the Penman-Monteith method. This method is considered to overcome the shortage of the previous FAO Penman method and provide more consistent and accurate values with actual plant water use data throughout the world, thereby creating a globally valid standard for calculating crop water requirements (Allen et al., 1998). The data used in ETo calculations using Cropwat 8.0 are station location data and climate data (maximum – minimum temperature data, air humidity, solar radiation, and wind speed) from the Karangkates climate station. ETo calculations using the Penman-Monteith method are carried out using Equation (7) (Allen et al., 1998):

$$ET_o = \frac{0{,}408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0{,}34U_2)} \quad (7)$$

ETo represents the evapotranspiration reference (mm/day), Rn is net radiation on the plant surface (MJ,/m2/day), G continuous heat density in the soil (MJ,/m2/day), T is the average daily temperature at a height of 2 m (°C), U_2 is wind speed at a height of 2 m (m/s), as is the saturated vapor pressure (kPa), e_a is actual vapor pressure (kPa), (e_s – e_a) is deficit saturated vapor pressure (kPa), Δ is vapor pressure slope curve (kPa/°C), ɣ is psychometric constant (kPa/°C).

(2) Effective Rainfall (P_{eff})

Calculation of effective rainfall value (P_{eff}) uses rainfall data from Ngajum rain station which has been tested for consistency and is 80% reliable (R_{80}). The rain data suitability test is used to determine the data correctness in the field (Atika et al., 2022). The method used is the double mass curve method; the cumulative annual rainfall value tested is compared with the cumulative annual rainfall value from the reference station.

R_{80} is the minimum average rainfall to be fulfilled which has been determined and can be used for irrigation (Fanmira and Soebagio, 2024). R_{80} is determined at 80% with the possibility of rainfall > 80% only being used at 20% (Direktorat Jendral SDA, 2013). The R_{80} calculation was carried out using probability analysis with Weibull method using Microsoft Excel. Weibull method was chosen because this method is most widely used in determining R_{80}. Besides that, Weibull method has been assumed that the results obtained have a value that is closest to the truth (Tiwery et al., 2022). Calculation of R_{80} using Weibull method is carried out using Equation (8):

$$R_{80} = \frac{m}{(n+1)} \times 100\% \quad (8)$$

R_{80} represents the rainfall with 80% reliability level (mm), m is the data sequence number, and n is observation year number.

P_{eff} was determined using Cropwat 8.0. P_{eff} 70% of R_{80} is used for rice crops, P_{eff} 60% of R_{80} is used for sugarcane crops and P_{eff} 50% of R_{80} is used for secondary crops (Direktorat Jendral SDA, 2013). P_{eff} is determined in monthly and decade periods. Monthly P_{eff} is determined using several methods provided in the Cropwat 8.0, while the P_{eff} value per decade is determined using the linear interpolation method (FAO, 2009). The method for determining P_{eff} for rice plants is a fixed percentage (Anton, 2014). The USDA soil conservation service method is used to determine P_{eff} in sugarcane and secondary crops (Anton, 2014). This method is divided into two; monthly effective rainfall and per decade. Monthly rainfall is used to determine monthly effective rainfall values, while rainfall per decade (10 days) is used to determine CWR values in Cropwat 8.0 (FAO, 2009).

(3) Planting Pattern

Planting pattern analysis was carried out using Cropwat 8.0 software to obtain plant coefficient value (kc). Besides that, planting pattern analysis is also used to determine plant growth stages, plant rooting depth and depletion fraction. The data used is data on plant types and planting dates for each planting season which is based on RTTG Garum and. Jatisari documents which are then input into Cropwat 8.0. Data on the types of plants selected are rice, maize (corn), and sugarcane which are already contained in the FAO database.

(4) Soil Type

The analysis used to determine soil type is laboratory analysis and direct observation in the field. This analysis was carried out to identify the soil physical properties, including soil texture, as an input data in Cropwat 8.0. Soil texture data is used to obtain information regarding the total of available water, maximum infiltration rate, maximum rooting depth and initial soil moisture depletion (% of total available moisture content). 4 (four) soil samples were taken at Garum and Jatisari.

