Water Balance Evaluation towards Cropping Index Enhancement in Belanti II Swamp Irrigation Area, Central Kalimantan

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ABSTRACT

Cropping season pattern which has been implemented in Belanti II Swamp Irrigation Area is two cropping seasons (IP2), however there are no water management analysis yet in terms of water availability and needs to apply three cropping seasons (IP3). Through this study, water availability and needs which are generated into water balance, will be searched towards IP3 in Belanti II Swamp Irrigation Area. Method used in this study are field and secondary data analysis based on KP-01 Ministry of Public Work and Public Housing. Calculation results show that the amount of water availability can fulfill water needs in Belanti II Swamp Irrigation Area from January until December. Sufficient water affects towards cropping season enhancement. Based on the results, optimization steps towards water management can be determined, so that cropping season pattern can be enhanced into three cropping seasons (IP3) impacted to productivity enhancement of paddy harvest and followed by increasing of farmers income.

Keywords: Water Balance, Swamp Irrigation Area, Cropping Season.

1. INTRODUCTION

In the history of swampland development in Indonesia, the One Million Hectare Peatland Development Project or better known as the PLG Project in Central Kalimantan Province has become the largest project ever carried out. The project is based on a Presidential Instruction dated June 5, 1995 on Food Security and is followed by Presidential Decree no. 82 of 1995 on Peatland Development for Food Crop Agriculture in Central Kalimantan Province. The purpose of the PLG Project is to convert swampland into agricultural land to maintain rice self-sufficiency in Indonesia. The PLG Project Area is divided into Block A, Block B, Block C and Block D. Soil in the ex-PLG area is peat soil with varying depths ranging from shallow to deep. The distribution of thick peat (> 3 meters) is dominant in Block C, partly in Block B and Block A. Thick peat is directed as a protected area and needs to be conserved. In addition, mineral soils are also found in all PLG Project work areas, especially Block D [1].

In the ex-PLG area, there are several irrigated areas that were built since the 1970s through the Tidal Rice Field Opening Project (P4S) and are still used for agriculture and fisheries. To support all agricultural and fishery cultivation activities in one food security program, the role of the water system and the realignment of channels and their complementary facilities properly and continuously is very necessary. The clearing of tidal marshlands in Kalimantan was carried out in connection with the transmigration program which began in 1969 through the Tidal Rice Field Opening Project (P4S) in the 1970s, then in 1995 it was continued with the one million ha Peatland Development (PLG) project for food crop farming in Central Kalimantan, the area is located between the Sebangau, Kahayan, Kapuas, Kapuas Murung and Barito Rivers which are included in the Kapuas Regency and Pulang Pisau Regency. The length of the Kapuas River in the PLG Area can reach 150 km, the Kahayan River 125 km, and the Barito River 158 km [2]. The PLG project began with the creation of an irrigation network that cuts and connects the Sebangau

River, Kahayan River, Kapuas River and Barito River as well as its tributaries. The water system developed in the Ex-PLG Area is a closed water system, meaning that water entering and leaving the water system can be controlled for optimization of the peat leaching process. In this closed water system is equipped with embankments and sluice buildings.

Swamps are lands that are constantly saturated with water or flooded for a long time, it can be all year round or for some time of the year. The area of swampland in Indonesia ± 33.4 million hectares, consisting of 20 million hectares of tidal land and 13.4 million hectares of pond land. The use of swampland to support agriculture is a step taken by the government since the 1970s. Swamp development was carried out starting with opening swampland and creating tidal channels, then in the 1990s the next stage of swamp development was carried out, at this stage water management is equipped with water regulatory buildings that are expected to regulate incoming and outgoing water so that overdrain does not occur.

