Impact of Changes in Rainfall Patterns and Air Temperature on Water Balance in Danda Besar Swamp Irrigation Area

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Original Article

Impact of Changes in Rainfall Patterns and Air Temperature on Water Balance in Danda Besar Swamp Irrigation Area

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Abstract *- Indonesia lies in a tropical climate area and depends on rainfall as the main source of irrigation. Changes in rainfall patterns and air temperature directly impact the water availability for irrigation purposes, including Danda Besar Swamp Irrigation Area (DIR). DIR Danda Besar is a tidal swamp irrigation field, but the tidal power cannot reach several areas, so it needs to use rainwater to supply water demand and becomes rainfed agriculture. The observation of changes in rainfall patterns and air temperature from 2001 to 2020 was conducted using daily TRMM (Tropical Rainfall Measurement Mission) data split into 2 observation periods: Period I from 2001 to 2010 and period II from 2011 to 2020. The data analysis process consists of validation and correction to the TRMM data before it is used for water balance analysis, calculation of effective rainfall for rice and evapotranspiration, and analysis of water availability and demand. From the comparison of water availability discharge between Period I (2001-2010) and Period II (2011-2020), the highest increase in mid-month water availability occured on December 1 and December 2, and the highest decrease in water availability occured on November 1 and November 2. The results of the water balance analysis are based on water demand according to the cropping scenario with two cropping scenarios. Water balance 1 has a deficit in water availability for Periods I and II; water balance 2 is recommended for cropping patterns due to climate change, so the water balance is calculated based on water availability for Period II. No water deficit in Water balance 2.*

Keywords *- TRMM (Tropical Rainfall Measurement Mission), DIR Danda Besar, Water availability, Water demand, Cropping scenario.*

1. Introduction

Danda Besar Swamp Irrigation Area (DIR) locates at -3.10799, 114.67021 coordinates. Based on Triadi B (2010) research, DIR Danda Besar is a tidal irrigation field with a hydrotopographic class of overflow types A, B and C. In 2021, the farmers stated that currently, tidal power could not reach the entire planting area, so it supplies the water demand with rainwater. DIR Danda Besar planting area and planting season, according to Agricultural Development Strategic Command Counselor (Kostratani) at BPP Rantau Badauh Petani in Danda Jaya Village, doing new planting in April to September with a planting area of 1460 hectares (Metro Kalimantan, 2020) and the area of DIR Danda Besar is 2200 ha.

Several water resource development issues are unpredictable climate changes, such as floods, droughts, and storms (Hukom, Limantara, & Andawayanti, 2012). Rainfall and air temperature are variables that affect most to climate change the most. Rainfall will increase the water volume, which affects plant growth. Air temperature affects the process of photosynthesis, respiration, transpiration, pollination growth, fertilization and fruit falling. The influence is related to other factors such as humidity, water availability and type of plant (Hariadi, 2007).

During the last 30 years, rainfall in DAS Ciliwung has fluctuatively increased, which resulted in water availability decreasing by 2 m^3/sec (Ariyani, 2017). Changes in DAS Krueng Aceh since 2001 showed that climate change had decreased the mainstay discharge in April-December by 23,5% (Ferijal, Mustafril, & Jayanti, 2016). Rainfall pattern change in Way Mital irrigation area occurred in 2009 with an annual rainfall of 2315 mm, 4615 mm in 2001 and 3886 mm in 2008 (Hukom, Limantara, & Andawayanti, 2012).

The purpose of this study is to analyze changes in rainfall patterns, including the decrease or increase in rainfall volume, shifts in wet, dry, and humid months and air temperature increase which directly impacts the water availability for irrigation in Barito Kuala, especially in DIR Danda Besar for the availability and demand of water for cropping patterns necessity.

