Optimization of Irrigation Water using System of Rice Intensification (SRI) Method in the Kereloko Irrigation Area West Sumba Regency

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Keywords: Optimation, Kereloko, Conventional Method, System of Rice Intensification, Water Requirement.

Abstract: Sumba Island is a semi-arid climate with an average annual rainfall of 800 mm. Low rainfall has an impact on the low potential of water resources needed for agriculture. This study was conducted to compare existing irrigation water supply techniques and water saving supply techniques. The water supply applied in the study area is a conventional technique, while the new technique that will be compared is SRI (System of Rice Intensification). The SRI technique is expected to save irrigation water and thereby increase the planted area. The available discharge data is used to calculate the irrigation water balance. The conventional method results show that the area of rice fields that can be irrigated for the first planting season to third planting season were 57.5 hectares, 32 hectares, and 19 hectares, respectively. The area of rice fields that can be irrigated by the SRI method for the first and second planting season is 85.5 hectares, and third planting season is 54.9 hectares. Compared with the conventional method, applying the SRI method can increase the planted area by 155.8% in the first and second planting season.

1 INTRODUCTION

According to the Schmidth-Fergudon climate classification, the island of Sumba is an area with climate type E, which is a semi-arid climate with a large area of savanna. As a semi-arid area, Sumba island is an area with low rainfall, with an average annual rainfall of 1200 mm. The eastern part of the island of Sumba is the area with the lowest rainfall. In the west, the average annual rainfall is 2,500 mm, while along the north and east coasts the average annual rainfall is only 800 mm (Nuri, 1985).

Low rainfall has an impact on the low potential of water resources. Limited water resources affect the agricultural sector, especially rice irrigated agriculture. The irrigation method applied on the island of Sumba is a conventional method, guided by the criteria for irrigation planning (KP/*Kriteria Perencanaan Irigasi*), from the Ministry of Public Works. This conventional method uses a continuous watering technique (continuous inundation), therefore it requires the large availability of water.

To anticipate the limited availability of water, it is necessary to apply water-saving rice cultivation methods. One method of water-saving rice cultivation that can be applied to optimize water use in areas with limited water resources is the System of Rice Intensification (SRI). SRI has the advantage, that it saves water (during the vegetative phase the land is in a *saturated* state to the micro crack state), entering the generative phase the land is irrigated a maximum of 2 cm. This inundated state is cultivated until 25 days before harvest (Rozen, 2018).

Many studies about the application of the SRI method have been carried out, including by Puteriana S. A. et.al (2016), in her study, comparing the conventional LPR-FPR (*Luas palawija relatif - Faktor palawija relatif*) method with the SRI method. The results of his study showed that the irrigation water supply system using the SRI method could increase cropping intensity by 300% and had a saving rate of 88.65% when compared to the conventional method. Hidayat YR & Suciaty T. (2019), in their study, compared income between SRI rice cultivation and conventional methods. The results of his study showed that with the SRI method, rice production increased by 20% compared to the conventional method. SRI rice production is 6.2 tons/ha, while the conventional method is 5.7 tons/ha.

This study compares irrigation water consumption between the Ministry of Public Works' conventional method and the SRI method. The aim of this study is

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to determine cropping intensity and irrigation water savings.

2 STUDY AREA

The study location is the Kereloko Ricefield Area (DI/*Daerah Irigsi*) in the District of Kota Waikabubak, West Sumba Regency (Fig 1). Administratively, DI Kereloko is located in the Wailingan Village, Kota Waikabubak sub district, West Sumba Regency, East Nusa Tenggara Province. The water source for irrigating the rice fields is taken from the Kereloko River. The total area of land that can be irrigated is about 54.9 ha. In DI Kereloko, three planting seasons were applied with the planting scheme in each season being paddy – paddy – secondary crops (crops planted as 2d crop in dry season). Limited water sources cause the area of rice fields that can be cultivated for each season is not maximal, especially in the third planting season, due to low water availability, only secondary crops can be planted.

3 MATERIALS AND METHODS

3.1 Data

The data used in this study include: (a) daily rainfall and temperature data – from Indonesian Meteorology and Geophysics Agency. Only 1 rainfall and temperature data is used. Rainfall data obtained from the Kota Waikabubak rainfall station gauge, while the weather data is taken from the Umbu Mehang Kuda Meteorological Station gauge, East Sumba Regency; (b) streamflow data and irrigation network scheme – from Water Resources division, West Sumba Regency Public Works Service.