The Belanti II Swamp Irrigation Area is a tidal swamp area located in Pulang Pisau Regency, Central Kalimantan Province. It was built in the 1980s which is part of the Tidal Rice Field Opening Project (P4S) and the Block D Peatland Development (PLG) project. The Belanti II Swamp Irrigation Area has an area of 3976 Ha with a position located between the Kahayan River to the west and the Kapuas River to the east. The source of the tide comes from the Kahayan River which enters through the primary channel, secondary channel, collector channel, and handil. The Belanti II irrigation network consists of a tidal pond with an area of 12 ha, a collector channel with a length of 14.22 km and a width of 6 m, a primary channel with a length of 8.70 km and a width of 45 m, 100 secondary channels (41 channels on the right side with a length of between 0.40 – 2.70 km and 59 channels on the left side with a length of between 2.0 – 2.80 km) with a width of 5.6 m and a distance between secondary channels of 200 m serving ± 3976 Ha of irrigation areas. Its water system is a two-way open channel system, in which river water flows into the system at high tide and returns to the river at low tide [1]. Currently, the Belanti II Swamp Irrigation Area has run two cropping seasons (IP2) with an average paddy harvest of 6-7 tons per hectare per cropping season based on interviews with local farmers. Although it is already relatively good, the Belanti II Swamp Irrigation Area still has the potential to be upgraded to three cropping seasons (IP3). However, it is necessary to calculate the amount of water availability and water needs to be able to ensure and optimize the implementation of the third cropping season. In addition to technical constraints regarding water, non-technical obstacles such as a sense of

adequacy by farmers so that it is felt that a third cropping season is not needed.

1.1. Problem Formulation

Based on the introduction that has been described, a formulation of the problem can be made as follows;
a. The amount of water availability in the Belanti II Swamp Irrigation Area
b. The amount of water needs in the Belanti II Swamp Irrigation Area
c. The amount of water balance in the Belanti II Swamp Irrigation Area

1.2. Objective

The objectives of this study include;
a. Knowing the dependable flow as water availability in Belanti II Swamp Irrigation Area
b. Knowing the water needs in Belanti II Swamp Irrigation Area
c. Knowing the amount of waater balance in Belanti II Swamp Irrigation Area

1.3. Limitations of the Issue

With limited time in this study, the problems that will be discussed in this study are limited as follows;
a. This study will focus on calculating the availability and needs for water in Belanti II Swamp Irrigation Area based on 10-year rainfall data (2011-2020) from Maliku Rainfall Station
b. The value of water availability used is 80% of dependable flow, using the FJ Mock method and the water needs of paddy are based on KP-01

2. METHODS

2.1. Data Used

The data used in this study are primary and secondary data. Primary data is obtained by direct measurement in the field, while secondary data is obtained from local agencies according to existing authorities. The data obtained such as;
a. The condition of the study site
b. Climatological data
c. Daily rainfall data

2.2. Data Analysis

Based on the data obtained, it is necessary to analyze to obtain the value of the water balance such as;

a. Analysis of water availability. Based on rainfall data. Using the Polygon-Theissen method, the rainfall data is processed into Potential Evapotranspiration (PET). Rainfall and Potential Evapotranspiration values were processed by the FJ Mock method into the values of Limited Evapotranspiration (Et), water surflus (ws), run-off, and the Mock discharge. Next, the Mock discharge value is calculated to be 80% dependable flow by sorting the Mock discharge from the largest to the smallest value and calculated arithmetically according to the number of available year data [3]. Based on the KP-01 Irrigation Planning Criteria of the Ministry of PUPR in 2013, the FJ Mock calculation model is relatively simple. The principle of the FJ Mock Model method states that rain that falls on a water catchment area will partly be lost due to evapotranspiration, some will immediately become direct runoff and some will enter the ground or infiltrate. The average monthly rainfall in the watershed is calculated from rainfall and evapotranspiration measurement data. The difference between precipitation and evapotranspiration results in direct rainwater runoff, heavy rainwater runoff, and bottom flow [4]. The dependable flow was obtained by calculating the water balance analysis of Dr. FJ Mock 1973 [5]. The data needed and processed in the FJ Mock calculation include:

