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APPLICATION OF THE PENMAN-MONTEITH METHOD TO DETERMINE THE CROP WATER REQUIREMENTS

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Abstract

Agricultural production is critical to meeting Indonesia's food demands. The water catchment area of Parit Keladi 1, located in Desa Parit Keladi, Kecamatan Sungai Kakap, Kabupaten Kubu Raya, Provinsi Kalimantan Barat, includes tidal swamp land that has a variety of plants. The Cropwat 8.0 Software will be used in this research to assess crop water needs. This research employs primary and secondary data, including soil samples, field cropping patterns, and plant hydration levels.

The type of clay soil was silty, the field cropping pattern at the study site was paddy, and the height of the water puddle on paddy was 3 mm/day/ha, according to the findings of primary data analysis on soil sampling. The maximum water need for paddy was 5.90 mm/day/ha in March period 1, while the lowest water requirement was 0 mm/day/ha in October period 1. The maximum water need for citrus was 2.62 mm/day/ha in August for period 3, while the lowest water requirement was 0 mm/day/ha from October to December and May to June for period 1. In September Period 3, the crop water required in the Cropwat 8.0 Software was 32.2 mm/day/ha for ten days; however, the water level in the field was 3 mm/ha for one day in late September. Thus, the estimate of water demands for rice plants using the Cropwat 8.0 Program is valid.

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1. Introduction

Indonesia is a developing nation with a rapidly growing population. Indonesia's agricultural land is shrinking due to the country's growing population. The extent of agricultural land has shrunk by 0.14 million hectares since last year (Badan Pusat Statistik, 2021). Continuous decrease of agricultural land causes agricultural production to decrease. Increasing agricultural production can be done by fulfilling water availability on agricultural land by plant needs, so it is necessary to calculate plant water needs so as not to experience a shortage or excess water in plants. Calculation of crop water requirement can be calculated using the Cropwat 8.0 Software. The Software was developed by the Food and Agricultural Organization (FAO) based on the Penman-Monteith method and produces effective and accurate calculations (Marica, 2000).

The catchment area of Parit Keladi 1 which is located in Desa Parit Keladi, Kecamatan Sungai Kakap, Kabupaten Kubu Raya, Provinsi Kalimantan Barat is tidal swamp land. The local community still uses a rainfed irrigation system where the source of water availability comes from rainfall and rivers. During the dry season, water availability decreased, and during the rainy season, water availability is abundant. Based on these conditions, it is necessary to evaluate the water requirements needed by plants. This study aims to analyze the water needs of plants using the Cropwat 8.0 software.

2. Materials and Methods

2.1. Theoretical Frame Work

Water problems in the Parit Keladi 1 Watershed are related to water supply, requiring the right solution. Water availability in the area must be able to meet the needs of crops, namely rice and oranges. This study's analysis of crop water requirements used the Penman-Monteith method with the help of the Cropwat 8.0 software. The software validation is based on the discharge of plant water needs on agricultural land in mm/day/ha. Thus, the results of this study can provide information to farmers and supporting materials to conduct further research.

2.2. Research Location

The study is being conducted in the Parit Keladi 1 water catchment region, which is situated in Desa Parit Keladi, Kecamatan Sungai Kakap, Kabupaten Kubu Raya, Provinsi Kalimantan Barat. Geographically, it is located at 00°02'55" south latitude and 109°12'46" east longitude. The area to be studied is 1,010,818 m2 with a trench length of 2,929 meters. This area is mostly planted with paddy, secondary crops, and mixed gardens.

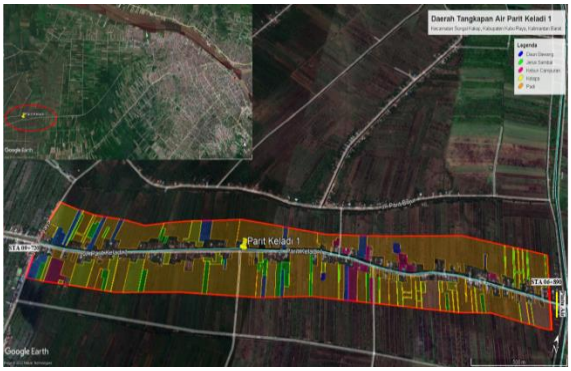


Fig. 1 Study Area (*Google earth pro,* 2022)

2.3. Data

The data for this study include primary data and secondary data. Field cropping patterns and plate water level observations were critical data in this investigation.