After all parameters have been input into the Cropwat 8.0, the next step is to calculate plant evapotranspiration and CWR every decade using Equations (9) and (10) (FAO, 2009):

$$ETc = Kc \times ETo \tag{9}$$

ETc represents the plant evapotranspiration (mm/day and mm/dec), Kc is plant coefficient, and ETo is potential evapotranspiration.

$$CWR = ETc - Eff\ rain \tag{10}$$

CWR represents the crop water requirements (mm/dec), ETc is plant evapotranspiration (mm/day and mm/dec), Eff rain is effective rainfall (mm/dec).

2.3.3 Diversion Requirement (DR)

The need for water extraction at the source or diversion requirement (DR) is the amount of tapping or extraction from a water source required by one hectare of rice field for planting crops (Puspitaningrum, 2018). The DR value calculation considers CWR and Irrigation efficiency. Irrigation efficiency is water loss either because seepage or canals evaporation when the water flows towards rice fields (Puspitaningrum, 2018). Irrigation efficiency is a factor that influences the DR because it can reduce the amount of irrigation water at the water distribution level (Muhtadi et al., 2017).

Irrigation efficiency is a comparison between incoming flow and outgoing flow expressed in percentage (%) (Norhadi, 2022). Determining irrigation efficiency is carried out by measuring the incoming and outgoing flow values in the irrigation canals. The method used is inflow-outflow or the water balance technique in the canal sections (Saputra et al., 2022). The data used is data measuring incoming and outgoing flows in irrigation canals. Inflow-outflow measurements are carried out directly using a current meter. The canal flow calculation method used is the velocity method.

The calculation of irrigation efficiency can be done using Equation (11) (Dairi, 2021):

$$Eff = \frac{Debit\ outflow}{Debit\ inflow} \times 100\% \tag{11}$$

Eff represents the Irrigation Efficiency (%), *Outflow* is outflow (m^3/sec), and *Inflow* is inflow (m^3/sec).

The DR calculation is carried out using Equation (12) (Bunganaen et al., 2020):

$$DR = \frac{CWR}{Eff \times 8.64} \tag{12}$$

DR represents the diversion requirement at the source (L/s/ha), CWR is crop water requirement (mm/day), Eff is irrigation efficiency (%), 8.64 is the unit conversion number from mm/day to L/s/ha.

2.3.4 Total Irrigation Water Requirement

The total irrigation water requirement is determined based on data on the planting area for each type of plant at the research location and the DR calculations results. The size of the planting area is a factor that needs to be considered in determining the total need for irrigation water to determine an appropriate amount of water needed for irrigation at the research location. Data on the planting area for each type of plant (rice, sugarcane and secondary crops) for 1 year were obtained from RTTG Garum and Jatisari. Calculation of total irrigation water requirements can be done using Equation (13) (Krisnayanti, 2020):

$$Total\ Water\ Req = DR \times planting\ area \quad (13)$$

Total Water Req represents the total irrigation water requirement (L/s), DR is the diversion requirement (L/s/ha), Planting area is the size of the planting area for each type of crop at the research location (ha).

2.3.5 Water Balance

The method used to determine water balance is a comparative method, comparing the available water flow and the total irrigation water requirement. Water balance is determined to determine the available water flow, so that it can fulfill the irrigation area water needs during the growing season. Water balance can be expressed using Equation (14) (Saputra et al., 2022):

$$Q_{sisa} = Q_a - Q_k \quad (14)$$

Q_{sisa} represents the building/section building residual flow (L/s), Q_a is the amount of water flow available in the intake dam (L/sec), Q_k is the irrigation water requirement flow (L/s).

The provisions for water balance analysis are a deficit if the water availability flow < irrigation water requirement, balanced/appropriate if the water availability flow = irrigation water requirement and a surplus if the water availability flow > irrigation water requirement (Maulana, 2017).

3. Result and Discussion

3.1 Water Availability

The water availability value is obtained through a 80% dependable flow calculation which is based on Garum intake flow data. The flow data was then subjected to a trend test and a uniformity test.

The trend of intake flow at Garum DAM does not show any trend with a t value (-5.62) < t table (1.86). Besides that, the homogeneity test results using the F and t-test show that the intake flow at Garum in the 10 years (2013-2022) has homogeneous data with a F value (0.03) < F table 96 .39 and t value (-21.29) < t table (1.86).