1. Average monthly rain (mm)
2. Average number of monthly rainy days (days)
3. Monthly potential evapotranspiration (mm)
4. Surface runoff ($m^3/s/km^2$)
5. Ground water storage (mm)
6. Base flow ($m^3/s/km^2$)

b. The water requirement discussed in the context of this study is the amount of water discharge that paddy need to grow. Some of the parameters needed for water needs analysis include evapotranspiration, effective rainfall, percolation, land preparation, planting patterns, and water layer replacement (WLR). The basis used for water needs is the KP-01 Irrigation Planning Standard, Directorate of Irrigation and Swamps of the Directorate General of Water Resources, Ministry of Public Works in 2013. Water requirements are expressed in mm/day or l/s/ha and will be converted to m^3/s according to the dependable flow or water availability. In calculating this water needs, it is greatly influenced by the length of time needed for land preparation and the amount of water needed for land preparation. Meanwhile, the duration of land preparation is largely determined by the availability of labor and tools. The socio-cultural conditions that exist in the paddy planting area will affect the length of time required for land preparation. It can be taken for a period of 1 or 1.5 months for land preparation depending on the readiness of the tool [4].

3. RESULTS

3.1. Calculation Results

Table 1. Amount of Rainfall from Maliku Station

Year	Month (mm)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	78.1	28.2	95	84.6	25.5	31	12.6	8.9	22	336.7	146.8	540.5
2012	180.2	187.2	203.3	268.8	63.3	79.3	148.5	46.4	11.2	256.3	248	345
2013	244.2	300.5	384.4	243.4	307.2	192	90.5	92.2	165.6	86.2	308.5	115.9
2014	37.3	244.6	333.6	130.9	128.7	75.6	40.3	126.5	13.9	86.2	155.4	390.3
2015	267.1	258.2	333.7	96	161	150	15.6	90	23	27	129	259.2
2016	274.8	416.2	333.6	346.3	180.4	102.8	33.7	34.5	68.3	261	534.1	170.5
2017	264.1	131.6	79.7	254.5	232.2	101	92.9	111.7	48.8	204.5	205	136.6
2018	251.8	251.7	467.9	343.8	61.2	31.8	19.5	21.4	122.7	100.6	177.3	299.6
2019	429.8	392.2	315.3	391.6	74.1	52.6	3.9	13.3	51.5	85.4	19.4	59.4
2020	190.5	416.7	174	184.8	128.3	103	159.6	245.6	92.5	77.8	165.6	195.8
Sum	2217.9	2627.1	2720.5	2344.7	1361.9	919.1	617.1	790.5	619.5	1521.7	2089.1	2512.8
Average	221.8	262.7	272.1	234.5	136.2	91.9	61.7	79.1	62.0	152.2	208.9	251.3
Max	429.8	416.7	467.9	391.6	307.2	192.0	159.6	245.6	165.6	336.7	534.1	540.5
Min	37.3	28.2	79.7	84.6	25.5	31.0	3.9	8.9	11.2	27.0	19.4	59.4

Source: BWSK II Palangkaraya

and Analysis

The availability of water, represented by the dependable flow value of 80% probability, it is obtained from the processing of rainfall and climatological data using the FJ Mock method. The value of the amount of rainfall of Maliku Station in 2011-2020 and the value of the rainy day of Maliku Station in 2011-2020 are shown in Table 1 and Table 2 respectively as follows.