3.2 Conventional Method Description

The irrigation method applied on the island of Sumba is a conventional method, guided by the criteria for irrigation planning (KP/*Kriteria Perencanaan Irigasi*), from the Ministry of Public Works. This method requires rainfall data and temperature data. Rainfall data is used to calculate the effective rainfall and temperature data is used to calculate evapotranspiration. Conventional method calculates net field water requirement according to the equation (Kementerian Pekerjaan Umum, 2013):

$$NFR = ET_c + P + WLR - R_e$$

Where NFR is the net rice field water requirement (mm/day), P is percolation (mm/day), ET_C is crop

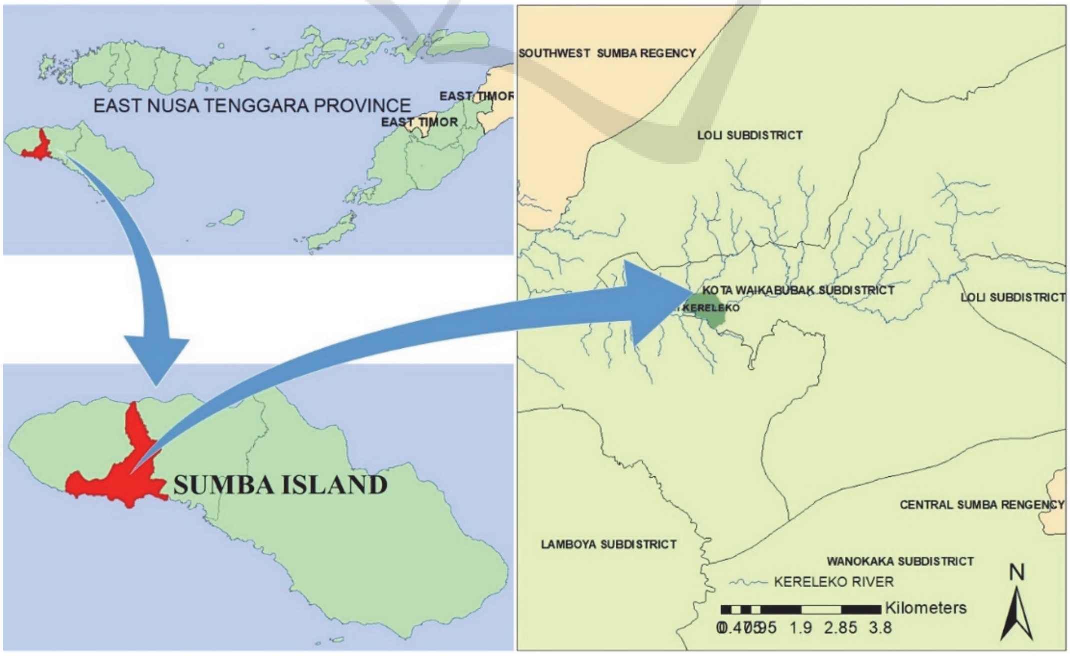

Figure 1: Study Area.

water requirement (mm/day), WLR is Water layer replacement (mm/day), and Re is effective rainfall (mm/day).

Crop water requirement (ET_C) obtained from evapotranspiration (ET_0) multiplied by the crop coefficient (K_c). Evapotranspiration is calculated by the Pennman-Modification formula. Pennman-Modification calculates evapotranspiration according to the equation (Doorenbos, 1977):

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

Where ET_0 is reference crop evapotranspiration (mm/day); W is temperature-related weighted factor; Rn is net radiation in equivalent evaporation (mm/day); f(u) is wind-related function; (ea – ed) is difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air (both in mbar); and c is adjustment factor to compensate for the effect of day and night weather conditions. Based on the guidelines from the KP, the amount of percolation (P) is between 1-3 mm/day, while Water layer replacement (WLR) is performed 2 times, each 50 mm during the first month and the second month after transplantation.

