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Analysis of Surplus Discharge of Banyubang River and Its Utilization to Increase the Rice Crops Intensity of Sumber Pakem Irrigation Area

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Abstract— *To support the improvement of agricultural production in the context of realizing national food security and the welfare of the community, especially farmers, better irrigation performance is needed. The utilization of the Banyubang River discharge in Jember Regency, East Java Province in Indonesia, which has not been maximized, needs to be carried out the studies to maximize its utilization. This study aims to analyze the surplus discharge of Banyubang River which can be used to increase rice crop intensity in the Sumber Pakem Irrigation Area. The results of the study show that there is a surplus discharge of the Banyubang River in the period I December to the period III May. The surplus discharge of the Banyubang River can increase the rice crop intensity of the Sumber Pakem Irrigation Area during the 1st planting season equal to 2,03% and the second planting season equal to 27,28%. Whereas during the 3rd planting season there was no increase in rice crops intensity because in that period there was no surplus flow/discharge of the river.*

Keywords— *River Surplus Discharge, Planting intensity, Method of FPR-LPR, Water Balance.*

I. INTRODUCTION

The availability of water in quantity and quality for various needs of the community including irrigation as the biggest water user in Indonesia must be maintained and regulated its use which plays an important role in national food security (Hatmoko. W, Radhika, Firmansyah. R, and Fathoni. A, 2017). The availability of water in human life is very vital and closely related to food and energy security as a nexus of water, food and energy security (Head. B, and Cammerman. N, 2010). The concept of water availability starts from the problem of water needs and supply which is the opposite of water scarcity with the indicator commonly used is the amount of water available, which one of them is to meet the availability of irrigation water (Falkenmark. M, 2013).

Development in the agricultural sector today is directed towards efficient and resilient agriculture, considering that efforts to increase rice production to meet the food needs for a growing population always become a top priority in agricultural development in Indonesia. (Suwarno, 2010). This requires the use of irrigation water to be carried out more effectively and efficiently by means of the provision and distribution of the water system properly so that all the plants get water according to their needs.

This study aims to analyze the surplus discharge of Banyubang River which can be used to increase rice crop intensity in the Sumber Pakem Irrigation Area so that it can support national food self-sufficiency, especially rice. The benefits of this study are to determine the existing water balance conditions and the pattern of water supply that can be done in the Sumber Pakem Irrigation Area.