After the data shows that there is no trend and the data is homogeneous, then the intake flow data at Garum DAM can be used to calculate dependable flow values. The dependable flow is determined at 80% which is calculated using the Weibull method using Microsoft Excel. The 80% dependable flow calculation results can be seen in (Table 2).

Table 2. Calculation of 80% dependable flow for Garum DAM Intake Dam 2013-2022

Month	Decade	Dependable Q 80% (L/s)	Month	Decade	Dependable Q 80% (L/s)
	I	57		I	37
Jan	II	57	Jul	II	32.2
	III	57		III	32.2
	I	57		I	32.2

Month	Decade	Dependable Q 80% (L/s)	Month	Decade	Dependable Q 80% (L/s)
Feb	II	50	Aug	II	32.2
	III	50		III	32.2
	I	43.4		I	38.2
Mar	II	43	Sep	II	43
	III	43		III	55.6
	I	43		I	50
Apr	II	43	Oct	II	50
	III	43		III	51.4
	I	43		I	56.2
May	II	43	Nov	II	57
	III	43		III	57
	I	37		I	57
Jun	II	38.2	Dec	II	57
	III	38.2		III	57

Table 2 shows the result of the highest flow value occurring in November period-II to February period-II; 57 L/s and the lowest flow value occurred in July period-II until August period-III; 32.2 L/s. Seasonal conditions influence the size of the flow at the research location, the amount of flow will increase in the rainy season and will decrease during the dry season.

3.2 Irrigation Water Requirement (Irr Req)

3.2.1 Crop Water Requirement (CWR)

The Irr Req value calculation for Garum and Jatisari consists of potential evapotranspiration (ETo), effective rainfall, planting patterns, and soil type using Cropwat 8.0. The results of calculating the Irr Req value for Garum and Jatisari are described as follows:

1) *Potential Evapotranspiration (ETo)*

The ETo value calculation using the Penman-Monteith method was carried out using Cropwat 8.0. The Potential Evapotranspiration (ETo) calculation results can be seen in (Table 3).

Table 3. Calculation of evapotranspiration potential (ETo)

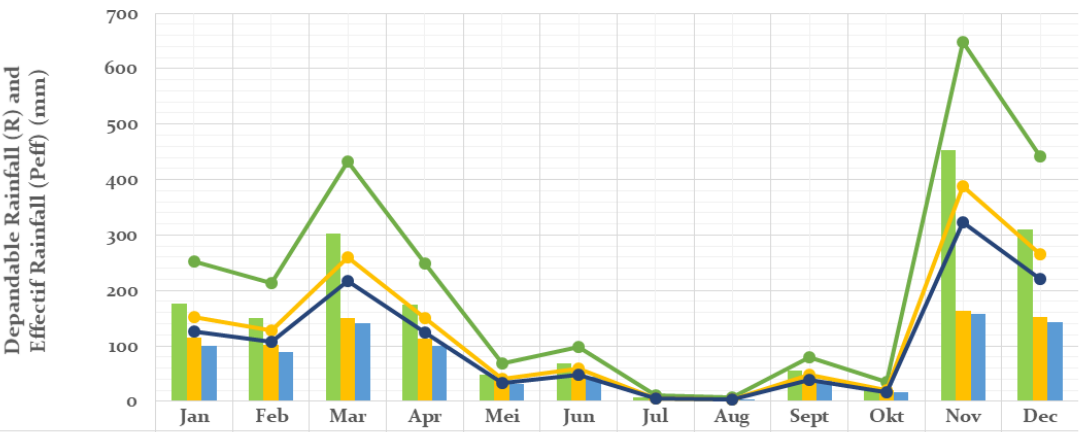
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hour	MJ/m²/day	mm/day
Jan	22.7	31.3	86	69	3.9	15.9	3.49
Feb	22.7	31.5	85	69	4.2	16.4	3.6
Mar	22.7	32	85	61	5.2	17.6	3.79
Apr	22.7	32.4	84	61	5.9	17.5	3.74
May	22.2	32.2	81	78	6.7	17.1	3.64
Jun	21.6	31.5	82	69	6.2	15.6	3.25
Jul	20,7	30.7	81	104	6.5	16.3	3.41
Aug	20.7	31	79	112	7	18.4	3.86
Sept	21.2	32.3	78	112	7.1	20	4.34
Oct	22.2	32.7	78	104	6.5	19.8	4.41
Nov	22.8	32.4	83	69	4.7	17.1	3.8