The time required for land preparation is 30-45 days. The water requirement for land preparation is calculated using the formula:

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

Where IR is the water requirement at the rice field; M is the water requirement to replace water loss due to evaporation and percolation in saturated rice fields. M is calculated by the formula

$$M = E_0 + P$$

Where E_0 is open water evaporation during land preparation (mm/day) (E_0 is taken as 1,1 ET_0); and P is percolation (mm/day). K is calculated by the formula:

$$K = M \cdot T/S$$

Where T is the land preparation time (days); and S is the water requirement for saturation plus 50 mm water layer.

3.3 SRI Description

In SRI rice cultivation, the condition of water availability in the land is regulated so that the land is slightly dry but still sufficient for plant water needs. Water supply for SRI method is based on 3 stages, namely, nursery, land preparation, and breeding. The breeding stage is divided into a vegetative phase and a generative phase. After the breeding stage, which is 10 days before harvest, the land is left to dry.

The nursery time was 10 days with the interval of watering is every 5 day and the thickness of the water layer was 75 mm. The land area for the nursery is 5% of the total land area. The time required for land preparation is 30 days, with the watering interval is every 5 days and the thickness of the water layer is 23 mm. Land area for land preparation is 95% of the total land area. The time required for breeding stage is 90 days. At the breeding stage the thickness of the water layer is 20 mm. The watering interval at the breeding stage was different between planting seasons I, II, and III. The watering intervals for the vegetative phase for each planting season are every 8 day, every 5 day, and every 5 day. Meanwhile, in the generative phase, the watering intervals for each planting season are every 10 day, every 7 day, and every 7 day.

4 RESULTS AND DISCUSSION

4.1 Conventional Method Analysis

Land preparation time was adjusted according to the SRI method, which was 30 days. Water requirements during land preparation can be seen in the table 1.
Before calculating the water requirement for rice plants, the effective rainfall and evapotranspiration are calculated first. The results of the calculation of effective rainfall can be seen in table 2 while evapotranspiration can be seen in table 3. Three planting seasons were applied with the planting scheme in each season being paddy – paddy – paddy. The beginning of planting is on November I. The results of calculating of net field water requirement (NFR) can be seen in table 4. The intake water requirement is calculated by dividing the net water requirement in the fields (NFR) by the overall irrigation efficiency (eff). According to KP the overall irrigation efficiency is 65%. By dividing the NFR by eff and multiplied by the fields area (54,9 hectares), the water demand at the intake (liter/second) is obtained. The water demand at the

Table 1: Water requirements for land preparation (mm/day).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IR	13.0	13.0	12.8	13.0	12.9	13.2	13.2	13.8	14.5	14.6	14.0	13.4

Table 2: Effective rainfall (mm/day).

Month	November			December			January			February			March			April		
Period	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II
Re	4.5	4.5	4.1	3.8	3.8	4.7	3.5	3.5	3.2	1.2	1.2	1.2	0.7	0.7	0.7	0.0	0.0	0.0
Month	May			June			July			Augustus			September			October		
Period	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II
Re	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.6	1.9	1.9	1.9	6.0	6.0	5.4

Table 3: Evapotranspiration (Mm/Day).

Month	November			December			January			February			March			April		
Period	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II
Et0	7.8	7.8	7.8	7.0	7.0	7.0	6.5	6.5	6.5	6.5	6.5	6.5	6.2	6.2	6.2	6.5	6.5	6.5
Month	May			June			July			Augustus			September			October		
Period	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II	I	II	II
Et0	6.4	6.4	6.4	6.8	6.8	6.8	6.8	6.8	6.8	7.6	7.6	7.6	8.4	8.4	8.4	8.5	8.5	8.5

Table 4: Net field water requirement / NFR (liter/second/hectare).

Month	November			December			January			February			March			April		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
NFR	1.3	1.3	1.4	0.9	0.9	0.9	1.0	0.9	1.0	1.1	1.0	1.6	1.6	1.6	1.6	1.3	1.2	1.4
Month	May			June			July			Augustus			September			October		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
NFR	1.4	1.3	1.4	1.3	1.5	1.9	1.9	1.8	1.8	1.3	1.3	1.5	1.5	1.4	1.5	0.9	0.8	1.3

Table 5: Water demand at the intake (liter/second).