II. RESEARCH METHODOLOGY

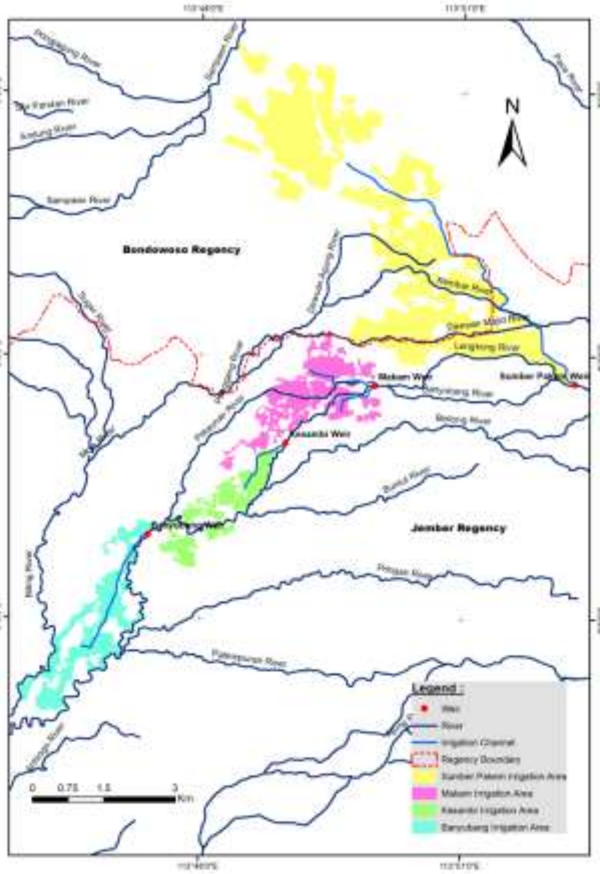

Fig. 1. Map of Study Location

Geographically the Sumber Pakem Irrigation Area is located at 113° 48' 15" EL - 113° 52' 15" EL and 7° 59' 25" SL - 8° 3' 19" SL. The natural conditions of the study area are plains in the south to the north with rainfall conditions averaging ± 1,900 mm per year. While the average air temperature is 26°C, minimum temperature 23°C, maximum temperature 30°C. The water source of Sumber Pakem Irrigation Area originated from Banyubang River which is dammed by Sumber Pakem Weir located in Sumber Pakem

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Village Sumber Jambe Subdistrict, Jember Regency, East Java Province, Indonesia to irrigate an area of 1,151 ha. The water dammed by the Sumber Pakem Weir is flowed through the Sumber Pakem Secondary Channel along 7.889 meters, then tapped by 10 (ten) offtake structures to be channeled to each tertiary plot.

As for the steps for the implementation on this study are as follows:

a. Data collection
   The data used in this study are:
   - 10 daily average discharge data of weir intake (2000 – 2017)
   - 10 daily average discharge data of weir runoff (2000 – 2017)
   - 10 daily crop data (2012 – 2017)

b. Analysis of river surplus discharge
   Analysis of river surplus flow/discharge is carried out in the following stages:
   - Considering the discharge requirements in the downstream area of Sumber Pakem Weir, where the Banyubang River discharge is also used for irrigation water extraction in the downstream of Sumber Pakem Weir.
   - Calculate the existing intake dependable flow in the Sumber Pakem Irrigation Area and the irrigation area in the downstream of Sumber Pakem weir using the modus method.
   - Calculate river discharge in each weir namely Sumber Pakem Weir and weir in the downstream of Sumber Pakem Weir by summing the intake discharge and weir runoff discharge.
   - Calculating the dependable flow of rivers in each weir namely Sumber Pakem Weir and weir in the downstream of Sumber Pakem Weir using the Q_{80} flow characteristic method.
   - Calculate the river surplus discharge in each weir namely Sumber Pakem Weir and weir in the downstream of Sumber Pakem Weir by means of river dependable flow minus intake dependable flow.
   - Determine the surplus flow/discharge of the river that can be used to fill the connected wells and re-evaluate the water balance of the study area that obtained from the smallest runoff discharge from Sumber Pakem Weir and weir in the downstream of Sumber Pakem Weir.

c. Analysis of existing water balance
   Water balance analysis is carried out in the following stages:
   - Evaluate the existing planting intensity with existing cropping patterns.
   - Calculate the real water requirements/needs using the LPR-FPR method and K factor, so that it will be known the water distribution in the study area namely continuously or rotationally.

d. Analysis of the increasing of rice crop intensity
   Reevaluating the water balance by maximizing the discharge/ flow of the river surplus through rearranging the water supply schedule in the study area by replacing the secondary crops in the field into rice plants.

Water Availability with Dependable Flow

Dependable flow is the minimum flow of the river for the possibility of being fulfilled which has been determined that can be used for irrigation. The possibility of being fulfilled is set at 80% or the possibility that the river discharge is lower than the dependable flow is 20% (Ministry of Public Works, 2011 p.85). For table forms, daily discharge data is sorted from the largest to the smallest value, the dependable percentage is obtained as the below equation which expressed in % (Triatmodjo, 2010, p.308):

$$Dependable\ (\%) = \frac{m}{n+1} \qquad (1)$$

with:
m = the serial number of the data
n = total data

To calculate the amount of intake discharge for which data is hypothetical, the modus value is used. The modus number is more useful as the forecast number of the amount of median value and as an indication of the data deployment center (Asdak, 2004), with the equation:

$$Mo = B + i\left[\frac{f - f_1}{(f - f_1) + (f - f_2)}\right] \qquad (2)$$

with:
Mo = modus
B = lower limit of the modus class interval
i = class interval
f = maximum frequency of modus class
f_1 = frequency before the modus class
f_2 = frequency after the modus class