Table 2. Amount of Rainy Day from Maliku Station

Year	Month (day)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	13	6	9	9	4	3	1	3	2	11	11	22
2012	14	16	15	13	4	5	12	2	2	8	16	14
2013	18	19	25	14	12	12	10	7	8	5	12	18
2014	9	15	17	16	6	7	2	7	1	5	10	19
2015	25	15	21	12	12	8	3	6	3	4	9	9
2016	15	20	17	19	14	9	7	4	6	16	16	19
2017	15	8	8	16	11	4	6	7	4	12	19	16
2018	15	18	24	18	8	5	3	4	9	7	11	14
2019	16	17	18	19	9	6	1	1	3	9	2	6
2020	14	16	15	16	11	9	13	6	19	15	22	23
Sum	154.0	150.0	169.0	152.0	91.0	68.0	58.0	47.0	57.0	92.0	128.0	160.0
Average	15.4	15.0	16.9	15.2	9.1	6.8	5.8	4.7	5.7	9.2	12.8	16.0
Max	25.0	20.0	25.0	19.0	14.0	12.0	13.0	7.0	19.0	16.0	22.0	23.0
Min	9.0	6.0	8.0	9.0	4.0	3.0	1.0	1.0	1.0	4.0	2.0	6.0

Source: BWSK II Palangkaraya and Analysis

This rainfall data is then processed with the Polygon-Theissen method to obtain the Theissen mean rainfall value which then becomes the Potential Evapotranspiration (PET) value shown in Table 3 below.

Table 3. Potential Evapotranspiration Value (PET)

Year	MONTH											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	4.35	5.05	4.64	4.39	4.53	3.81	3.88	4.85	4.60	3.47	4.18	2.99
2012	3.84	4.10	3.89	3.94	4.19	3.57	3.38	4.66	4.67	3.49	3.29	3.16
2013	3.61	3.84	3.18	3.84	3.54	3.26	3.91	4.18	4.04	4.02	3.25	3.81
2014	3.74	3.77	3.03	3.87	3.77	3.20	3.79	4.17	4.54	4.09	3.70	2.94
2015	3.33	4.07	3.34	4.38	3.78	3.34	4.06	4.21	4.39	4.46	3.80	3.41
2016	3.09	3.30	3.59	3.43	3.49	3.33	3.77	4.37	4.06	3.45	2.79	3.65
2017	3.42	3.98	4.38	3.75	3.30	3.11	3.24	4.07	4.27	3.50	3.48	3.74
2018	3.23	3.36	2.76	3.46	4.01	3.60	3.75	4.59	3.72	3.73	3.55	3.04
2019	2.66	3.16	3.11	3.20	3.79	3.38	3.73	4.44	4.01	3.73	4.14	4.00
2020	3.38	3.15	3.66	3.90	3.74	3.33	3.26	3.48	3.92	3.82	3.51	3.47
Sum	34.66	37.77	35.57	38.17	38.13	33.93	36.77	43.02	42.21	37.77	35.68	34.22
Average	4.35	5.05	4.64	4.39	4.53	3.81	4.06	4.85	4.67	4.46	4.18	4.00
Max	2.66	3.15	2.76	3.20	3.30	3.11	3.24	3.48	3.72	3.45	2.79	2.94
Min	3.47	3.78	3.56	3.82	3.81	3.39	3.68	4.30	4.22	3.78	3.57	3.42

The value of water availability is obtained by processing rainfall data and potential evapotranspiration which takes into account Limited Evapotranspiration (Et), water surflus (ws), the number of run off, and ground water storage until a Mock discharge is obtained. Furthermore, the Mock discharge value will be calculated to be the dependable flow of 80% probability by sorting the Mock discharge from largest to smallest and calculated statistically according to the number of years of data available. The dependable flow calculated is the flow on the primary channel and on the field. The dependable flow resume

(availability) can be shown in Table 4 and Figure 1 below.

