How to Cite
Landrawijaya, R. B., & Amalia, M. (2023). Evaluation of water balance in the Jaro Irrigation area, Tabalong Regency, South Kalimantan Province. *International Journal of Life Sciences & Earth Sciences*, *6*(1), 39-48.
https://doi.org/10.21744/ijle.v6n1.2125

Evaluation of Water Balance in the Jaro Irrigation Area, Tabalong Regency, South Kalimantan Province

Raka Bagoes Landrawijaya
Master Degree Program of Civil Engineering, Universitas Lambung Mangkurat, Banjarmasin, Indonesia
Corresponding author email: raka.bagoess@gmail.com

Maya Amalia
Lecturer in the Civil Engineering Master Program, Universitas Lambung Mangkurat, Banjarmasin, Indonesia
Email: m.amalia@ulm.ac.id

Abstract---*In the Tabalong Regency, South Kalimantan Province, many irrigation networks have not worked optimally. The Jaro Irrigation Area is one of these irrigation networks, the majority of available fields are planted with Paddy. Evaluation of irrigation water to irrigate paddy fields is very important for optimal growth and development of paddy. The objective of this research is to evaluate the water balance, the potential area for paddy field area development can be obtained by applying the optimal crop pattern. Analysis of the rainfall data used in this study with statistical analysis in the form of validation and correction of rainfall data. Rainfall data were obtained from the Tropical Rainfall Measurement Mission (TRMM) and the Meteorology, Climatology, and Geophysics Agency (BMKG) Jaro Station in the period 2013-2019, the data using statistical analysis obtained a correlation coefficient and regression equation. The regression equation is used to obtain the corrected rainfall value which will be used in the hydrological analysis. Water requirement analysis with several cropping pattern scenarios. Calculation of evapotranspiration using the Modified Penman method. The F.J. Mock method is used to develop the discharge value. Dependable discharge, 80%, is used to estimate water availability. Furthermore, an evaluation of the water balance is carried out for each scenario, and the result of information on surplus or deficit conditions can be obtained each month. Analysis of water demand discharge based on planting scenarios is divided into three. First Scenario with a high-yield paddy - a high-yield paddy according to the existing conditions at the research location. The second scenario is with a high-yield paddy - high-yield paddy - beans and the third scenario is with a high-yield paddy - paddy. According to the results of the water balance evaluation for the three scenarios, the potential area can be reached up to 900 ha from 850 ha with the chosen crop pattern in scenario number 2.*
Keywords---*Crop pattern, DI Jaro, water availability, water balance, water demand.*

Introduction

In the Tabalong Regency, South Kalimantan Province, many irrigation networks have not been used optimally (Sujono, 2022). One of them is the Jaro Irrigation Area, business in the agricultural sector is dominated by rice plants, so the need for irrigation water to irrigate rice fields is very important for rice growth. The water balance is a description of the evaluation of water entering and leaving a hydrological system (DAS, reservoirs, lakes, runoff) in a certain period (Abdul-Ganiyu et al., 2015). The water balance can be used to determine the surplus or deficit of a hydrological system so that further action can be taken to overcome this (Putra et al., 2018).

In 2018, Jaro District had a rice harvest of 16,651 tons, with details of 12,750 tons of paddy rice and 3,901 tons of field rice. As for food crops other than rice, the biggest harvest was cassava with 275 tons. Rubber plants are plantation crop commodities that have the largest production in 2018, which is 6,328 tons with a planting area of 3,229 hectares (Hidayat et al., 2022).

ISSN 2632-9425
Submitted: 09 February 2023|Revised: 18 March 2023| Accepted: 27 April 2023

Tabalong Regency with red-yellow Podzolic soil type with sedimentary rock parent material which is easily eroded. The slope is dominated by land with a low slope (0-5%), the rest has a moderate slope (15-40%) and more than 40%. The effective soil depth averages over 90 cm (97.8%), and the soil is mostly fine-textured (Akas et al., 2018).

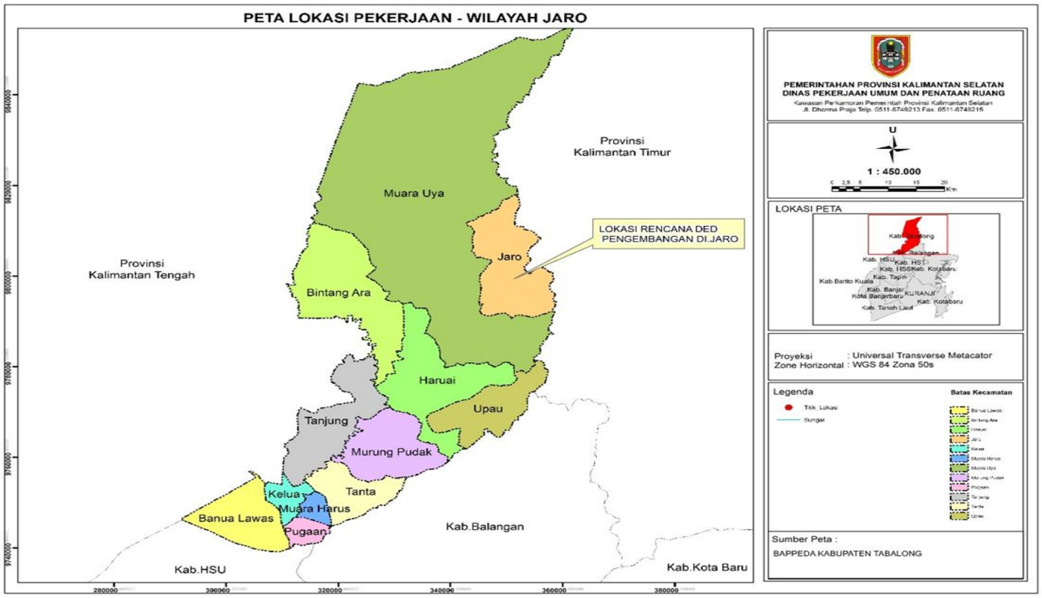


Figure I. DI Jaro, Tabalong Regency (Source PUPR Kalsel 2020)