Month	November			December			January			February			March			April		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Water demand	103	103	107	69	67	68	78	69	78	85	79	123	126	126	126	97	94	104
Month	May			June			July			Augustus			September			October		
Period	1	2	3	1	1	2	1	2	3	1	2	3	1	2	3	1	2	3
ater demand	107	98	105	100	113	146	146	136	136	103	102	112	116	106	112	68	59	100

intake can be seen in table 5.

4.2 SRI Analysis

The calculation of irrigation water requirements using the SRI method is simpler than the conventional method. The SRI method does not require rainfall data and climate data. As a substitute for the influence of rainfall and evaporation, in the first planting season (high rainfall), during the breeding stage, the interval of watering is longer than the second and third planting seasons, i.e. every 8 days for the vegetative phase and every 10 days for the generative phase. During planting season II and III (very little rain/no rain and high evaporation), watering interval is shorter, i.e. every 7 days for the vegetative phase and every 5 days for the generative phase. The nursery stage coincides with field preparation, starting in November I. The results of the calculation of irrigation water requirements using the SRI method can be seen in table 6.

The intake water requirement is calculated by dividing the water requirement in the fields (by the overall irrigation efficiency (eff). The irrigation efficiency is the same as the conventional method which is 65%. By dividing the water requirement in the fields by eff, the water demand at the intake is obtained. The water demand at the intake can be seen in table 7.

4.3 Optimization

The Kereloko irrigation area gets its water supply from the Kereloko river. The discharge data of the Kereloko river is very limited. The river discharge data is a manual measurement from the Water Resources division, West Sumba Regency Public Works Service. River discharge measurements were

Table 6: Crop water requirements using the SRI method (liters/second).

Month	Period	Cropping scheme			Water requirement	Month	Period	Cropping scheme			Water requirement
Nov	I	PL	K	G	19.08	May	I	G	V	V	7.94
	II	PL	PL	K	29.72		II	G	G	V	7.41
	III	V	PL	PL	32.36		III	G	G	G	6.88
Des	I	V	V	PL	20.19	June	I	G	G	G	6.35
	II	V	V	V	7.94		II	G	G	G	6.35
	III	V	V	V	7.94		III	K	G	G	4.24
Jan	I	G	V	V	7.41	July	I	PL	K	G	16.97
	II	G	G	V	6.88		II	PL	PL	K	29.70
	III	G	G	G	6.35		III	V	PL	PL	32.34
Feb	I	G	G	G	6.35	Agust	I	V	V	PL	20.14
	II	G	G	G	6.35		II	V	V	V	7.94
	III	K	G	G	4.24		III	V	V	V	7.94
Mar	I	PL	K	G	17.01	Sept	I	G	V	V	7.41
	II	PL	PL	K	29.70		II	G	G	V	6.88
	III	V	PL	PL	32.34		III	G	G	G	6.35
Apr	I	V	V	PL	20.14	Okt	I	G	G	G	6.35
	II	V	V	V	7.94		II	G	G	G	6.35
	III	V	V	V	7.94		III	K	G	G	4.24

Note: PL is nursery and field preparation; V is the vegetative phase; G is the generative phase; and K is when the land is allowed to dry.

Table 7: Water demand at the intake (liter/second).

Month	November			December			January			February			March			April		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Water demand	29	46	50	31	12	12	11	11	10	10	10	7	26	46	50	31	12	12
Month	May			June			July			Augustus			September			October		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Water demand	12	11	11	10	10	7	26	46	50	31	12	12	11	11	10	10	10	7

Table 8: Kereloko river discharge.

Month	Nov			Dec			Jan			Feb			Mar			Apr		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Discharge	125	125	125	142	142	143	127	127	127	129	129	129	122	122	122	106	106	106
Month	May			Jun			Jul			Aug			Sep			Oct		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Discharge	89	89	89	74	74	74	56	56	61	83	83	83	113	113	113	118	118	129

Table 9: Water Balance (conventional method).