Table 4. Dependable Flow 80% (Availability)

Primary Channel		On Land		Availability Total	
Month	Flow (m³/s)	Month	Flow (m³/s)	Month	Availability (m³/s)
Jan	37.73	Jan	0.69	Jan	38.42
Feb	69.91	Feb	1.27	Feb	71.18
Mar	52.17	Mar	0.95	Mar	53.12
Apr	72.53	Apr	1.32	Apr	73.84
May	49.91	May	0.91	May	50.82
Jun	26.34	Jun	0.48	Jun	26.82
Jul	7.12	Jul	0.13	Jul	7.25
Aug	6.77	Aug	0.12	Aug	6.90
Sep	6.39	Sep	0.12	Sep	6.51
Oct	9.02	Oct	0.16	Oct	9.18
Nov	44.65	Nov	0.81	Nov	45.46
Dec	49.38	Dec	0.90	Dec	50.28
Average	35.99	Average	0.65	Average	36.65
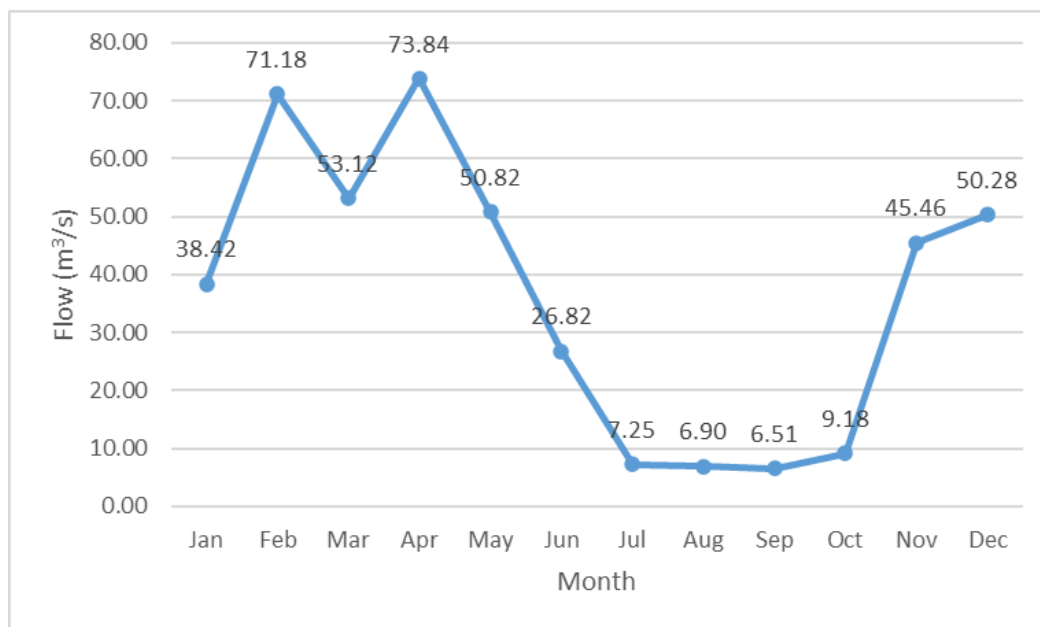
Figure 1 Total of Water Availability Graph

The water needs in the context of this study is the amount of water discharge needed to irrigate plants until they can grow. The parameters used in this analysis include evapotranspiration, effective rainfall, percolation, land preparation, planting patterns, and water layer replacement (WLR). Some of the data was obtained in the form of secondary data sourced from the Kalimantan River Area Center II Palangkaraya while some of the data was obtained through calculations.

Table 5 show the resume of effective rainfall that has been empirically calculated as per KP-01.

Table 5. Empirical Effective Rainfall

Month	RE (mm)	RE$_{monthly}$ (mm/day)	RE$_{paddy}$ (mm)
Jan	109.40	3.65	2.55
Feb	133.44	4.45	3.11
Mar	141.40	4.71	3.30
Apr	123.68	4.12	2.89
May	47.17	1.57	1.10
Jun	40.20	1.34	0.94
Jul	2.84	0.09	0.07
Aug	5.18	0.17	0.12
Sept	9.49	0.32	0.22
Oct	46.28	1.54	1.08
Nov	68.73	2.29	1.60
Dec	101.89	3.40	2.38

Source: Analysis

Through the Re value, calculations are carried out with percolation factors, paddy coefficient values, land preparation, and evapotranspiration to obtain the NFR value (clean water needs for paddy) expressed in

mm/day and converted into a water needs discharge expressed in m³/s. A resume of water needs with a land area of DIR Belanti II covering an area of 3976 Ha can be shown in Table 6 and Figure 2 below.