Irrigation Water Needs Method of FPR-LPR

The Relative Secondary Crops Factor/Faktor Palawija Relatif (FPR) is the water discharge needed in tertiary off take structure by one hectare of palawija/secondary crops plants which is calculated based on the following equation (Martani, 1997):

$$FPR = \frac{Q}{LPR} \qquad (3)$$

with:
FPR = faktor palawija relative/relative secondary crops factor (l/s/ha.pol)
Q = discharge at intake gate (l/s)
LPR = luas palawija relative/the area of relative secondary crops (ha.pol)

The value of LPR is basically a comparison of water requirements between one types of plants with other types of plants. Plants used as a comparison are secondary crops which have a value of 1 (one). All water requirements of the plants that will be searched are first converted to secondary crops water needs which are finally obtained one number as a conversion factor for each type of plant. LPR is the product of the plant area of a type of plant multiplied by a value of the ratio between the water needs of the plant to the water needs of the secondary crops. Comparative figures for plant LPR can be seen in Table 1.

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LPR = Planting Area x Comparative Figures for Plant LPR (4)

TABLE 1. Comparative Figures for Plant LPR

No.	Plant Type	Comparative Coefficient
1.	Secondary Crops	1
2.	Rice/padi at rainy season (rendeng)	
	a. Tilling of the soil for seeding	20
	b. Tilling of the soil for rice plants	6
	c. Growth/maintenance	4
3.	Rice at dry season (permit gadu)	Same with rendeng rice
4.	Gadu rice not permit	1
5.	Sugar cane	
	a. Seed/young	1.5
	b. Old	0
6.	Tobacco/rosella	1
7.	Filling the pond (ponding rice field)	3

Source: Martani, 1997

Irrigation Water Supply System

The water supply system applied to the study area is FPR LPR method with continuous inundation (*stagnant constant level*) system. The water requirements in the rice fields and the required discharge at the intake gate are calculated using the equation below (Department of Agriculture, 1983 p.155 in Puteriana, 2016 p.13):

$$Q_1 = \frac{H\ x\ A}{T}\ x\ 10.000 \quad (5)$$

$$Q_2 = \frac{Q_1}{86.400}\ x\ \frac{1}{(1-L)} \quad (6)$$

with:

Q_1 = daily needs of water in fields/plots of rice fields (m^3/day)
Q_2 = daily water requirements at the intake gate (m^3/s)
H = inundation height (m)
A = area of rice fields (ha)
T = water supply interval (day)
L = water loss on land and canals (m)

From the types of irrigation water supply, can be grouped into two ways, namely: (1) continuous and proportional on the condition of peak discharge and changing discharge, and (2) intermittent rotationally for fixed discharge conditions. The method of continuous supply can be given at $K \geq 1$ while for intermittent only on $K < 1$. The criteria for irrigation water supply with K factor and FPR values are explained in Table 2 and Table 3.

$$K = \frac{Intake\ discharge}{Required\ discharge} \quad (7)$$

TABLE 2. Criteria for Water Supply with K Factor

K Factor	Criteria
0.75 – 1.00	Continously
0.50 – 0.75	Rotation in tertiary channel
0.25 – 0.50	Rotation in secondary channel
< 0.25	Rotation in primary channel

Source: Kunaifi, 2011 p.16

TABLE 3. Conversion of K Factor and FPR for Water Distribution

K Factor	FPR (l/s/ha.pol)	Water Distribution	
		K Factor	FPR
> 0,75	> 0,12	Continously	Adequate
0,50 – 0,75	0,06 – 0,12	Rotation in tertiary channel	Sufficient
< 0,50	< 0,06	Rotation in secondary channel	Less

Source: Kunaifi, 2011 p.16

III. Results and Discussion

Analysis of the Intake Dependable Flow in Sumber Pakem Irrigation Area

To calculate the intake dependable flow of Sumber pakem Irrigation Area using data recording of 10 daily discharge that enter the intake. Discharge data used from 2000 to 2017 (18 years). The calculation results of the intake dependable discharge of the Sumber Pakem Irrigation area using the modus method can be seen in Figure 2. Modus discharge is used as a discharge for the next analysis which is used as a reference whether the discharge is sufficient or not for the water needs of plants on the land.