In the meanwhile, secondary data supplement information gathered from connected authorities. In this research, secondary data include:

a. Rainfall data for PTK-12 Station 2009-2020 from the Balai Wilayah Sungai Kalimantan 1.
b. Climate data for Kabupaten Kubu Raya 2009-2020 from Badan Pusat Statistik (BPS).

2.4. Analysis Method

The data obtained is then processed using the Cropwat 8.0 Software to produce plant water needs. The data processing steps are carried out as follows:

a. Install the CROPWAT 8.0 Software on the computer and run the Software

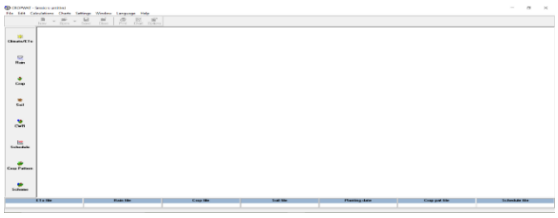


Fig. 2 Initial view Cropwat 8.0 Software (Cropwat 8.0 Software)

b. Click the climate menu to calculate the potential evapotranspiration (ETo) value. Then input data for name country, station, latitude, longitude, average air temperature (°C), wind speed (km/day), dan solar radiation duration (hours). After all, data has been inputted, the evapotranspiration calculation in mm/day will be accumulated automatically.
c. After entering all the data, the effective rainfall in mm will be calculated automatically.
d. Click the crop menu to find the coefficient value and plant age. Select the plant data to be calculated based on the FAO database, then edit the specified planting start date.
e. Click the soil menu to find out the soil data. Select the soil data in the software based on the type of soil in the field.
f. After calculating the potential evapotranspiration and effective rainfall and inputting plant and soil data. Then the calculation of plant water needs will accumulate automatically in units of mm/second.

3. Result and Discussion

3.1. Existing Condition of Research Site

The Parit Keladi catchment area is a preparation village in the administrative area of Kecamatan Sungai Kakap with a concentration in agriculture. Most of these areas have paddy fields to be planted with paddy plants and several other crops, namely citrus plants, leeks, eggplant, cucumber, cassava leaves, and pepper as well as mixed gardens such as coconut, banana, sugar cane, langsat, etc.

Fig. 3 Paddy fields in the catchment area Parit Keladi 1 (Research, 2022)

In addition to being planted with several plants, the Parit Keladi 1 water catchment area also has a sluice gate that can regulate the discharge of water that comes out so it is channeled into the paddy fields. The condition of the floodgates has been damaged with 2 damaged floodgates and 2 floodgates that can still be used.

Fig. 4 Condition of the floodgates in the catchment area Parit Keladi 1 (Research, 2022)

3.2. Soil Sample Data Analysis

Soil sample data analysis aims to determine the soil type in the study site. Soil sampling was carried out in 3 places: paddy plants, leek plants, and coconut plants. Soil samples were taken every 40 cm to a depth of 120 cm; then the pieces will be examined and analyzed at the Soil Mechanics Laboratory, FT UNTAN. Based on the results of the analysis that has been carried out, the type of soil can be determined based on the USDA soil classification system. The results of the study of soil types are presented in Table 1.

Table 1. Analysis of soil types in the catchment area Parit Keladi 1 (Research, 2022)

No	Plants	Depth (cm)	Soil Type
		0 - 40	Silty clay
1	Paddy	40 - 80	Silty clay
		80 - 120	Silty clay
		0 - 40	Silty clay
2	Leek	40 - 80	Silty clay
		80 - 120	Silty clay
		0 - 40	Silty clay
3	Coconut	40 - 80	Silty clay
		80 - 120	Silty clay

3.3. Field Cropping Pattern

The field cropping patterns data on the fields can be known after interviews with farmers. The results of discussions are paddy plants there are the paddy-paddy cropping pattern with a planting period of 1 from March to June and a planting period of 2 from September to December. The types of paddy varieties used were superior with a growth period of 120 days.