Jaro District is an administrative area of Tabalong Regency with an altitude of 1500 meters above sea level. This sub-district is located between 2º south latitude and 166º east longitude. It is bordered to the north by North Kalimantan Province, to the east by Muara Uya District, to the south by Muara Uya District, and to the west by East Kalimantan Province (Budi, 2021).

The water balance is one of the most important aspects of the hydrological system. The water balance is a comparison between the potential availability of water and the demand for water in a certain place in a certain period (Pamadya et al., 2022; Azmeri et al., 2019). Water balance analysis studies can find out whether the amount of water needed is in excess (surplus) or vice versa experiences a deficiency (deficit) (Qarinur et al., 2022; Duffková et al., 2019). By knowing these two factors, the utilization of water can be managed as well as possible (Zhao et al., 2023). Reliable debit or availability of discharge is a discharge that can be relied on in a river, both in the dry season and especially the rainy season. Several methods can be used to determine this reliable discharge, such as the empirical method, namely the FJ Mock method. Calculations using the FJ Mock method are based on approximate calculation approaches using rain data, climatology, and land cover vegetation (Sihombing et al., 2021).

Provision of irrigation water that is not appropriate, whether it is excess or deficiency will harm the growth of rice plants, so the discharge of irrigation water needs must be calculated and adjusted to the available irrigation area (Hariyadi, 2020). For this reason, optimizing maximum yields in DI Jaro with an evaluation of the available water balance. The purpose of this research is to evaluate the water balance in the Jaro Irrigation Area so that the potential area for land development can be obtained by applying the right cropping pattern (Singh et al., 2001; Martínez-Casasnovas et al., 2005).

Method

The data used in this study is TRMM (Tropical Rainfall Measurement Mission) rainfall data obtained by accessing the site on the internet page, namely https://giovanni.gsfc.nasa.gov/giovanni from 2000-2019. Observational rainfall data were obtained from Jaro rain gauge data for 2013-2019 and the climatological data used was in the form of monthly data for 2000-2019, namely air humidity, air temperature, wind speed, and solar radiation obtained from the BMKG (Geophysics and Climatology Meteorology Agency). at Syamsudin Noor station. Before being used for data analysis, it is necessary to validate and correct TRMM rainfall data for 2000 – 2019 with observation posts using the

Correlation Coefficient method which produces a determination value and continues data correction by selecting the regression equation with the highest determination value. The regression equation used is linear, geometric, logarithmic, and exponential regression (Gichamo et al., 2022; Ezuar et al., 2018). The criteria for the determination value (R2) according to Setyorini & Hardaningrum (2020), is a very low interpretation is 0.00-0.199, Low is 0.20-0.399, moderate is 0.40-0.599, strong is 0.60-0.799 and very strong is 0.80-1.000. After correcting the rainfall data, the data can be used in the analysis of rainfall in the calculation of the water balance.

Oldeman's classification is based on the amount of water needed by plants, especially rice (Ikhwali et al., 2022; Canet-Martí et al., 2023). In the Oldeman climate classification, wet months are determined when rainfall is more than 200 mm/month, dry months when rainfall is less than 100 mm/month, and humid months when rainfall is between 100-200 mm/month according to Oldeman (Qarinur et al., 2022; Ariyani et al., 2020). Calculation of the potential evapotranspiration value using the Penman formula Modification and effective rainfall for rice based on the KP-01 formula (2013), namely Re paddy = (R80 x 0.7) and pulses = (R80 x 0.5) observation period, R80 value is rainfall The mainstay is obtained from the Weibull equation.

Discharge analysis for calculating water availability uses the F.J. Mock method. The mainstay discharge is the minimum discharge of the river with the probability that the discharge is fulfilled in the percentage of 80% (Duffková et al., 2019; Liu et al., 2020). Analysis of water needs based on KP-01 with the calculation of water demand discharge based on planting scenarios (number of growing seasons and cropping pattern). Supporting data are evapotranspiration (ETo), calculation of effective rainfall (Re), planting area, cropping pattern, and TRMM climatological data. Water balance analysis with a comparison of water demand and water supply discharges, water demand discharge based on planting scenarios, and water availability discharges is the flow rate of the F.J. Mock method. If there is a water deficit, a change in the cropping pattern or a change in the schedule is made (Döll et al., 2003; Huber et al., 2011).

Results and Discussion

Data validation and correction

Rainfall validation and correction analysis was carried out using monthly TRMM rainfall data locations in DI Jaro monthly correlated with monthly rainfall data observed for the Jaro rain post for a period of 7 years from 2013 - 2019 Table 1. Regression Equation and Determination Value (R2) of Rainfall and Air Temperature TRMM.