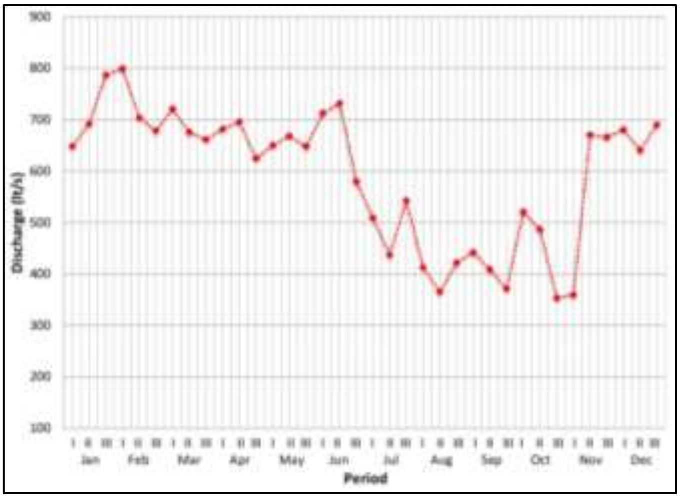

Fig. 2. Graph of Intake Dependable Flow of Sumber Pakem Irrigation Area

Analysis of River Surplus Discharge

To calculate the potential of river discharge that can be used to re-evaluate the water balance in the study area using the Q_{80} flow characteristics method by considering the discharge requirements in the downstream area of Sumber Pakem Weir as shown in Figure 1. So that the calculation of the potential of river discharge that can be used to re-evaluate the water balance in the study area is also taking into account the intake dependable flow and the river dependable flow in each of the weirs, which will be known later the surplus discharge of Banyubang River that can be used to fill the connected well and re-evaluate the water balance in Sumber Pakem Irrigation area. Discharge data used from 2000 to 2017 (18 years).

The calculation results of river surplus flow (weir runoff dependable flow) in each weir and surplus discharge of Banyubang River which can be used to re-evaluate the water balance of Sumber Pakem Irrigation Area can be seen in Figure 3. Figure 3 shows that the surplus discharge of

Banyubang River which can be used to re-evaluate water balance in Sumber Pakem Irrigation Area can be done in the period I December until the period III May. Runoff in Sumber Pakem Weir always occurs throughout the season for one year, but during period I June to period III November or during the third planting season (MT 3) all water overflowing above Sumber Pakem Weir is all used to meet irrigation water needs in the Irrigation Area which is in the downstream of the weir. So that from the period I June to the period III November or when planting season/MT 3 there is no surplus discharge, except only in the period I November ($Q_{surplus}$ = 10.17 lt/s).

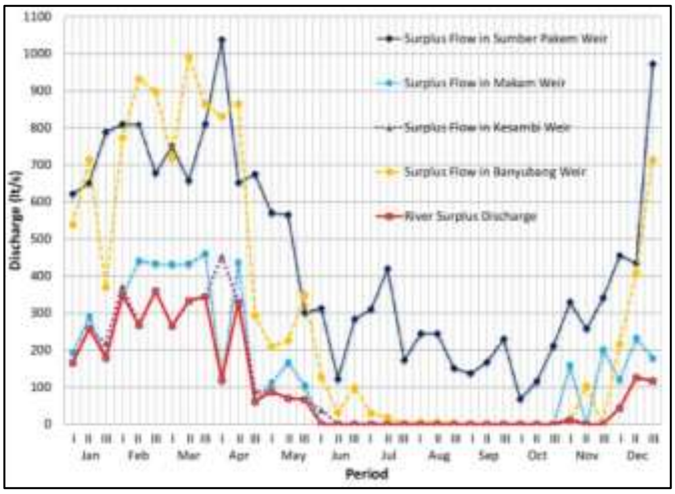

Fig. 3. Graph of Banyubang River Surplus Discharge

Evaluation of the Existing Cropping Patterns and Cropping Intensity

Evaluation of cropping patterns and cropping intensity was carried out for the last 5 (five) years, namely from the period 2012/2013 - 2016/2017. The analysis results of the existing average cropping patterns and planting intensity can be seen in Table 4.