Table 6. Resume of Water Needs

Month	NFR mm/day	DR l/s/ha	DR l/s	DR m³/s
Jan	8.24	1.47	5832.90	5.83
Feb	8.57	1.53	6064.65	6.06
Mar	8.99	1.60	6367.67	6.37
Apr	9.44	1.68	6685.81	6.69
May	9.99	1.78	7075.21	7.08
Jun	9.11	1.62	6449.23	6.45
Jul	7.62	1.36	5397.61	5.40
Aug	5.42	0.97	3840.28	3.84
Sept	5.31	0.94	3756.40	3.76
Oct	5.43	0.97	3844.50	3.84
Nov	6.01	1.07	4252.56	4.25
Dec	6.23	1.11	4407.64	4.41
Average	7.53	1.34	5331.20	5.33
DIR Belanti II	3976 Ha			
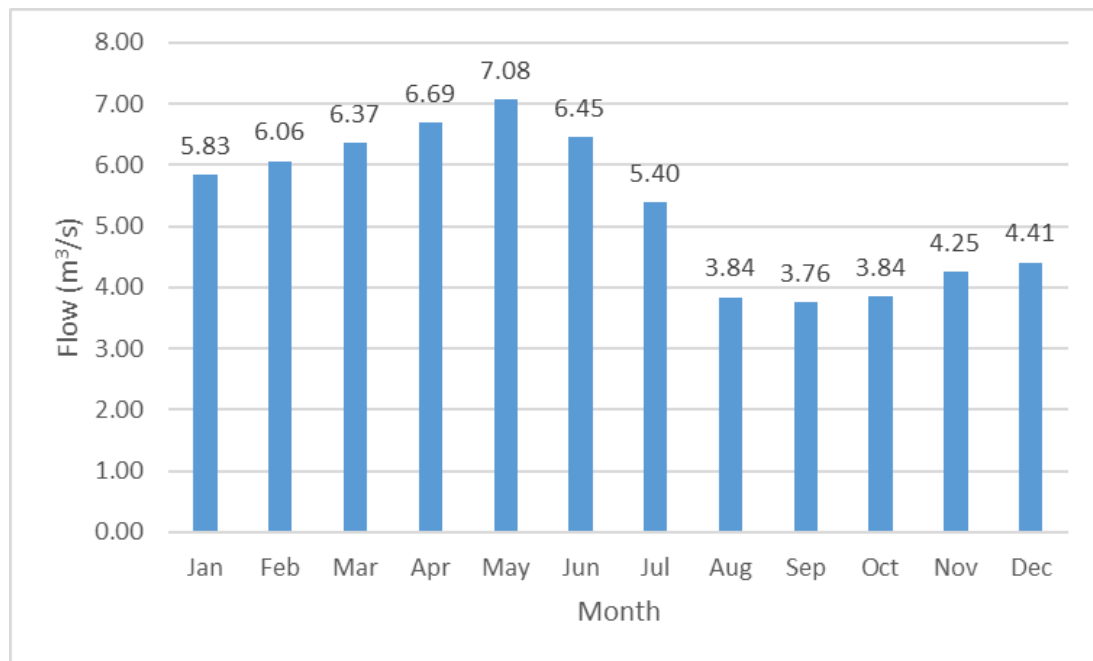
Figure 2 Water Needs Graph

4. DISCUSSIONS

Based on the analysis and calculations in Table 4 and Figure 1, the dependable flow value (availability) was obtained on average at 36.65 m³/s from January to December. The highest water availability was in April at 73.84 m³/s while for the lowest water availability was in September at 6.51 m³/s.