Table 1
Regression equation values and TRMM rainfall determination values

Month	Regression Equation	Determination Value (R^2)	Interpretation
January	y = 0.4562x + 167.18	0.60	Strong
February	y = 0.9907x + 52.69	0.76	Strong
March	y = 0.244x + 238.72	0.09	Very low
April	y = -0.2809x + 334.2	0.07	Very low
May	y = 0.7091x + 21.487	0.85	Very strong
June	y = 0.266x + 143.59	0.11	Very low
July	y = 0.4623x + 56.881	0.62	Strong
August	y = -0.0527x + 132.52	0.00	Very low
September	y = 0.6999x + 19.728	0.42	Currently
October	y = 0.6112x + 58.495	0.70	Strong
November	y = 0.1101x + 272.16	0.05	Very low
December	y = -0.0487x + 323.77	0.00	Very low

From the results of Table 1 above the correlation between rainfall data from January to December in 2000 – 2019 TRMM rainfall data and observation data obtained a very strong coefficient of determination in May with a value of 0.85. The coefficient of determination is strong in January, February, July, and October with a value of 0.60 – 0.76. The coefficient of determination is moderate in September with a value of 0.40 – 0.42. The coefficient of determination is very low in March, April, June, August, November, and December with a value of 0.00 – 0.09. According to Balai Dam (2019) if the correlation coefficient value is <0.60, then the rain post cannot be used to calculate flood discharge at the dam, however, for this research, it will continue to correct TRMM rainfall data.

Average rainfall

Analysis of changes in rainfall using corrected rainfall data. The data comes from the TRMM location in DI Jaro. The average rainfall value using corrected rainfall data can be seen in Table 2 below:

Table 2
Average monthly rainfall value

Month	Rainfall 2000-2019
Jan	281.97
Feb	277,84
Mar	300.78
Apr	234.54
May	124,37
Jun	176,16
Jul	87.50
Aug	122.39
Sept	44,32
Oct	108.35
Nov	233,46
dec	306,37

Average monthly rainfall data with maximum rainfall in December 306.37 mm and minimum in September 44.32 mm. Another parameter to determine changes in rainfall patterns is the shift in wet months, humid months, and dry months with Oldeman's classification. The results of the analysis can be seen in Figure 1. below:

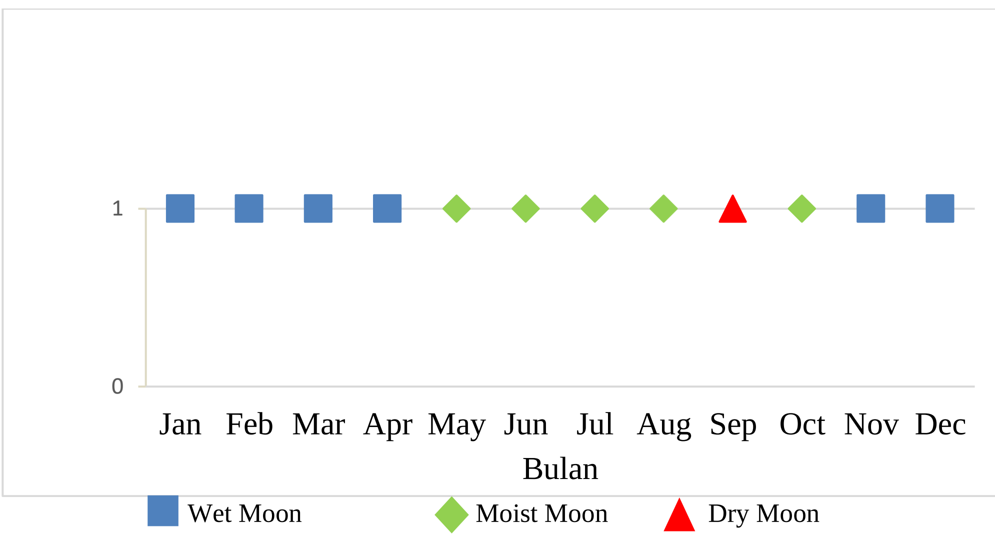
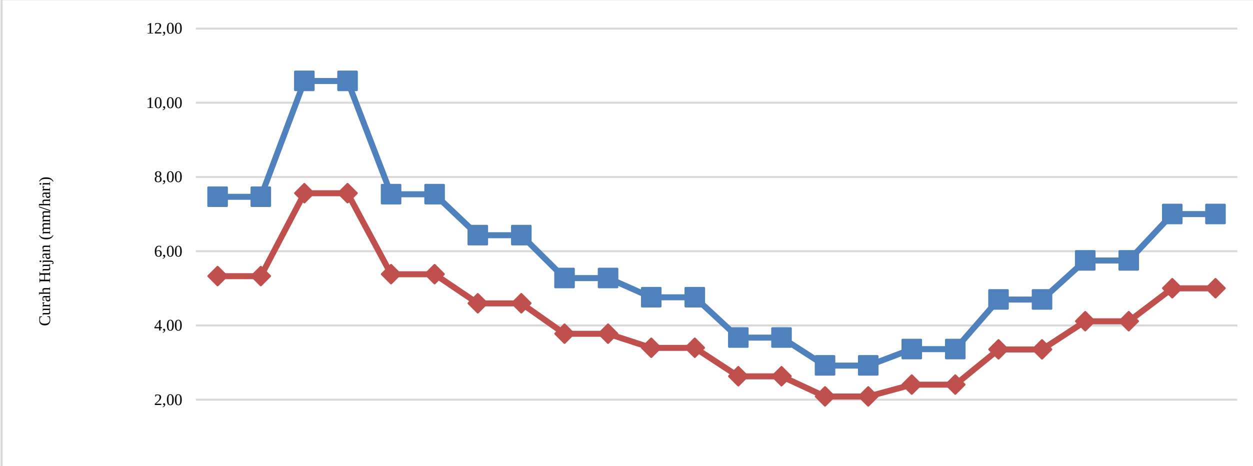