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hour	MJ/m²/day	mm/day
Dec	22.9	31.3	85	61	4	15.9	3.5
Average	**22.1**	**31.8**	**82**	**81**	**5.7**	**17.3**	**3.74**

Table 3 shows that the largest ETo value occurred in October; 4.41 mm/day and the smallest ETo value occurred in June; 3.25 mm/day. The high ETo value is influenced by high temperature, low air humidity, and high solar radiation. However, on the contrary, if the air temperature is low, the air humidity is high and the sunlight duration is also low, the ETo will also be low (Sabilau et al., 2021). The ETo value will increase as the solar radiation duration increases, which can be caused by an increase in surface temperature and a decrease in air humidity, causing more water vapor to be lifted into the atmosphere (Sagita et al., 2020). Besides that, high wind speed also influences the high ETo value, by helping the movement of water vapor out of the leaf pores (Nurliani et al., 2019).

2) Effective Rainfall (P_{eff})

P_{eff} is rainfall that seeps into the soil and can be used to fulfill the water needs of plants (Nur et al., 2021). The calculation of 80% dependable rainfall and effective rainfall is presented in (Figure 2).



	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sept	Okt	Nov	Dec
Peff Rice	177	149.4	303.1	174.3	47.5	68.3	7.3	4.5	55.4	24.1	453.3	309.8
Peff Sugarcane	114.9	101.8	151	113.7	38	53.1	6.2	3.8	43.9	20	163.9	151.6
Peff Secondary Crop	100.8	88.5	141.5	99.7	32.1	45	5.2	3.2	37.1	16.7	157.4	142.9
R80 (Rice)	252.8	213.4	433	249	67.8	97.6	10.4	6.4	79.2	34.4	647.6	442.6
R60 (Sugarcane)	151.7	128	259.8	149.4	40.7	58.6	6.2	3.8	47.5	20.6	388.6	265.6
R50 (Secondary Crop)	126.4	106.7	216.5	124.5	33.9	48.8	5.2	3.2	39.6	17.2	323.8	221.3

Figure 2. Calculation diagram for 80% dependable rainfall and effective rainfall (rice) 70%, 60% (sugarcane), and 50% (secondary crops)

Figure 2 shows that the P_{eff} value has a lower value than the R_{80} value. This is because P_{eff} is part of the rainfall that can be utilized by plants (Nurliani et al., 2019). Besides that, in Figure 2, P_{eff} values tend to be high from November to April with the highest rainfall occurring in November. P_{eff} values tend to be low from July to August with the lowest rainfall occurring in August. The P_{eff} value magnitude is influenced by the increasing amount of rainfall to the highest value, causing a large P_{eff} value (Faishal, 2013).

3) Planting Pattern

The planting pattern in Garum and Jatisari is by the Malang Regency Global Planting Plan and Procedure (RTTG). The planting period at Garum is divided into 2 periods, planting period 1 (MT-I) and planting period 2 (MT-II), while the planting period at Jatisari is divided into 3 periods, planting period 1 (MT-I), planting period 2 (MT-II) and planting period 3 (MT-III). Besides that, the planting dates for Garum and Jatisari are divided into 2 groups with different sizes of land. This is done to reduce the peak need for irrigation water. So the types of commodities planted in the MT-I are rice, sugarcane, and secondary crops, while the types of commodities planted in MT-II are rice and secondary crops and the types of commodities planted in MT-III are secondary crops.

Plant type and plant age are also factors that need to be considered to determine the amount of water needed for agriculture (Fatchan and Purwanto, 1990). Differences in plant age are one of the factors that determine the consumptive water requirements (ETc) value (Sabilau et al., 2021). ETc is the amount of water that can be used by plants to help plants during the photosynthesis process (Anisarida and Hafudiansyah, 2022). Plant factors are things that can influence the ETc value according to the plant growth period and water evaporation from the soil surface, especially on agricultural land (Tampubolon and Suprayogi, 2017). ETc will have different values depending on the age of each plant so it can also influence the amount of irrigation water requirement (Sabilau et al., 2021).