2. Materials and Methods

This study uses TRMM (Tropical Rainfall Measurement Mission) rainfall and climatological data from the NASA Prediction Of Worldwide Energy Resources (POWER) project by accessing the site https://power.larc.nasa.gov/data-access- viewer/ from 2001-2020. Observational rainfall data were obtained from Mandastana rain gauge data for 2008-

2013 and air temperature data from Syamsudin Noor climatology station for 2016-2020. Before using the data for analysis, it is necessary to test the validation and correction of the TRMM observation data to determine the accuracy using the Correlation Coefficient method that creates a determination value and then continues with data correction by selecting the regression equation with the highest determination value in several regression equations, such as linear regression, geometri, logarithmic and exponential (Mamenun, Pawitan, & Sophaheluwakan, 2014). The criteria for determination value (R2), according to Sugiyono (2010), is the interpretation for very low is 0.00-0.199, low 0.20-0.399, moderate 0.40-0.599, strong 0.60-0.799 and very strong 0.80-1.000. The data correlation of rainfall and air temperature can be used to analyze changes in rainfall patterns and air temperature and to calculate the water balance.

Analysis of rainfall patterns and air temperature changes is carried out by comparing rainfall data, shifts in wet months, dry months, and humid months, and air temperature in Period I (2001-2010) with Period II (2011-2020). The criteria for wet months are more than 200 mm/month, dry months are less than 100 mm/month, and humid months are between 100-200 mm/month according to the Oldeman classification (Oldeman, Irsal, & Muladi, 1980). Calculation of potential evapotranspiration value based on Badan Standar Nasional Indonesia (2012) using the Penman-Monteith formula and the effective rainfall for rice based on the formula KP-01 (2013) is Re padi = (R80 x 0.7)/ the observation period, the value of R80 is the mainstay of rainfall obtained from Weibull equation.

Analysis of water availability using the Mock flow discharge simulation method with the formula Q = TRO x A, where Q is the flow rate, TRO is the total runoff, and A is the area. Analysis of water demand based on cropping scenarios (number of growing seasons and cropping patterns) where irrigation water needs discharge according to rice according to KP-01 (2013) the equation IR = NFR/e, where NFR is the basic water requirement of paddy fields, IR is irrigation water demand, and e is irrigation efficiency due to rainfed, then the value of e is 1. The DR value with the formula IR/8.64 produces irrigation water intake requirements in liters/sec. The water balance is generated by subtracting the flow rate from the water demand discharge based on the cropping scenario. If there is a water deficit, cropping patterns are scheduled according to rainfall patterns and air temperature changes.

3. Results and Discussion

3.1. Validation and Correction Data

Data validation using the Correlation Coefficient method produces a determination value (R2) which shows the relationship between two variables, namely observation data and TRMM data. Correction analysis using the Regression Analysis method by connecting the observation post data with TRMM data through the process of the scatter plot by selecting the greatest determination value for each regression equation.