3.4. Water Level of Plants

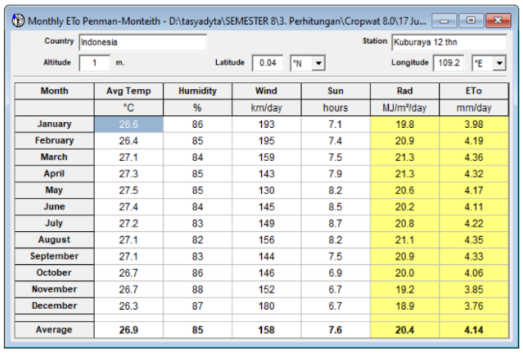
The plant water level was measured in paddy plants as proof that the calculation of the water requirements of the analyzed plants was correct. Measurements were made using a ruler placed on the surface of the ground so that the puddles ground's surface. The height of the water table at the study site was 3 mm above ground level.

Fig. 5 The water level in paddy (Research, 2022)

3.5. Analysis of Crop Water Requirements in Cropwat 8.0 Software

The steps for calculating plant water needs using Cropwat 8.0 Software are as follows:

a. Calculating the value of potential evapotranspiration (ETo)



Monthly ETo Penman-Monteith - D:\tasyadyta\SEMESTER 8\3. Perhitungan\Cropwat 8.0\17 Ju...

Country: Indonesia — Station: Kuburaya 12 thn

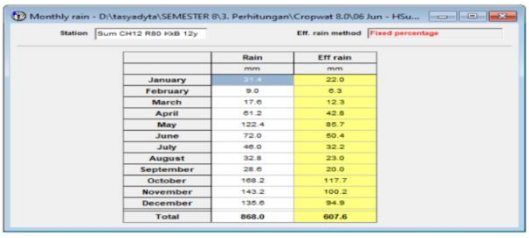
Altitude: 1 m. — Latitude: 0.04 °N — Longitude: 109.2 °E

Month	Avg Temp	Humidity	Wind	Sun	Rad	ETo
	°C	%	km/day	hours	MJ/m²/day	mm/day
January	26.6	86	193	7.1	19.8	3.98
February	26.4	85	195	7.4	20.9	4.19
March	27.1	84	159	7.5	21.3	4.36
April	27.3	85	143	7.9	21.3	4.32
May	27.5	85	130	8.2	20.6	4.17
June	27.4	84	145	8.5	20.2	4.11
July	27.2	83	149	8.7	20.8	4.22
August	27.1	82	156	8.2	21.1	4.35
September	27.1	83	144	7.5	20.9	4.33
October	26.7	86	146	6.9	20.0	4.06
November	26.7	88	152	6.7	19.2	3.85
December	26.3	87	180	6.7	18.9	3.76
Average	**26.9**	**85**	**158**	**7.6**	**20.4**	**4.14**

Fig. 6 Calculation of evapotranspiration potential (Cropwat 8.0, 2022)

Fig. 6 shows the average evapotranspiration value of 4.14 mm/day, the maximum evapotranspiration value occurs in March with a value of 4.36 mm/day which was influenced by high air temperature and sunlight values, and the minimum evapotranspiration value occurs. In December with a value of 3.76 mm/day which is influenced by wind humidity and high wind speed.

b. Calculating the value of effective rainfall (Re)



Monthly rain - D:\tasyadyta\SEMESTER 8\3. Perhitungan\Cropwat 8.0\06 Jun - HSu...