4) Soil Texture

Differences in soil texture can influence the ability level to absorb and bind water, thereby influencing plant water requirements (Musdalipa, 2019). CWR is determined by the amount of water that enters the soil, so that not all of the water that enters the soil is used for irrigation but some is also absorbed by the soil (Maulana, 2017). The soil texture analysis results in the laboratory can be seen in (Table 4).

Table 4. Soil texture analysis results

Soil Texture (%)			Class
Sand	**Silt**	**Clay**	
1.24	54.32	44.44	Silty Clay

Table 4 shows that the soil at the research location is dominated by soil with a silty clay texture with an average sand fraction of 1.24%, silt of 54.32%, and clay of 44.44%. The ability of clay-textured soil tends to be greater in holding water than sand-textured soil (Mutmainnah et al., 2021). This is because clay textured soil has micropores (fine pores). Therefore, the amount of water that can be retained is greater and can increase the water capacity available (Intara et al., 2011). This means that agricultural land with clay soil requires less water than agricultural land with sandy soil.

3.3 Diversion Requirement (DR)

The amount of irrigation water requirement is also influenced by diversion requirements. The DR value considers CWR and Irrigation efficiency. Irrigation efficiency values are obtained based on the results of incoming and outgoing flow measurements in the field. Based on the flow measurements of irrigation canals in Garum and efficiency calculations, it shows that the irrigation efficiency for all Garum canals is 90.16%. Water loss in the Garum irrigation canal was 9.84%.

The water requirement value calculation for plants is carried out using Cropwat 8.0 which is based on factors that have been considered, while the DR is carried out using Microsoft Excel. Calculations were carried out for three commodities found in Garum and Jatisari; rice, sugarcane, and secondary crops. Besides that, CWR and DR in Garum and Jatisari are similar because the initial planting date in both is the same. The following are the results of calculating the value of CWR and DR:

3.3.1 Rice Plant Water Requirement

One of the crop commodities found in Garum and Jatisari is rice. Rice plants were planted twice in MT-I and MT-II. Rice plants have a total lifespan of 150 days which is divided into nursery stage which includes a land preparation stage including a puddling stage. The initial stage, the development stage, the mature stage (mid-season), and the final stage (late season). The results of rice plant data processing using Cropwat 8.0 can be seen in (Table.S2).

(Table.S2) shows that the highest water requirement values in MT-I and MT-II occur at the land preparation stage (Nurs/LPr). The MT-I land preparation stage (Group-1 & 2) starts from October period-II to November period-II, with the highest water demand occurring in the final period of land preparation between November period-I and period-II; 67.9 mm/dec. or 9.23 L/s/ha for Group-1 and 59.2 mm/dec or 7.60 L/s/ha for Group-2, while the MT-II land preparation phase (Group-1 & 2) starts in February period-I until March period-II with the highest irrigation water requirements v also occurring in the final period of land preparation, 74 mm/dec or 9.50 lt /s/ha for Group-1 and 70.1 mm/dec or 9 L/s/ha for Group-2. These results are in line with research by Hariz et al. (2020) which shows the high water requirements value at the land preparation stage (Nur/LPr), this is because at that stage there is a puddling period which requires more water (Hariz et al., 2020). Water requirements will tend to be greater at the land preparation stage for puddling so that it can be processed, while at the final stage (late season) or ripening, water requirements tend to be less because if the rice is submerged in water, the rice will fall and rot (Direktorat Jendral SDA, 2013).

In (Table.S2), it is also known that the amount of irrigation water requirement in MT-I has a value that tends to be lower when compared to the amount of irrigation water requirement in MT-II. This could be because at that time the dry months had begun so the effective rainfall value tended to be lower and the consumptive water requirements (ETc) value tended to be higher, thus requiring additional irrigation water. Additional irrigation water is carried out if the plant's water requirement cannot be fulfilled by rainfall or groundwater (Sapei and Fauzan, 2012).

3.3.2 Sugarcane Plant Water Requirement

Sugarcane plants have a total lifespan of 356 days or one year so this plant is only planted during one planting period. The sugarcane plants growth stages are divided into the initial stage, the development stage, the mature stage (mid-season), and the final stage (late season). The results of calculating irrigation water requirements for sugarcane plants can be seen in (Table.S3).