Figure 2. The shift of wet, wet, and dry months

Effective Rainfall

Effective rainfall is for Re padi and Re Palawija in DI Jaro using the corrected 15 daily average monthly TRMM data. The value of Rice Paddy and Rice Palawija is based on semi-monthly reliable rainfall data (R_{80}). The Weibull method is to sort from small to large. The results of calculating the effective rainfall for 15 days can be seen in Figure 2. as follows:



	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	Mei 1	Mei 2	Jun 1	Jun 2	Jul 1	Jul 2	Agst 1	Agst 2	Sept 1	Sept 2	Okt 1	Okt 2	Nov 1	Nov 2	Des 1	Des 2
Re Padi	7,46	7,46	10,59	10,59	7,53	7,53	6,43	6,43	5,28	5,28	4,76	4,76	3,67	3,67	2,92	2,92	3,36	3,36	4,70	4,70	5,75	5,75	7,00	7,00
Re Palawija	5,33	5,33	7,56	7,56	5,38	5,38	4,60	4,60	3,77	3,77	3,40	3,40	2,62	2,62	2,08	2,08	2,40	2,40	3,35	3,35	4,11	4,11	5,00	5,00

Figure 3. Re Paddy and Re Palawija

The results of the calculation of Re paddy for 15 days the maximum value is in February 1 and 2 with a value of 6.79 mm/day while the minimum value is in August 1 and 2 with a value of 1.03 mm/day. The results of the calculation of Re palawija for 15 days in 2000 - 2019 the maximum value is on February 1 and 2 with a value of 7.59 mm/day while the minimum value is on August 1 and 2 with a value of 2.08 mm/day.

Potential evapotranspiration

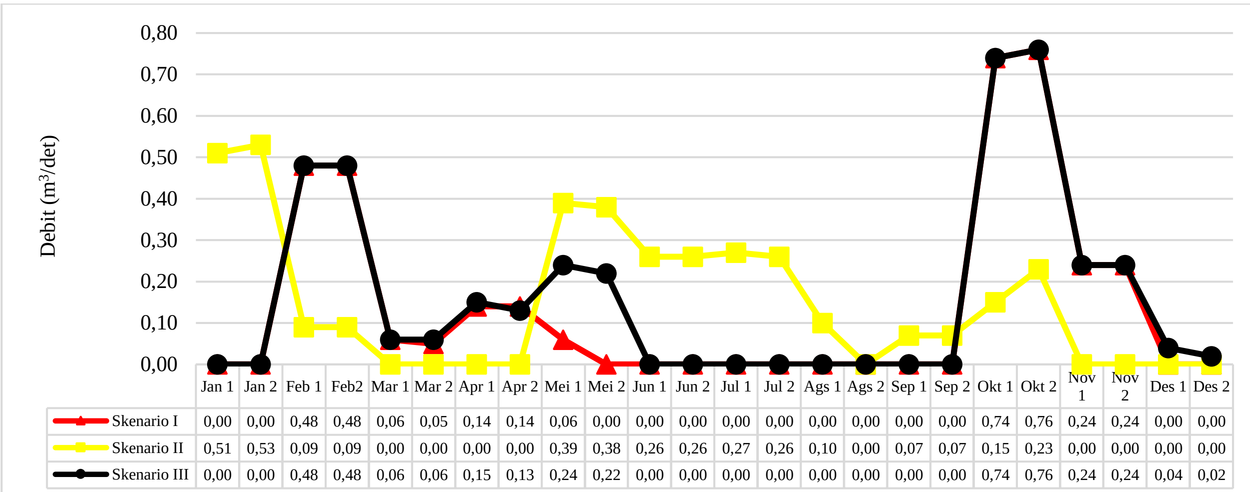
Calculation of potential evapotranspiration at the Jaro DI research site using the Modified Penman method. The climatological data parameters used from this method are the average monthly BMKG climatology, namely relative humidity (Rh), wind speed (U), solar radiation n/N, and air temperature (T). ETo calculation results, the maximum value in September is 4.33 mm/day, and the minimum value in June is 2.80 mm/day. The daily ETo value has increased and decreased in certain months. January to February increased by 0.47 mm/day, February to March decreased by 0.20 mm/day, March to April decreased 0.35 mm/day, April to May decreased by 0.08 mm/day, May to June decreased by 0.39 mm/day, June to July increased 0.37 mm/day, July to August increased 0.72 mm/day, August to September increased 0.44 mm/day, September to October decreased 0.30 mm/day, October to November decreased 0.11 mm/day, November to December decreased 0.04 mm/day.