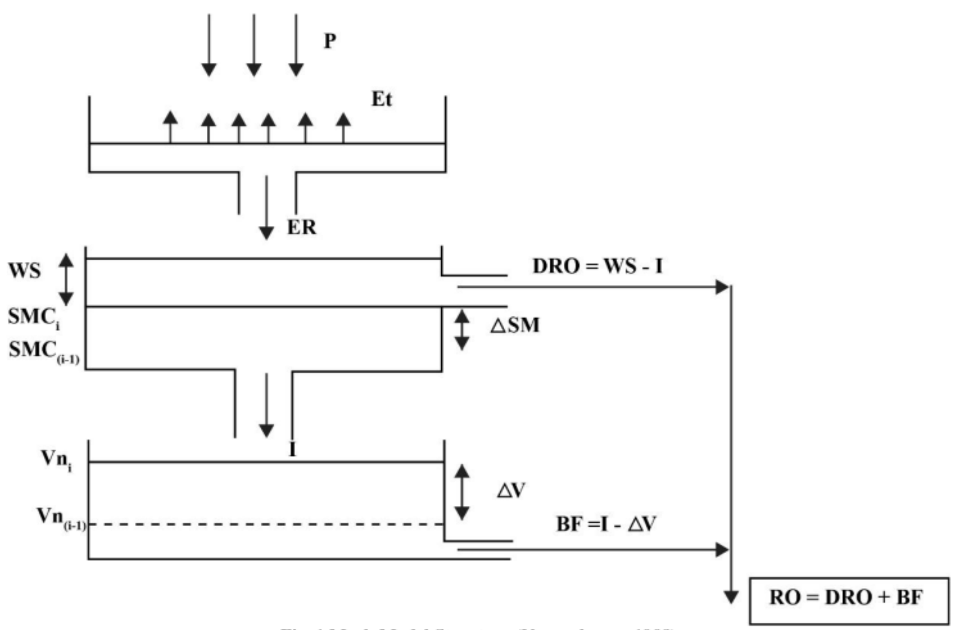

Fig. 1 Mock Model Structure (Nurrochman, 1998)

Table 1. Regression Equation dan Determination Value of Rainfall TRMM

Month	Regression Equation	R^2
January	$y = 16.274x^{0.527}$	0.61
February	y = 134.33ln(x) - 424.9	0.14
March	$y = 32.138x^{0.39}$	0.89
April	y = 76.507ln(x) - 171.7	0.19
May	y = 0.1542x + 159.44	0.13
June	y = 0.5212x + 73.439	0.65
July	y = 0.9598x + 71.84	0.70
August	$y = 4.3899x^{0.7051}$	0.46
September	$y = 33.577e^{0.0082x}$	0.60
October	$y = 0.1463x^{1.3267}$	0.90
November	y = 164.19ln(x) - 646.63	0.73
December	$y = 18.09x^{0.507}$	0.29

Table 2. Regression Equation dan Determination Value of Temperature TRMM

Month	Regression Equation	R^2
January	y = 0.9795x1.0014	0.82
February	y = 0.0355x + 25.968	0.00
March	y = 13.166e0.0265x	0.83
April	y = 0.5977x + 10.826	0.91
May	y = 30.081ln(x) - 72.991	0.84
June	y = 13.95e0.0236x	0.71
July	y = 1.0336x - 1.7616	0.89
Month	**Regression Equation**	**R2**
August	y =10.475e0.0337x	0.98
September	y = 0.5547x + 11.619	0.39
October	y = 0.8156x + 4.7883	0.73
November	y = 0.8175x + 5.2357	0.59
December	y = 0.4524x + 14.753	0.20

Based on Tables 1 and 2, the determination result values that connect Mandastana rain station with TRMM data, there are months with strong to very strong interpretations in January, March, June, July, September, October and November. R2 value below 0.6 in February, April, May, August and December. Correction of TRMM rainfall data is carried out by inverting it to the regression equation.

3.2. Changes in Rainfall Patterns and Air Temperature

Analysis of rainfall pattern changes shows an increase in rainfall during Period II (2011-2020) compared to Period I (2001-2010) in Figure 2. The increase occurred in January, February, March, April, May, June, July, August and December. The rainfall decreased in August, September and November. Due to the increase and decrease in rainfall during Period II, the wet months became wetter, and the dry months became drier. The maximum rainfall during the period I occurred in December by 350.35 mm, and the minimum in August by 82.43 mm. The maximum rainfall in Period II occurred in December by 388.35 mm and the minimum in September by 74.54 mm. Comparison of the highest increase in rainfall in December by 38.00 mm and the highest decrease in September by 19.67 mm.

Another parameter to determine changes in rainfall pattern is the shift of wet, humid, and dry months with the Oldeman classification. Based on Figure 3, the criteria changed in July and October. The first period of July is humid; the second period becomes wet due to increased rainfall volume. The first period of October has the criteria for a humid month, then becomes dry months in the second period.

For temperature changes, the temperature increased in January, March, April, May, June, July, August, September, October, November, and December. No air temperature decrease, as seen in Figure 4. Maximum air temperature during the period I occurred in November by 27.5°C and the minimum temperature in July by 24.9°C. Maximum air temperature during Period II occurred in November by 27.8°C and the minimum temperature in July by 25.0°C. Comparison In November, the highest increase in air temperature is 0.3°C.