TABLE 4. Evaluation of the Achievement of Planting Area in Sumber Pakem Irrigation Area with Existing Planting Patterns Period 2012/2013 - 2016/2017

Plant Type	Achievement of Planting Area (%)			
	MT 1	MT 2	MT 3	Total
Rice	97.53	72.28	20.97	190.79
Gadu rice not permit	0.00	3.89	2.48	6.38
Secondary crops	2. 03	23.39	35.55	60.67
Tobacco	0.00	0.00	40.56	40.56
Sugar cane	0.43	0.43	0.43	1.30
Planting intensity	100.00	100.00	100.00	300.00

Source: analysis results

Based on Table 4 shows that rice crop intensity during Planting Season 1 (MT 1) is 97.53% and Planting Season 2 (MT 2) is 72.28%. This shows that in the study area it is necessary to evaluate the water balance and evaluate the design cropping pattern by increasing the intensity of rice plants at planting season 1 and planting season 2. Increasing the intensity of rice plants can be done by means of secondary crops on the land replaced with rice plants. Where the water needs of rice plants are higher than secondary crops. So that increasing the intensity of rice plants when Planting Season 1 and Planting Season 2 required additional water availability at the intake by utilizing the surplus river discharge in that period.

Evaluation of the Need for Real Plant Water and Existing Water Balance

Evaluation of real water needs of plants is carried out in each planting season for the last 5 (five) years, namely from the period 2012/2013 - 2016/2017. This is conducted in order to find out how much the real water needs of plants are in each phase and/or type of plant in each planting season. So that later the real plant water needs will be obtained in each phase and/or plant type for one year. In addition, evaluation of real water needs of plants is also carried out to obtain the value of existing FPR in each planting season for the last 5 (five) years, namely from the period 2012/2013 - 2016/2017. So that later the average FPR value will be obtained in each planting season for one year.

The average real water requirements of the plant in each phase and/or type of plant for one year and the average FPR value in each planting season for one year will be used as a reference in calculating the irrigation water needs of the plan according to the planned cropping pattern. So that later the irrigation water needs will be obtained every planting season for one year. The analysis results of the average real water requirements of the plant are presented in Table 5.

TABLE 5. Average Real Irrigation Water Needs in Sumber Pakem Irrigation Area

Description	Average Real Water Needs (lt/sec/ha)	Average LPR	FPR
Nursery	5.10	20.02	MT 1 = 0.22
Rice fields processing	1.40	5.86	MT 2 = 0.19
Maintenance of rice	0.96	3.82	MT 3 = 0.31
Secondary crops	0.25	1.00	
Tobacco	0.30	1.19	
Sugar cane	0.35	1.38	

Source: analysis results

Design Planting Pattern

Based on the evaluation of existing planting patterns for 5 (five) years of planting period and the results of the analysis of river surplus discharge in the study area, the planned cropping pattern is to increase the plan/design rice crop intensity by considering cropping patterns that are in accordance with the habits of local farmers. So that the types of secondary crops in each planting season need to be analyzed again to be improved into rice plants.

Types of secondary crops in Planting Season 1 (MT 1) and Planting Season 2 (MT 2) were increased become rice plants with consideration in that period there was a surplus flow/discharge of the river. During Planting Season 3 (MT 3) there is no surplus flow/discharge of the river so that the intensity of rice plants is the same as the existing conditions. For this reason, in the study area, it is planned the cropping pattern as follows:

Planting Season 1 : Rice (99.,57%) - Sugarcane (0.43%)
Planting Season 2 : Rice (99.57%) - Sugarcane (0,43%)

Planting Season 3 : Rice (20,97%) – Secondary crops (38,04%) – Tobacco (40,56%) – Sugar cane (0,43%)

Water Distribution Plan

Water distribution is planned using the basis of the calculation of the unit of Relative Secondary Crop factor/Faktor Palawija Relatif (FPR) based on the values obtained in accordance with the conditions in the study area. In addition, it is also based on the criteria of K factor (Equation 7 and Table 2). the division of group blocks in each irrigation network system at Sumber Pakem Irrigation Area is planned as in Figure 4.