In (Table.S3), it is known that the initial stage of sugarcane growth starts from November period-II to the December period-II. Water requirements at this stage tend to be low, 0 mm/dec or 0 L/s/ha. The development stage starting from December period-III to February period-I with the highest water requirement value of 2.4 mm/dec or 0.31 L/s/Ha in Group-1 and 2.3 mm/ dec or 0.30 L/s/Ha in Group-2. The mature stage (mid-season) is the longest stage for sugarcane plants starting from February period-I to August period-I with the highest irrigation water requirement value of 45 mm/ dec or 5.78 L/s/ha in Group-1 and 45.1 mm/dec or 5.79 L/s/ha in Group-2. The final stage (late season) starting from the first August to the second November with the highest water requirement value of 43.6 mm/dec or 5.60 L/s/ha in Group-1 and 45.9 mm/dec or 5.89 L/s/ha in Group-2.

The water requirements of sugarcane plants tend to continue to increase from the initial stage to the mature stage (mid-season) and begin to decline in the final stage (late season). This can be influenced by differences in growth phases and rainfall. The sugarcane plants water requirements will be different at each growth phase and can also be influenced by variations in monthly rainfall (Yusara et al., 2019).

The initial stage is the germination stage which has a low leaf area index so that water loss because evapotranspiration/evaporation is also low. If there is excess water at this stage it will result in the rotting of the shoots or sugarcane plants, whereas in the development stage which is the shoot growth stage where the evapotranspiration value increases because the significant growth of sugarcane leaves, then in the mature stage (mid-season) which is the stem elongation stage there is a leaf growth process which continues but more slowly until it reaches maximum conditions which result in evapotranspiration reaching maximum value and the need for biomass formation and stem water storage is added so that the need value at this stage tends to be greater than other growth stages, and at the final stage (late season) or the ripening to harvest stage, the need value tends to start to decrease because the leaf area index is low. It causes water loss because the evapotranspiration process is also lower (Yusara et al., 2019).

3.3.3 Water Requirement for Secondary Crops

The type of secondary crop commodity found in Garum and Jatisari is corn. Corn plants were planted three times, namely at MT-I, MT-II, and MT-III. Corn plants have a total lifespan of 125 days which is divided into the initial stage, the development stage, the mature stage (mid-season) and the final stage (late season). The results of calculating irrigation water requirements for corn plants can be seen in (Table.S4).

(Table.S4) shows that in MT-I, the highest water requirement for corn plants occurs at the mature stage (mid-season), in the third January, 11.5 mm/dec or 1.48 L/s/ha for Group-1, while Group-2 occurs in the first February, it was 13.3 mm/dec or 1.71 L/s/ha. In MT-II, the highest water requirement for corn plants also occurs during the mature stage (mid-season), in the second May; 33.9 mm/dec or 4.35 L/s/ha for Group-1, while for Grop 2 occurs in May third, 33.7 mm/dec or 4.33 L/s/ha. In MT-III, the highest water requirement for Group-1 occurs in the final stage (late season), the second October; 47.3 mm/dec, while for Group-2 occurs in the mature stage (mid-season), in the second October, 50.5 mm/dec or 6.48 L/s/ha.

The high value of irrigation water requirement at the mature stage (mid-season) occurs because at that stage, the consumptive water requirement (ETc) value tends to be high but the effective rainfall is low, resulting in a larger additional supply of irrigation water requirement. Besides that, at the mature stage (mid-season) the flowering and the seed-filling process occurs in corn plants and at this stage the coefficient value tends to be higher, resulting in high water loss due to plant evapotranspiration (ETc) (Sirait et al., 2020).

3.4 Total Irrigation Water Requirement

The results of total irrigation water requirements in Garum and Jatisari can be seen in (Table.S5) and Figure 3.