Station: Sum CH12 R80 H3B 12y — Eff. rain method: Fixed percentage

	Rain	Eff rain
	mm	mm
January	22.0	22.0
February	9.0	6.3
March	17.6	12.3
April	61.2	42.8
May	122.4	85.7
June	72.0	50.4
July	46.0	32.2
August	32.8	23.0
September	28.6	20.0
October	168.2	117.7
November	143.2	100.2
December	135.6	94.9
Total	868.0	607.6

Fig 7. Calculation of effective rainfall (Cropwat 8.0, 2022)

Fig. 7 shows the amount of effective rainfall of 607.6 mm, the maximum effective rainfall value occurs in October with a value of 117.7 mm influenced by high rainfall, and the minimum effective precipitation occurs in February with a value of 6.3 mm.

c. *The coefficient and stage of plants*

In this research, we only analyze the water requirements of paddy and citrus based on the FAO database presented in Cropwat 8.0 Software. The initial date of the paddy plant is based on the cropping pattern in the field. The initial planting date for planting period 1 is on 1st March and the initial planting date for producing period two on 1st September with a growth period of 120 days.

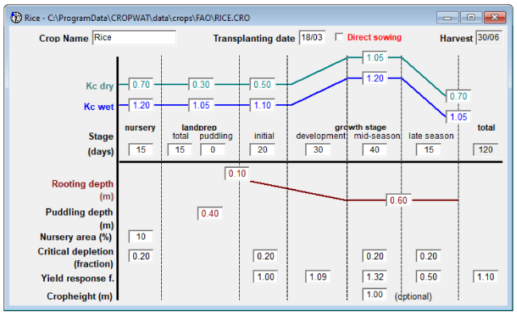


Fig 8. Coefficient and stage of paddy plants period 1 (Cropwat 8.0, 2022)

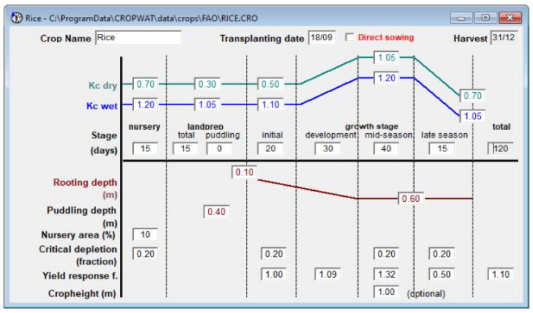


Fig. 9. Coefficient and stage of paddy plants period 2 (Cropwat 8.0, 2022)

The initial planting date for citrus on 1st July 2022 and the growing period of citrus are 365 days.

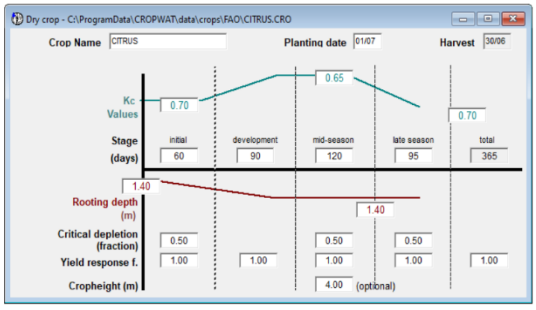


Fig 10. Coefficient and stage of citrus plants (Cropwat 8.0, 2022)

d. *The soil type*

The type of soil found in the catchment area of Parit Keladi 1 is silty clay. Based on the type of soil in the FAO database, this location has a heavy soil type (clay).

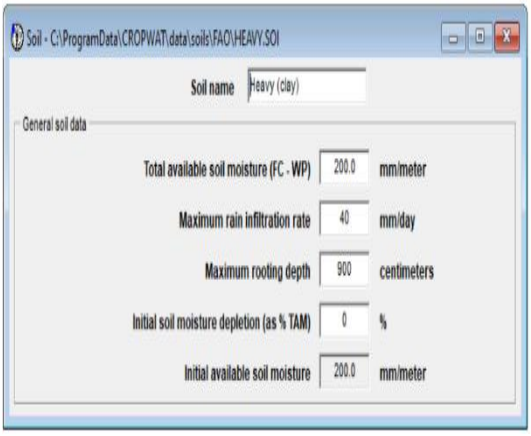
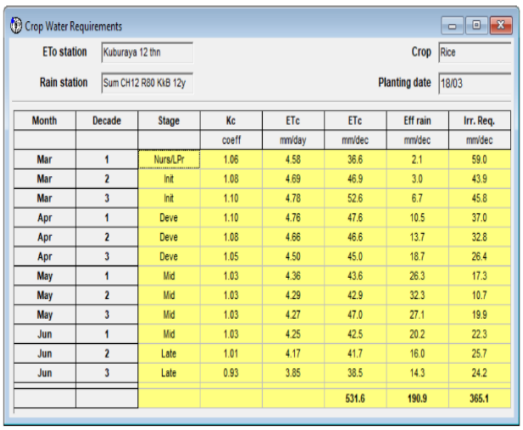