Month	November			December			January			February			March			April		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Availability	125	125	125	142	142	143	127	127	127	129	129	129	122	122	122	106	106	106
Requirement	103	103	107	69	67	68	78	69	78	85	79	123	126	126	126	97	94	104
Water Balance	22	22	18	73	75	75	48	58	48	44	50	6	-4	-4	-4	9	11	2
Information	S	S	S	S	S	S	S	S	S	S	S	S	D	D	D	S	S	S
Month	May			June			July			August			September			October		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Availability	89	89	89	74	74	74	56	56	61	83	83	83	113	113	113	118	118	129
Requirement	107	98	105	100	113	146	146	136	136	103	102	112	116	106	112	68	59	100
Water Balance	-19	-9	-16	-26	-39	-72	-90	-80	-75	-21	-19	-29	-3	7	1	50	58	29
Information	D	D	D	D	D	D	D	D	D	D	D	D	D	S	S	S	S	S

Note: S is Surplus; D is deficit.

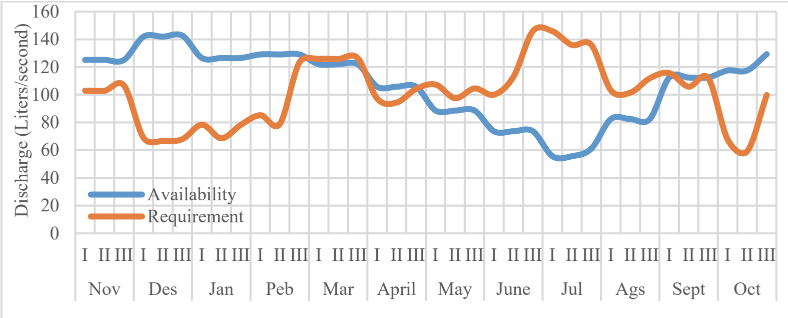

Figure 2: Water balance curve (conventional method).

Table 8: Water Balance (SRI method).

Month	Nov			Dec			Jan			Feb			Mar			Apr		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Availability	125	125	125	142	142	143	127	127	127	129	129	129	122	122	122	106	106	106
Requirement	33	51	56	35	14	14	13	12	11	11	11	7.3	29	51	56	35	14	14
Water Balance	92	74	69	107	128	129	114	115	116	118	118	122	93	71	66	71	92	92
Information	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Month	May			Jun			Jul			Aug			Sep			Oct		
Period	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Availability	89	89	89	74	74	74	56	56	61	83	83	83	113	113	113	118	118	129
Requirement	13.7	13	12	11	11	7.3	29	51	56	35	14	14	13	12	11	11	11	7.3
Water Balance	75	76	77	63	63	66	26	4	5	48	69	69	100	101	102	107	107	122
Information	S	S	S	S	S	S	S	D	D	S	S	S	S	S	S	S	S	S

Note: S is Surplus; D is deficit

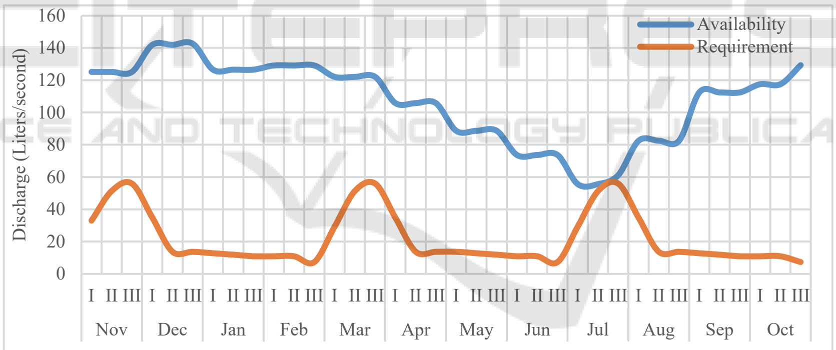

Figure 3: Water balance curve (SRI method).

carried out only once in 2016. The data on the Kereloko river discharge can be seen in table 8.

Based on requirement discharge in the field and the available discharge data, then a water balance analysis is carried out to determine the balance of irrigation water. The irrigation water balance for conventional methods can be seen in table 9 and figure 2. While the water balance of the SRI method can be seen in table 10 and figure 3.

I to October III there was a surplus of water because at that time it had entered the beginning of the rainy season. In order to avoid water shortages, in the second and third planting seasons, the cropping intensity is reduced. The appropriate planting intensity to avoid water shortages was 58.29% (32 hectares) for the 2nd planting season, and 34.61% (19 hectares) for the 3rd planting season. For the first planting season (November-February) the availability of water is greater than the need, therefore the planting intensity can be increased by 104.71% (57.5 hectares). The water balance with a planting intensity of 104.71% for the first planting season, 58.29% for the second planting season, and 34.61% for the third planting season can be seen in Figure 4.