Table 3
Results of potential evapotranspiration (ETo)

Month	ETo mm/day
Jan	3.53
Feb	3.82
Mar	3,62
Apr	3,27
May	3,19
Jun	2.80
Jul	3,17
august	3.89
Sept	4,33
Oct	4.03
Nov	3.92
dec	3.88

Analysis of water needs

Analysis of the water needs of DI Jaro according to the scenario of the cropping pattern so that the water needs of the rice fields are met according to the planting area of 850 Ha. Scenario 1 is superior rice - superior rice with MT 1 scheduled for land preparation in October with a January harvest schedule, and MT 2 scheduled for land preparation in February with a harvest schedule in May. Scenario 2 is superior rice - superior rice - secondary crops with MT 1 scheduled for land preparation in January with an April harvest schedule, MT 2 scheduled for land preparation in May with a harvest schedule in September, and MT 3 scheduled for land preparation in October with schedule harvest in December. Scenario 3 is superior rice – ordinary rice MT 1 is scheduled for land preparation in October with a January harvest schedule, MT 2 is scheduled for land preparation in February with a harvest schedule in May.

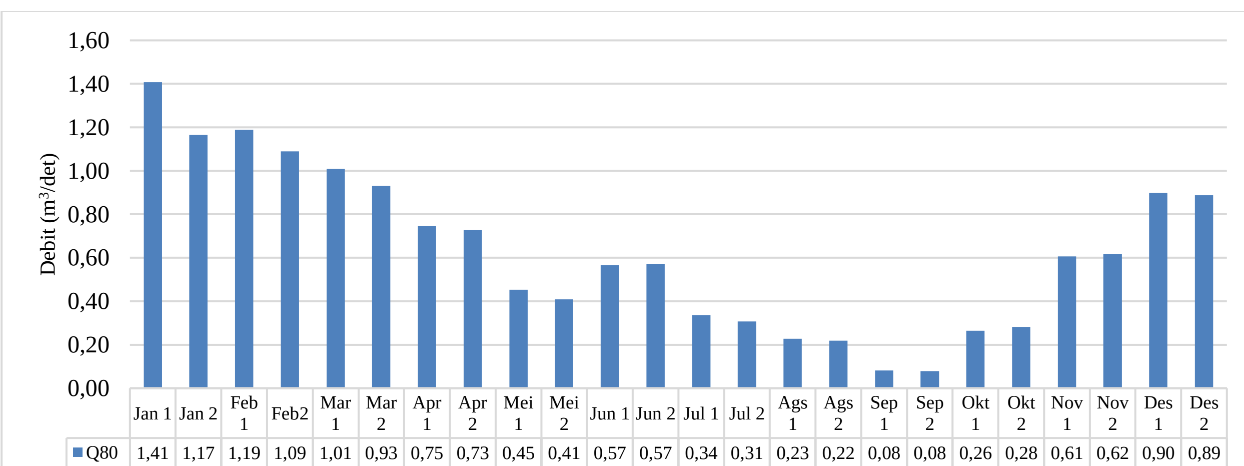


	Jan 1	Jan 2	Feb 1	Feb2	Mar 1	Mar 2	Apr 1	Apr 2	Mei 1	Mei 2	Jun 1	Jun 2	Jul 1	Jul 2	Ags 1	Ags 2	Sep 1	Sep 2	Okt 1	Okt 2	Nov 1	Nov 2	Des 1	Des 2
Skenario I	0,00	0,00	0,48	0,48	0,06	0,05	0,14	0,14	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,74	0,76	0,24	0,24	0,00	0,00
Skenario II	0,51	0,53	0,09	0,09	0,00	0,00	0,00	0,00	0,39	0,38	0,26	0,26	0,27	0,26	0,10	0,00	0,07	0,07	0,15	0,23	0,00	0,00	0,00	0,00
Skenario III	0,00	0,00	0,48	0,48	0,06	0,06	0,15	0,13	0,24	0,22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,74	0,76	0,24	0,24	0,04	0,02

Figure 4. Water needs 3 scenarios

Analysis of water availability

Analysis of water availability in Jaro DI with an area of 1016 Ha so that the mid-month water availability discharge value is obtained using the Mock method. To find out the 80% reliable discharge is based on a debit value that is close to or equal to the probability (P) value of 80%, it can be seen in Table 4. as follows:

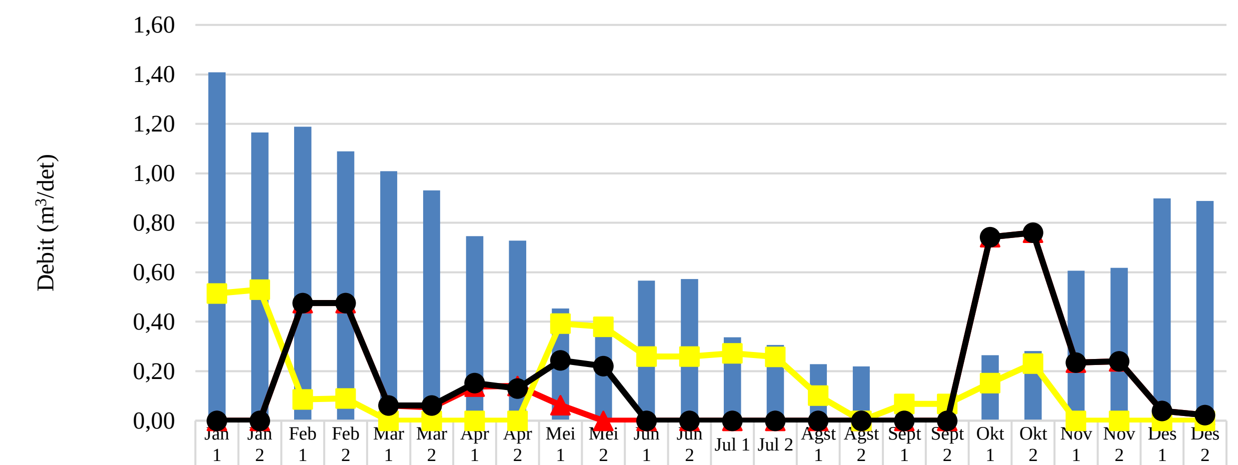


	Jan 1	Jan 2	Feb 1	Feb2	Mar 1	Mar 2	Apr 1	Apr 2	Mei 1	Mei 2	Jun 1	Jun 2	Jul 1	Jul 2	Ags 1	Ags 2	Sep 1	Sep 2	Okt 1	Okt 2	Nov 1	Nov 2	Des 1	Des 2
Q80	1,41	1,17	1,19	1,09	1,01	0,93	0,75	0,73	0,45	0,41	0,57	0,57	0,34	0,31	0,23	0,22	0,08	0,08	0,26	0,28	0,61	0,62	0,90	0,89

Figure 5. Water availability in an area of 1016 ha

Water balance analysis

The water balance with an area of 850 ha using the surplus and deficit of water is obtained from the results of reducing the discharge of water availability with water demand if the result is positive then it is a surplus and if it is negative then it is a deficit (Chen et al., 2010; Sun et al., 2006). From Figure 5 below, it can be concluded that the water deficit scenario 1 is October 1, and October 2. Scenario 2 does not have a water deficit month or all months have a surplus of water, meaning that the availability of water is sufficient to meet their needs. Scenario 3 water deficit on October 1, October 2.

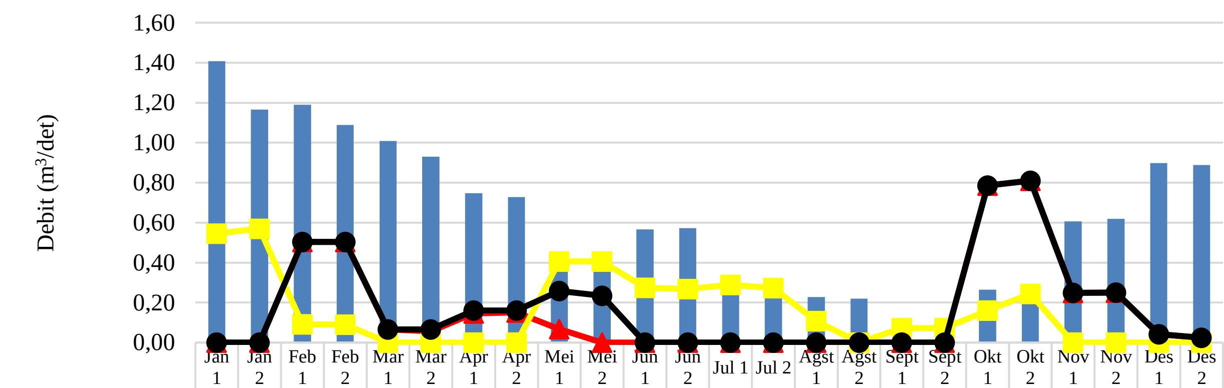


	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	Mei 1	Mei 2	Jun 1	Jun 2	Jul 1	Jul 2	Agst 1	Agst 2	Sept 1	Sept 2	Okt 1	Okt 2	Nov 1	Nov 2	Des 1	Des 2
Q80	1,41	1,17	1,19	1,09	1,01	0,93	0,75	0,73	0,45	0,41	0,57	0,57	0,34	0,31	0,23	0,22	0,08	0,08	0,26	0,28	0,61	0,62	0,90	0,89
Skenario 1	0,00	0,00	0,48	0,48	0,06	0,05	0,14	0,14	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,74	0,76	0,24	0,24	0,04	0,02
Skenario 2	0,51	0,53	0,09	0,09	0,00	0,00	0,00	0,00	0,39	0,38	0,26	0,26	0,27	0,26	0,10	0,00	0,07	0,07	0,15	0,23	0,00	0,00	0,00	0,00
Skenario 3	0,00	0,00	0,48	0,48	0,06	0,06	0,15	0,13	0,24	0,22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,74	0,76	0,24	0,24	0,04	0,02

Figure 6. Water supply and water demand for 3 scenarios with a land area of 850 ha

Land development water balance analysis

The water balance for land development with an area of 900 ha using a surplus of water deficit is obtained from the results of reducing the debit of water availability with water demand if the result is positive then it is a surplus and if it is negative then it is a deficit (Herrera et al., 2010). From Figure 5 below, it can be concluded that the water deficit scenario 1 is October 1, and October 2. Scenario 2 does not have a water deficit month or all months have a surplus of water, meaning that the availability of water is sufficient to meet their needs. Scenario 3 water deficit on October 1, October 2.