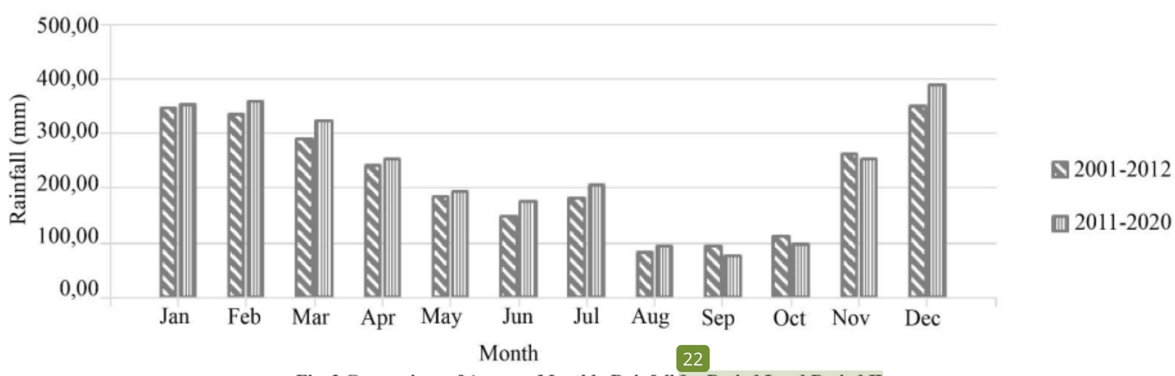

Fig. 2 Comparison of Average Monthly Rainfall for Period I and Period II

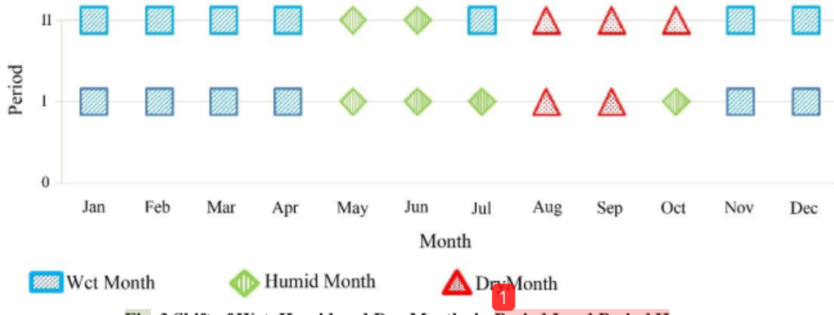

Fig. 3 Shift of Wet, Humid and Dry Months in Period I and Period II

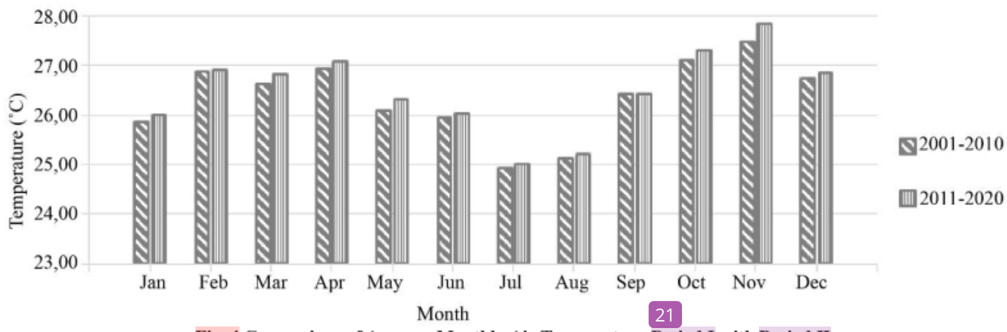

Fig. 4 Comparison of Average Monthly Air Temperature Period I with Period II

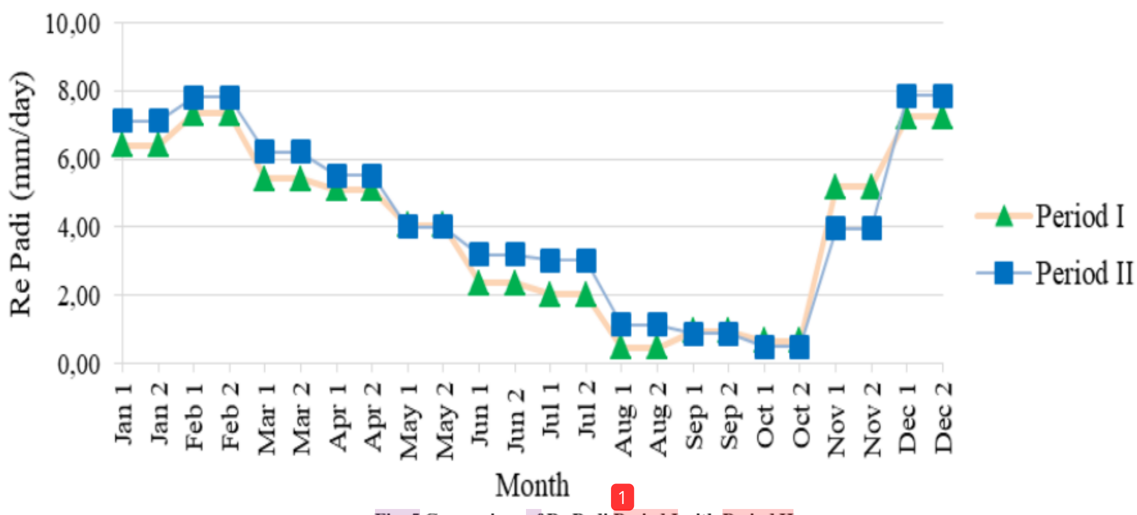

Fig. 5 Comparison of Re Padi Period I with Period II

3.3. Effective Rainfall

The calculation of effective rice rainfall (Re Padi) at DIR Danda Besar is based on semi-monthly mainstay rainfall data (R80). There was an increase or decrease in the value of Re rice from Period I to period II due to changes in rainfall patterns and air temperature, an increase in the effective half-monthly rainfall of rice in January, February, March, April, June, July, August and December. The decline also occurred in the middle of October and November. A comparison of the highest increase in Re rice on July 1 and July 2 with 0.99 mm/day and the highest decrease on November 1 and November 2 with 1.22 mm/day can be seen in Figure 5.