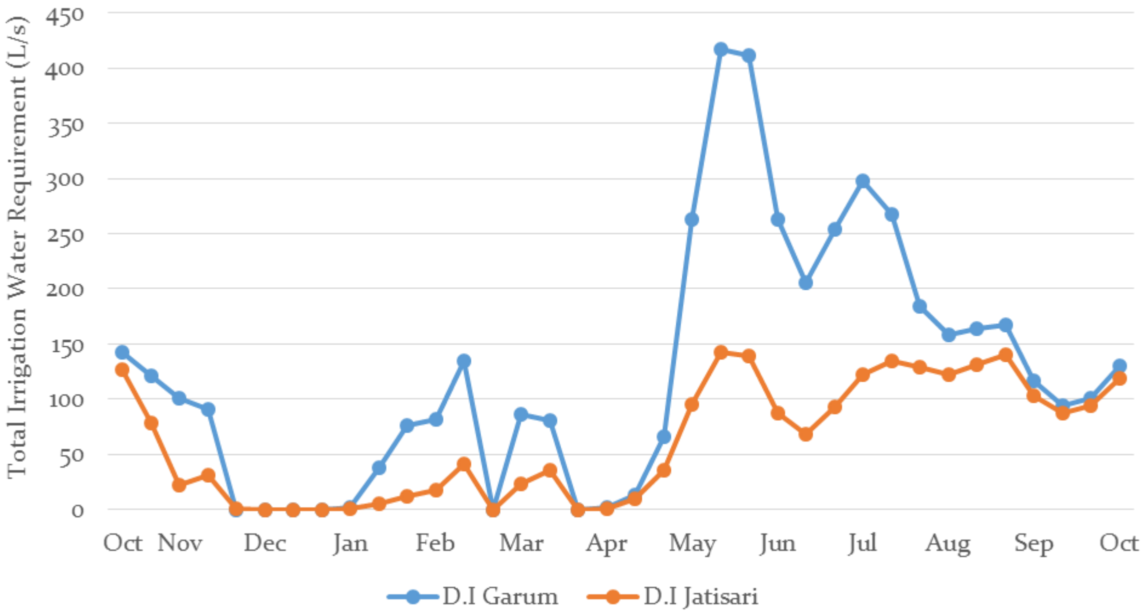


Figure 3. Graph of total irrigation water requirements in Garum and Jatisari

(Table.S5) and Figure 3. shows that the total irrigation water requirements results in Garum and Jatisari show that the need for irrigation water in Garum and Jatisari tends to be high during the dry season from May to September with the highest value of total irrigation water requirement occurring in

May period-II; 417.17 L/ dt for Garum and 142.40 L/s for Jatisari. The irrigation water requirement value tends to decrease from November to January with the smallest need value occurring in December; 0 L/s. The low value of irrigation water requirements is influenced by the high level of rainfall that falls so that effective rainfall can fulfill the amount of water needed for agriculture and no longer require additional water supplies for agriculture.

3.5 Irrigation Water Balance

The irrigation water balance in this research is the difference between the availability of water from the Garum DAM intake and the total irrigation water requirement value in the two irrigation areas; Garum and Jatisari. The results of the irrigation water balance calculation can be seen in (Table.S6). (Table.S6) shows that the water availability from Garum DAM intake cannot fulfill the total water requirement for the two irrigation areas; Garum and Jatisari. This is indicated by the existence of a water deficit in April period-III to November period-II, in January period-III to February period-II, and in March period-I until period-II. The highest water deficit occurred in May period-II; 516.58 L/s with a total irrigation water requirement of 559.58 L/s and water availability of only 43 L/s. Water surplus occurs in March period-III to April period-II and November period-III to January period-II with the total irrigation water requirement tending to be low, therefore the available water is still sufficient to fulfill the total irrigation water requirement in the two irrigation areas. The results of irrigation water balance calculations for Garum and Jatisari can be seen in (Table.S7) and Figure 4.