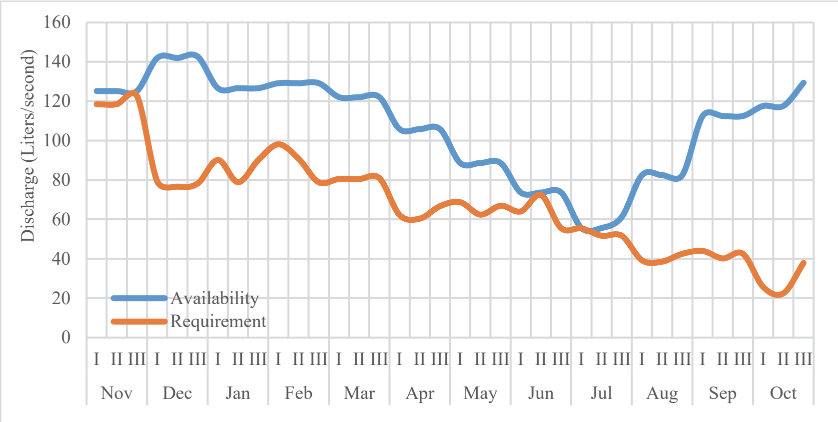

Figure 4: Water balance (planting intensity 104.71%, 58,29%, and 34,61%).

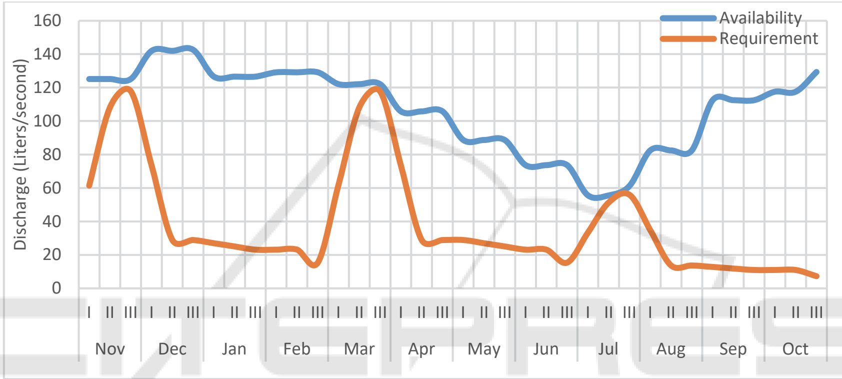

Figure 5: Water balance (planting intensity 155.8%, and 100%).

Meanwhile, by applying the SRI method (table 8 and figure 3), the availability of water for the entire growing season is sufficient. For the first and second planting seasons, the planting intensity can be increased, while for the third planting season, the planting intensity cannot be increased because the disparity between the availability of discharge and the discharge of demand is very low. As shown in table 8 and figure 5, the surplus of water in July II was only 4 liters/second and July III was only 5 liters/second. For the first and second planting seasons, each planting intensity can be increased by 155.8% (85.5 hectares). In other words, for the first and second planting seasons, the land area can be increased by 30.6 hectares from the existing condition (54.9 hectares). The water balance with a planting intensity of 155.8% for the first and second planting seasons, and 100% for the third planting season can be seen in Figure 5.

5 CONCLUSION

This study shows that the rice fields that can be irrigated is not optimal when using conventional methods. For the first planting season, the planting intensity can be increased to 104.71% or the rice field area can be increased to 57,5 hectares, an increase of 2,6 hectares from the existing rice field area (the existing rice field area is 54.9 hectares). Meanwhile, in the second planting season, the planting intensity was only 58.29% (32 hectares of rice field that can be irrigated). In the third planting season, the planting intensity was lower than the second planting season, which was 34.61% (the area of rice field that could be irrigated was 19 hectares). With the SRI method, the planting intensity for the first and second planting seasons can be increased, while in the third planting season, the planting intensity cannot be increased, but the available water discharge is enough to irrigate the entire existing land area (54.9 hectares). For the first and second planting seasons, each planting intensity can be increased by 155.8% (the area of rice field that can be irrigated is 85.5 hectares).

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