Calculation of the Planned Irrigation Water Requirements

Calculation of planned irrigation water needs is based on the planned cropping pattern, plan for group block distribution and results of the evaluation of FPR and LPR criteria in Table 5. The results of planned irrigation water needs analysis can be seen in Table 6.

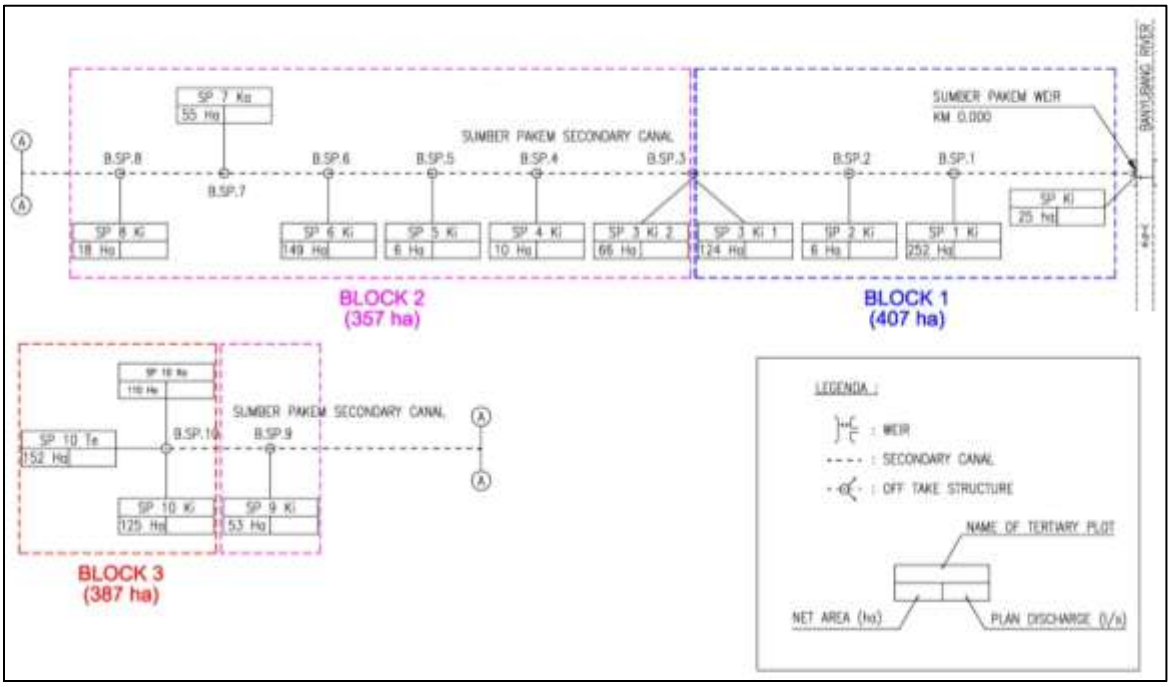

Fig. 4. Distribution of Group Blocks in Sumber Pakem Irrigation Area

TABLE 6. Results of Analysis of Water Balance and Water Distribution in Sumber Pakem Irrigation Area