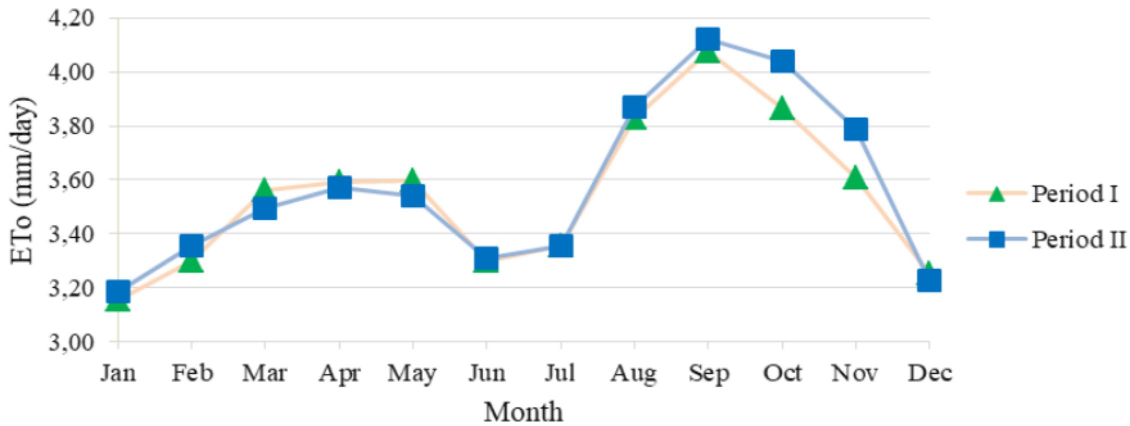

Fig. 6 Comparison of ETo Period I with Period II

3.4. Potential Evapotranspiration

Calculation of daily potential evapotranspiration (ETo) at DIR Danda Besar using the Penman-Monteith method with TRMM climatological data parameters, including relative humidity (Rh), wind speed (U), solar longwave radiation (Rl), solar shortwave radiation (Rs) and temperature corrected air (T). Monthly ETo increase in January, February, August, September, October and November. The decline also occurred in March, April, May and December. Comparison of the highest increase in evapotranspiration in October and November of 0.18 mm/day and the highest decrease in March of 0.07 mm/day.

3.5. Water Availability

Analysis of water availability at DIR Danda Besar with an area of 2200 Ha, the semi-monthly water availability discharge value is obtained using the Mock method. Furthermore, the recapitulation of the calculation result of the flow rate (Q) semi-monthly water availability of Period I (2001-2010) and Period II (2011-2020) can be seen in Table 3.

In the period I, the peak discharge occurred on January 1st with a discharge of 3.56 m3/s, and the minimum discharge occurred in the early dry month, on September 2nd, with a discharge of 0.09 m^3/s. In Period II, the peak discharge occurred on January 1st with a discharge of 3.60 m^3/s, and the minimum discharge occurred in the early dry month on October 2nd with a discharge of 0.08 m^3/s. Comparison of water availability discharge for the period I (2001-2010) and Period II (2011-2020) experienced the highest increase in discharge on December 2nd by 0.32 m^3/sec. The trend of increasing discharge is influenced by changes in rainfall pattern, rainfall increase, and the number of wet months, as seen in Figure 1 and Figure 2. The effect of air temperature increase on daily evapotranspiration value is greater than daily rainfall, thus no excess water.

Table 3. Flow Discharge Period I (2001-2010) and Period II (2011-2020)

Month		Period I Flow Discharge (m^3/s)	Period II Flow Discharge (m^3/s)
January	1	3.56	3.60
	2	3.47	3.52
February	1	3.03	3.20
	2	2.88	3.09
March	1	1.95	2.26
	2	1.84	2.15
April	1	1.48	1.62
	2	1.44	1.57
May	1	0.89	0.98
	2	0.85	0.92
June	1	0.64	0.87
	2	0.65	0.87
July	1	0.89	1.07
	2	0.85	1.06
August	1	0.13	0.15
	2	0.10	0.12
September	1	0.10	0.09
	2	0.09	0.08
October	1	0.14	0.09
	2	0.10	0.08
Month		**Period I Flow Discharge (m3/s)**	**Period II Flow Discharge (m3/s)**
November	1	1.48	1.38
	2	1.52	1.41
December	1	2.29	2.61
	2	2.31	2.64

Table 4. Discharge of Water Demand Period I (2001-2010) and Period II (2011-2020) Scenario 1

Month		Period I DR (m^3/s)	Period II DR (m^3/s)
January	1	0.00	0.00
	2	0.00	0.00
February	1	0.00	0.00
	2	0.00	0.00
March	1	0.00	0.00
	2	0.00	0.00
April	1	1.11	1.03
	2	1.11	1.03
May	1	0.60	0.60
	2	0.60	0.60
June	1	0.83	0.68
	2	0.83	0.68
Month		**Period I DR (m^3/s)**	**Period II DR (m^3/s)**
July	1	0.62	0.45
	2	0.59	0.42
August	1	0.87	0.77
	2	0.26	0.15
September	1	0.00	0.00
	2	0.00	0.00
October	1	0.00	0.00
	2	0.00	0.00
November	1	0.00	0.00
	2	0.00	0.00
December	1	0.00	0.00
	2	0.00	0.00

3.6. Water Demand Analysis

Analysis of water demand of DIR Danda Besar according to the scenario of cropping pattern for agriculture water fulfilment based on changes in rainfall pattern and air temperature with a planting area of 1460 Ha in Period I (2001-2010) and Period II (2011-2020). Planting scenario 1 is the planting season on existing conditions from April to September using local rice. Scenario 2 is a scenario with a planting season after climate change as a recommendation for farmers to follow rainfall patterns and air temperature changes by one planting season with local rice cropping patterns starting from February.