Meanwhile, for water needs, it can be seen from Table 6 and Figure 2 that the highest water demand for paddy was in May at 7.08 m³/s, while for the lowest water needs fell in September, which was 3.76 m³/s with an average water need throughout the year of 5.33 m³/s. The result of this water requirement is calculated assuming the planting pattern of Paddy-Paddy-Paddy.

So that for the value of the water balance, it is obtained through the difference between water

availability and water needs. The condition of the water balance can be shown in Table 7 and Figure 3 below.

Table 7. Condition of Water Availability and Needs

Availability		Needs		Condition
Month	Flow (m^3/s)	Month	Flow (m^3/s)	Sufficient/Insufficient
Jan	38.42	Jan	5.83	Sufficient
Feb	71.18	Feb	6.06	Sufficient
Mar	53.12	Mar	6.37	Sufficient
Apr	73.84	Apr	6.69	Sufficient
May	50.82	May	7.08	Sufficient
Jun	26.82	Jun	6.45	Sufficient
Jul	7.25	Jul	5.40	Sufficient
Aug	6.90	Aug	3.84	Sufficient
Sep	6.51	Sep	3.76	Sufficient
Oct	9.18	Oct	3.84	Sufficient
Nov	45.46	Nov	4.25	Sufficient
Dec	50.28	Dec	4.41	Sufficient
Average	36.65	Average	5.33	
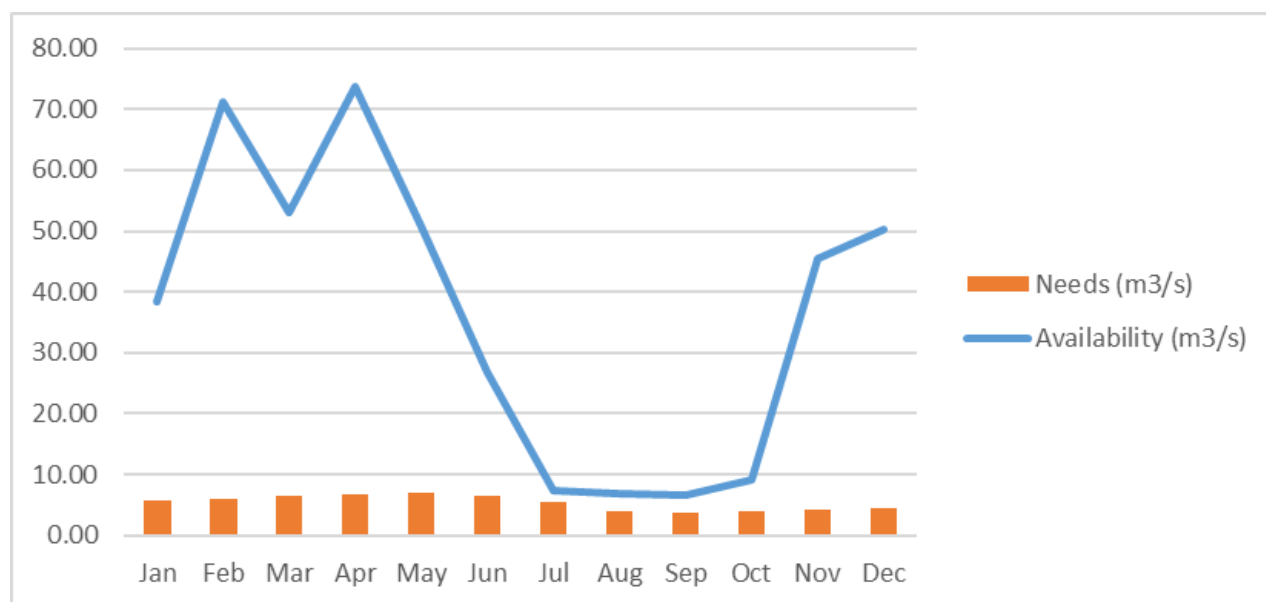
Figure 3 Water Availability and Needs Graph