	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	Mei 1	Mei 2	Jun 1	Jun 2	Jul 1	Jul 2	Agst 1	Agst 2	Sept 1	Sept 2	Okt 1	Okt 2	Nov 1	Nov 2	Des 1	Des 2
Q80	1,41	1,17	1,19	1,09	1,01	0,93	0,75	0,73	0,45	0,41	0,57	0,57	0,34	0,31	0,23	0,22	0,08	0,08	0,26	0,28	0,61	0,62	0,90	0,89
Skenario 1	0,00	0,00	0,50	0,50	0,07	0,06	0,15	0,15	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,79	0,81	0,25	0,25	0,04	0,02
Skenario 2	0,55	0,57	0,09	0,09	0,00	0,00	0,00	0,00	0,41	0,41	0,27	0,27	0,29	0,27	0,11	0,00	0,07	0,07	0,16	0,24	0,00	0,00	0,00	0,00
Skenario 3	0,00	0,00	0,50	0,50	0,07	0,07	0,16	0,16	0,26	0,23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,79	0,81	0,25	0,25	0,04	0,02

Figure 7. Water supply and water demand for 3 scenarios with a land area of 900 ha

Analysis of rainfall on the water balance of DI Jaro using TRMM rainfall and air temperature data which was previously validated and corrected with Jaro rain post-observation data. The results of data validation using the Correlation Coefficient method which produces a determination value with a strong to very strong interpretation is then corrected using the selected regression equation value according to the largest R2 value. TRMM data after correction is used for rainfall analysis and water balance analysis. Changes in rainfall, namely an increase in monthly rainfall in the shifting months of wet, humid, and dry months.

As a result of changes in rainfall, there is an increase in the value of effective rainfall and evapotranspiration as parameters in calculating water demand and availability (De Fraiture & Wichelns, 2010; Olmstead et al., 2007). Water demand discharge scenario 1 is a planting scenario according to existing conditions on October 1 and 2. Scenario 2 does not have a water deficit month or all months have a surplus of water, meaning that the availability of water will meet their needs. Scenario 3 in the month of the deficit on October 1 and 2.

Conclusion

Analysis of water demand discharge based on planting scenarios is divided into 3 scenarios. scenario 1 with a cropping pattern of superior rice - superior rice according to existing conditions, scenario 2 with a cropping pattern of superior rice - superior rice - secondary crops, and scenario 3 with a superior rice cropping pattern - ordinary rice. Scenario 1 discharge water demand maximum value on October 1 is 0.74 m3/s and October 2 is 0.76 m3/s, Scenario 2 maximum value on January 1 is 0.51 m3/s and January 2 is 0. 53 m3/s, Scenario 3 maximum value on October 1 is 0.74 m3/s and October 2 is 0.76 m3/s. Analysis of the highest peak water availability discharge occurred on January 1 with a discharge value of 1.41 m3/s and February 1 with a discharge value of 1.19 m3/s while the minimum discharge occurred on September 1 of 0.08 m3/s and the month September 2 of 0.08 m3/sec. From the results of the data on water availability and water demand, the potential for land development and the application of the right cropping pattern is obtained by 50 ha with the application of the Scenario 2 cropping pattern with the MT 1 schedule for land preparation in January with the April harvest schedule, the MT 2 schedule for land preparation in May with harvest schedule in September, MT 3 land preparation schedule in October with harvest schedule in December.

Acknowledgements
This paper is part of the requirements for completing the Masters in Civil Engineering, Universitas Lambung Mangkurat.

References

Abdul-Ganiyu, S., Kyei-Baffour, N., Agyare, W., & Dogbe, W. (2015). An evaluation of economic water productivity and water balance of dry season irrigated rice under different irrigation regimes in northern Ghana.

Akas, P. S., Ismail, I., & Napitupulu, M. (2018). Monthly Water Balance Analysis at Palaran District-the Province of East Kalimantan. *Acta Scientific Agriculture*, *2*(12), 39-44.

Ariyani, D., Putuhena, F. J., & Wira, D. (2020). Using Water Balance to Analyse Water Availability for Irrigation with Upraising Surface Temperature (Acase Study Pasar Baru Barrage in Cisadane Watershed). *Civil and Environmental Science Journal (Civense)*, *3*(1), 1-9.

Azmeri, A., Yulianur, A., Zahrati, U., & Faudli, I. (2019). Effects of irrigation performance on water balance: Krueng Baro Irrigation Scheme (Aceh-Indonesia) as a case study. *Journal of Water and Land Development*, *42*(1), 12–20.

Budi, A. S. (2021). Calculation and Mapping of Water Demand Balance in Pacal Bojonegoro Irrigation Area. In *Journal of World Conference (JWC)* (Vol. 3, No. 3, pp. 336-341).

Canet-Martí, A., Morales-Santos, A., Nolz, R., Langergraber, G., & Stumpp, C. (2023). Quantification of water fluxes and soil water balance in agricultural fields under different tillage and irrigation systems using water stable isotopes. *Soil and Tillage Research*, *231*, 105732. https://doi.org/10.1016/j.still.2023.105732

Chen, C., Wang, E., & Yu, Q. (2010). Modelling the effects of climate variability and water management on crop water productivity and water balance in the North China Plain. *Agricultural Water Management*, *97*(8), 1175-1184. https://doi.org/10.1016/j.agwat.2008.11.012

De Fraiture, C., & Wichelns, D. (2010). Satisfying future water demands for agriculture. *Agricultural water management*, *97*(4), 502-511. https://doi.org/10.1016/j.agwat.2009.08.008

Döll, P., Kaspar, F., & Lehner, B. (2003). A global hydrological model for deriving water availability indicators: model tuning and validation. *Journal of Hydrology*, *270*(1-2), 105-134. https://doi.org/10.1016/S0022-1694(02)00283-4

Duffková, R., Holub, J., Fučík, P., Rožnovský, J., & Novotný, I. (2019). Long-term water balance of selected field crops in different agricultural regions of the czech republic using fao-56 and soil hydrological approaches. *Sustainability*, *11*(19), 5243.