3.7. Water Balance Analysis

Analysis of water balance using the surplus water deficit method is obtained from the results of reducing the water availability flow and water demand. If the impact is positive, it is a surplus, and a deficit is negative. Water balance 1 is the mid-month water availability discharge for Period I 2001-2010 and Period II 2011-2021 minus the water demand discharge for cropping pattern 1, and water balance 2 is the result of mid-month water availability discharge for Period II 2011-2021 minus the water demand discharge cropping scenario 2.

Table 5. Discharge of Water Demand Period II (2011-2020) Scenario 2

Month		Period II DR (m^3/s)
January	1	0.00
	2	0.00
February	1	1.38
	2	1.38
March	1	0.16
	2	0.16
April	1	0.30
	2	0.30
May	1	0.31
	2	0.28
June	1	0.37
	2	-0.20
July	1	0.00
	2	0.00
August	1	0.00
	2	0.00
September	1	0.00
	2	0.00
October	1	0.00
	2	0.00
November	1	0.00
	2	0.00
December	1	0.00
	2	0.00

Table 6. Water Balance 1

Month		Water Balance 1 Period I	Water Balance 1 Period II
January	1	Surplus	Surplus
	2	Surplus	Surplus
February	1	Surplus	Surplus
	2	Surplus	Surplus
March	1	Surplus	Surplus
	2	Surplus	Surplus
April	1	Surplus	Surplus
	2	Surplus	Surplus
May	1	Surplus	Surplus
	2	Surplus	Surplus
June	1	Deficit	Surplus
	2	Deficit	Surplus
July	1	Surplus	Surplus
	2	Surplus	Surplus
August	1	Deficit	Deficit
	2	Deficit	Deficit
September	1	Surplus	Surplus
	2	Surplus	Surplus
October	1	Surplus	Surplus
	2	Surplus	Surplus
November	1	Surplus	Surplus
	2	Surplus	Surplus
December	1	Surplus	Surplus
	2	Surplus	Surplus

Table 7. Water Balance 2

Month		Water Balance 2 Period II
January	1	Surplus
	2	Surplus
February	1	Surplus
	2	Surplus
March	1	Surplus
	2	Surplus
April	1	Surplus
	2	Surplus
May	1	Surplus
	2	Surplus
June	1	Surplus
	2	Surplus
July	1	Surplus
	2	Surplus
August	1	Surplus
	2	Surplus
September	1	Surplus
	2	Surplus
October	1	Surplus
	2	Surplus
November	1	Surplus
	2	Surplus
December	1	Surplus
	2	Surplus

For water balance 1, there is a water deficit in the existing condition during the first period on June 1st, June 2nd, August 1st and August 2nd. Period II is still considered to have a water deficit on August 1st and 2nd. The water balance 2 result does not show any water deficit, which means that the water availability is sufficient for water demand. Thus, the planting scenario recommendations for farmers due to changes in rainfall patterns and air temperature is one planting season using local rice starting from February.

4. Conclusion

Changes in rainfall patterns and air temperature in Period II (2011-2010) compared to Period I (2001-2020), including rainfall increase, especially in wet months and a change in criteria from July to wet month and October to dry month, as well as an increase in air temperature. The highest increase in water availability during mid-month from Period I to period II occurred on December ^{1st} by 0.32 m^3/s, December ^{2nd} by 0.33 m^3/s, and the highest decrease occurred on November ^{1st} by 0.10 m^3/s and November ^{2nd} by 0.11 m^3/s. Thus, the water balance value obtained from the water availability flow minus water demand according to the cropping scenario for water balance 1 experienced a water deficit in periods I and II, and water balance 2 experienced no water deficit in Period II. Thus, the cropping scenario recommendations for farmers are the planting pattern and the planting schedule for scenario 2 by one planting season starting from February.

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