On the chart it can be seen that there is no line of water availability that intersects with water needs. It is also in the table that the water conditions of Belanti II Swamp Irrigation Area are met all for the needs of paddy growth. For details of the difference in the water balance, please see figure 4 below.
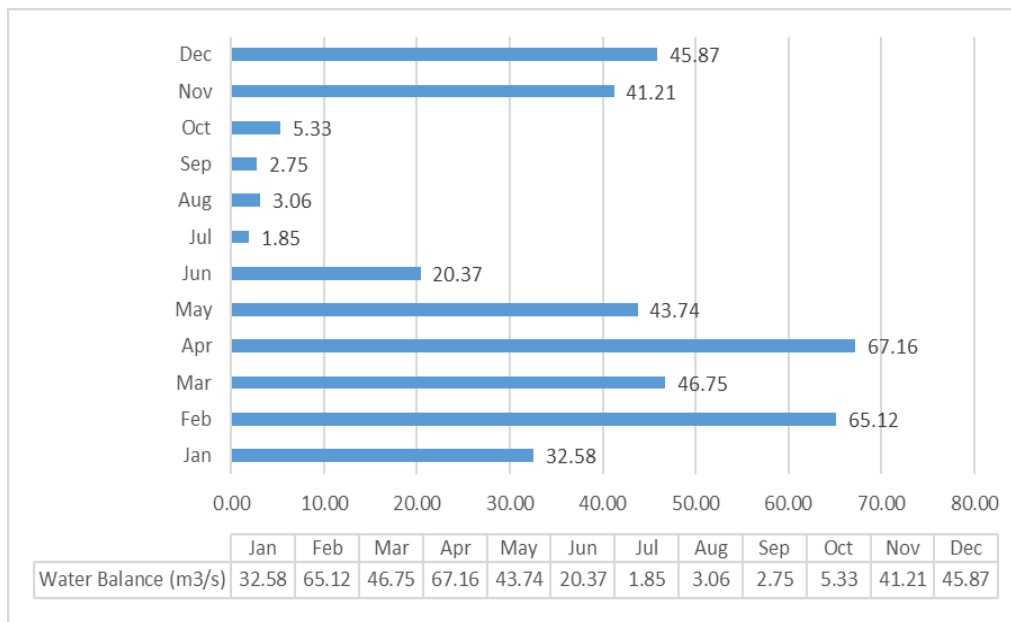
Figure 4 Water Balance (Difference)

It can be seen on the chart that the biggest difference occurred in April with a water balance of 67.16 m^3/s (surplus). Meanwhile, the smallest difference occurred in July at 1.85 m^3/s (surplus). From the calculation results and graphs, it can be said that the conditions of water availability can meet the needs of water throughout the year for the growth of paddy with the Paddy-Paddy-Paddy planting pattern.

5. CONCLUSIONS

The average value of Belanti II Swamp Irrigation Area water availability was 36.65 m^3/s throughout January to December. The highest water availability was in April at 73.84 m^3/s while the lowest water availability was in September at 6.51 m^3/s.

The average value of Belanti II Swamp Irrigation Area water needs was 5.33 m^3/s throughout January to December. The highest water requirement for paddy was in May at 7.08 m^3/s, while the lowest water requirement fell in September at 3.76 m^3/s.

It can be said that the condition of water availability in Belanti II Swamp Irrigation Area can meet the needs of water throughout the year for the growth of paddy with the Paddy-Paddy-Paddy planting pattern with the largest difference in water balance occurring in April at 67.16 m^3/s (surplus), while for the smallest water balance difference occurred in July at 1.85 m^3/s (surplus). So that with three cropping seasons (IP3), hopefully that paddy harvest will increase followed by the increasing of farmer's income.

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