Month	Period	Planting Season	Irrigation Water Needs (l/s)				Intake Discharge (lt/sec)	Water Distribution Evaluation	
			Group I	Group II	Group III	Total		K Factor	Criteria
October	I	III	302.90	51.55	96.72	451.18	521.55	1.16	Continuously
	II	I	389.78	187.41	232.53	809.73	487.20	0.60	Tertiary Rotation
	III	I	493.84	349.63	375.14	1218.61	354.00	0.29	Secondary Rotation
November	I	I	597.90	524.45	562.72	1685.06	370.44	0.22	Secondary Rotation
	II	I	514.50	451.29	484.44	1450.23	671.25	0.46	Secondary Rotation
	III	I	431.10	378.14	406.16	1215.4	666.93	0.55	Tertiary Rotation
December	I	I	347.70	304.99	327.89	980.58	724.11	0.74	Tertiary Rotation
	II	I	347.70	304.99	327.89	980.58	767.38	0.78	Continuously
	III	I	347.70	304.99	327.89	980.58	807.70	0.82	Continuously
January	I	I	347.70	304.9930	327.89	980.58	814.55	0.83	Continuously
	II	I	347.70	4.99304.9	327.89	980.58	950.13	0.97	Continuously
	III	I	347.70	9	327.89	980.58	967.42	0.99	Continuously
February	I	I	347.70	304.99	327.89	980.58	1148.77	1.17	Continuously
	II	II	400.96	351.70	377.87	1130.53	972.40	0.86	Continuously
	III	II	454.21	398.41	427.86	1280.49	1039.01	0.81	Continuously
March	I	II	507.47	445.13	477.84	1430.44	986.76	0.69	Tertiary Rotation
	II	II	436.68	383.04	411.41	1231.13	1009.33	0.82	Continuously
	III	II	365.90	320.95	344.97	1031.82	1006.92	0.98	Continuously
April	I	II	295.11	258.86	278.53	832.51	802.51	0.96	Continuously
	II	II	295.11	258.86	278.53	832.51	1026.17	1.23	Continuously
	III	II	295.11	258.86	278.53	832.51	686.97	0.83	Continuously
May	I	II	295.11	258.86	278.53	832.51	738.34	0.89	Continuously
	II	II	295.11	258.86	278.53	832.51	739.00	0.89	Continuously
	III	II	295.11	258.86	276.99	830.96	715.15	0.86	Continuously
June	I	II	295.11	258.86	276.99	830.96	713.48	0.86	Continuously
	II	III	360.52	185.17	229.62	775.31	732.42	0.94	Continuously

Month	Period	Planting Season	Irrigation Water Needs (l/s)				Intake Discharge (lt/sec)	Water Distribution Evaluation	
			Group I	Group II	Group III	Total		K Factor	Criteria
	III	III	443.09	137.84	189.05	769.99	580.56	0.75	Continuously
July	I	III	525.67	90.51	148.48	764.67	509.92	0.67	Tertiary Rotation
	II	III	474.31	116.88	155.28	746.47	438.00	0.59	Tertiary Rotation
	III	III	405.78	116.88	155.28	677.94	543.60	0.80	Continuously
August	I	III	337.25	116.88	155.28	609.40	414.00	0.68	Tertiary Rotation
	II	III	337.25	116.88	155.28	609.40	365.80	0.60	Tertiary Rotation
	III	III	337.25	116.88	155.28	609.40	422.80	0.69	Tertiary Rotation
September	I	III	337.25	116.88	155.28	609.40	443.00	0.73	Tertiary Rotation
	II	III	337.25	116.88	155.28	609.40	409.63	0.67	Tertiary Rotation
	III	III	320.07	90.51	148.48	559.07	372.20	0.67	Tertiary Rotation

Source: analysis results

The utilization of surplus discharge of Banyubang River can increase rice crop intensity of Sumber Pakem Irrigation Area for 1 (one) year by 9,76%, with the improvement of the rice crop intensity each planting season as follows:

1. Planting Season 1 (MT 1) increases by 2,03%
2. Planting Season 2 (MT 2) increases by 27,28%
3. Planting Season 3 (MT 3) no increase (constant)

IV. CONCLUSION

The surplus discharge of the Banyubang River occurs in the period I December to the period III May so that water balance can be evaluated in the Sumber Pakem Irrigation Area to increase the intensity of rice plants in the irrigation area. The surplus discharge of the Banyubang River can increase the rice crop intensity of the Sumber Pakem Irrigation Area during the 1st planting season equal to 2,03% and the second planting season equal to 27,28%. Whereas during the 3rd planting season there was no increase in rice crops intensity because in that period there was no surplus flow of the river.

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