Ezuar, N., Cahyandito, M. F., & Hendarmawan, H. (2018). Groundwater Balance Evaluation for Groundwater Availability in Ngarawan Watershed, Belitung Timur Regency. *Ecodevelopment*, *1*(1).

Gichamo, T., Abate, B., Esimo, F., Gokcekus, H., & Gelete, G. (2022). Analysis of water balance and hydrodynamics of Lake Beseka, Ethiopia. *Journal of Water and Climate Change*, *13*(5), 2034-2047.

Hariyadi, H. (2020). The ability of water hyacinth, heartshape false pickerelweedand water lettuce as chlorine phitoremediation in water. *International Journal of Life Sciences & Earth Sciences*, *3*(1), 30-37. https://doi.org/10.31295/ijle.v3n1.180

Herrera, M., Torgo, L., Izquierdo, J., & Pérez-García, R. (2010). Predictive models for forecasting hourly urban water demand. *Journal of hydrology*, *387*(1-2), 141-150. https://doi.org/10.1016/j.jhydrol.2010.04.005

Hidayat, A., Rustanto, F. R., Gunawansyah, G., & Saima, F. C. (2022). Optimization of Water Utilization for Irrigation Networks (Case Study: Wawotobi Dam, Unaaha District, Konawe Regency). *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, *5*(2).

Huber, S., Fensholt, R., & Rasmussen, K. (2011). Water availability as the driver of vegetation dynamics in the African Sahel from 1982 to 2007. *Global and Planetary Change*, *76*(3-4), 186-195. https://doi.org/10.1016/j.gloplacha.2011.01.006

Ikhwali, M. F., Ersa, N. S., Khairi, A., Prayogo, W., & Wesli, W. (2022). Development of Soil & Water Assessment Tool Application In Krueng Aceh Watershed Review. *TERAS JURNAL*, *12*(1), 191-204.

Liu, Z., Huang, Y., Liu, T., Li, J., Xing, W., Akmalov, S., ... & Duan, Y. (2020). Water balance analysis based on a quantitative evapotranspiration inversion in the Nukus irrigation area, Lower Amu River Basin. *Remote Sensing*, *12*(14), 2317.

Martínez-Casasnovas, J. A., Martín-Montero, A., & Casterad, M. A. (2005). Mapping multi-year cropping patterns in small irrigation districts from time-series analysis of Landsat TM images. *European Journal of Agronomy*, *23*(2), 159-169. https://doi.org/10.1016/j.eja.2004.11.004

Olmstead, S. M., Hanemann, W. M., & Stavins, R. N. (2007). Water demand under alternative price structures. *Journal of Environmental economics and management*, *54*(2), 181-198. https://doi.org/10.1016/j.jeem.2007.03.002

Pamadya, O., Juwono, P. T., Andawayanti, U., & Asmaranto, R. (2022). Detection of Climate Change in the Kedungsoko Irrigation Area–Nganjuk, Indonesia. *Journal of Hunan University Natural Sciences*, *49*(4).

Putra, G. M. D., Setiawati, D. A., & Sumarjan, S. (2018). Water Balance Analysis In Pijenan Bantul Irrigation Area. *Jurnal Agrotek Ummat*, *5*(1), 37-45.

Qarinur, M., Silitonga, E. M. R., Sibuea, D. T. A., & Rahayu, T. (2022). Evaluasi Neraca Air Daerah Irigasi Sei Belutu Kabupaten Serdang Bedagai. *Jurnal Teknik Sipil dan Lingkungan*, *7*(1), 89-100.

Setyorini, A., & Hardaningrum, F. (2020). Calculation and Mapping of Water Balance Sheet Based on Geographic Information Systems in The Irrigation Area in Padi Pomahan Mojokerto. *ADRI International Journal of Engineering and Natural Science*, *5*(02), 15-26.

Sihombing, A. M. C., Indarto, I., & Wahyuningsih, S. (2021). Assessment of Water Balance at Mayang Watershed, East Java. *Geosfera Indonesia*, *6*(1), 55-76.

Singh, D. K., Jaiswal, C. S., Reddy, K. S., Singh, R. M., & Bhandarkar, D. M. (2001). Optimal cropping pattern in a canal command area. *Agricultural Water Management*, *50*(1), 1-8. https://doi.org/10.1016/S0378-3774(01)00104-4

Sujono, J. (2022). Water Balance Evaluation towards Cropping Index Enhancement in Belanti II Swamp Irrigation Area, Central Kalimantan. In *International Conference on Sustainable Environment, Agriculture and Tourism (ICOSEAT 2022)* (pp. 82-90). Atlantis Press.

Sun, H. Y., Liu, C. M., Zhang, X. Y., Shen, Y. J., & Zhang, Y. Q. (2006). Effects of irrigation on water balance, yield and WUE of winter wheat in the North China Plain. *Agricultural water management*, *85*(1-2), 211-218. https://doi.org/10.1016/j.agwat.2006.04.008

Zhao, J., Yu, Y., Lei, J., & Liu, J. (2023). Multi-Objective Lower Irrigation Limit Simulation and Optimization Model for Lycium Barbarum Based on NSGA-III and ANN. *Water*, *15*(4), 783.