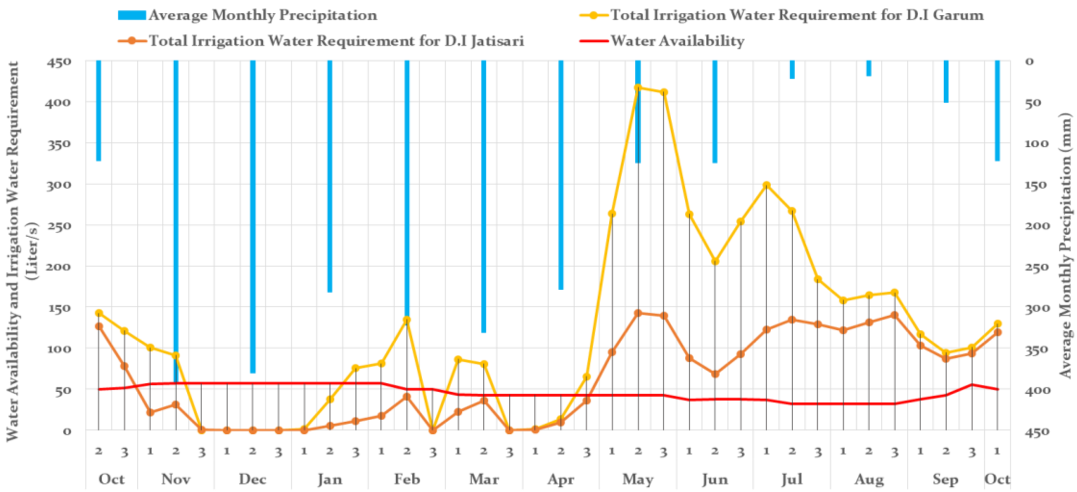


Figure 4. Results of irrigation water balance calculations in Garum and Jatisari

Water shortage or deficit in Garum with a 97 Ha area occurs in April period-III to November period-II. The most severe water deficit condition occurs in April period-III to August period-III or during the dry season with a deficit value > 100 L/s. Besides that, water deficit also occurs in January period-III to February period-II and in March period-I until period-II or during the rainy season. There is a water deficit during these months because the land is in the land preparation stage for rice crops (Nurs/LPr) so the water requirement is higher. The water surplus in Garum occurs in November period-III to January period-II, in February period-III, and in March period-III to April period-II. Water surplus generally occurs during the rainy season. Effective rainfall values tend to be higher and evapotranspiration is lower, resulting in the soil in this condition becoming more humid and the need for irrigation water being lower.

In Jatisari with a 33 Ha area, there is also a water deficit during the dry season, from May period-I to October period-III. The highest deficit value occurred in August period-III; 107.74 L/s. This value corresponds to the lowest flow intake value and total irrigation water requirements which tend to be high. The high value of total irrigation water requirements and flow intake values is caused by low rainfall during the dry season. Water surplus in Jatisari occurs during the rainy season, from November period-I to April period-III. The high value of rainfall and low water loss because of the evapotranspiration process in the rainy season result in a smaller need for additional irrigation water on agricultural land.

The results of irrigation water balance calculations show that water deficit tends to occur more in Garum than in Jatisari. This can be influenced by differences in the size of the planting area in each irrigation area. Garum has a larger area than Jatisari so the water requirement for irrigation is greater than the water requirement for irrigation in Jatisari. This is in line with the results of research by Rahmanda & Dasanto (2018) which shows that the highest need for irrigation water in the Madiun Sub-watershed occurred in 2015, which had the largest irrigation area compared to previous years, so the irrigation area is also a factor that can influence to the amount of water needed (Rahmanda and Dasanto, 2018).

4. Conclusions

This research concludes that the highest irrigation water availability at the intake of Garum DAM occurred in November period-II to February period-II; 57 L/s and the lowest value of water availability occurred in July period-II to August period-III; 32.2 L/s. Besides that, the maximum irrigation water requirement in Garum and Jatisari irrigation areas occurs during MT-II; 417.17 L/s for Garum and 142.40 L/s for Jatisari, while the minimum irrigation water requirement occurs in MT-I; 0 L/s/ at Garum and Jatisari irrigation area. The amount of irrigation water requirement can be influenced by differences in water needs at each growth phase, the effective rainfall value, and the plant evapotranspiration (ETc) value. The water balance results show that the water availability from Garum DAM intake cannot fulfill the total irrigation water requirement for Garum and Jatisari irrigation area for one year. This is indicated by the water deficit in certain months.

Efforts that can be made to overcome the problem of water availability that is less than irrigation water requirements are to repair damaged irrigation networks so that they can function normally again. However, this requires large amounts of funds and quite a long time, so another effort that can also be made to overcome the high water deficit is to increase the irrigation water supply in months that experience a water deficit. Efforts to increase water supply can be made by carrying out further studies and surveys to look for new water sources both below the surface and surface as additional water supply to fulfill irrigation needs. Besides that, when the water availability condition is less than the amount of irrigation water required, modifications can also be made to water supply arrangements and planting planning patterns to suit conditions in the field, such as changing plant varieties and reducing the area of land to be planted in irrigation areas.

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