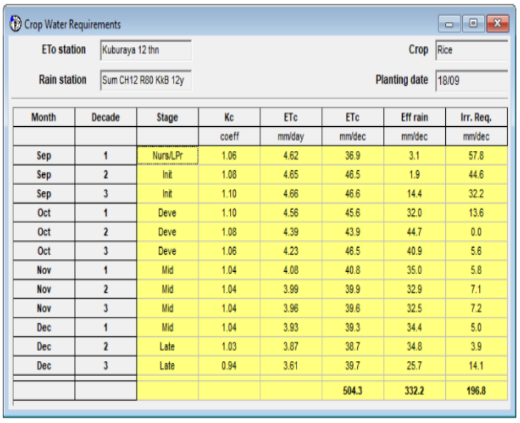
Fig 11. Data of Heavy Soil (Clay) (Cropwat 8.0, 2022)

e. *Crop Water Requirements*



Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	1	Nurs/LPr	1.06	4.58	36.6	2.1	59.0
Mar	2	Init	1.08	4.69	46.9	3.0	43.9
Mar	3	Init	1.10	4.78	52.6	6.7	45.8
Apr	1	Deve	1.10	4.76	47.6	10.5	37.0
Apr	2	Deve	1.08	4.66	46.6	13.7	32.8
Apr	3	Deve	1.05	4.50	45.0	18.7	26.4
May	1	Mid	1.03	4.36	43.6	26.3	17.3
May	2	Mid	1.03	4.29	42.9	32.3	10.7
May	3	Mid	1.03	4.27	47.0	27.1	19.9
Jun	1	Mid	1.03	4.25	42.5	20.2	22.3
Jun	2	Late	1.01	4.17	41.7	16.0	25.7
Jun	3	Late	0.93	3.85	38.5	14.3	24.2
					531.6	190.9	365.1

Fig 12. Crop water requirements for paddy crops period 1 (Cropwat 8.0, 2022)



Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Sep	1	Nurs/LPr	1.06	4.62	36.9	3.1	57.8
Sep	2	Init	1.08	4.65	46.5	1.9	44.6
Sep	3	Init	1.10	4.66	46.6	14.4	32.2
Oct	1	Deve	1.10	4.56	45.6	32.0	13.6
Oct	2	Deve	1.08	4.39	43.9	44.7	0.0
Oct	3	Deve	1.06	4.23	46.5	40.9	5.6
Nov	1	Mid	1.04	4.08	40.8	35.0	5.8
Nov	2	Mid	1.04	3.99	39.9	32.9	7.1
Nov	3	Mid	1.04	3.96	39.6	32.5	7.2
Dec	1	Mid	1.04	3.93	39.3	34.4	5.0
Dec	2	Late	1.03	3.87	38.7	34.8	3.9
Dec	3	Late	0.94	3.61	39.7	25.7	14.1
					504.3	332.2	196.8

Fig 13. Crop water requirements for paddy crops period 2 (Cropwat 8.0, 2022)

Table 2. Recapitulation of water requirements for paddy crops (Research, 2022)

No	Crop Pattern	Month	Period	Stage	NFR		DR	
					mm/sec	mm/day	l/dt/ha	m3/sec
1		January						
2		February						
3		March	1	Landprep	59.00	5.90	1.05	0.059
			2	Initial	43.90	4.39	0.78	0.044
			3		45.80	4.58	0.82	0.046
4		April	1		37.00	3.70	0.66	0.037
			2	Development	32.80	3.28	0.58	0.033
	Pattern 1		3		26.40	2.64	0.47	0.026
5		May	1		17.30	1.73	0.31	0.017
			2	Mid	10.70	1.07	0.19	0.011
			3		19.90	1.99	0.35	0.020
6		June	1		22.30	2.23	0.40	0.022
			2	Late	25.70	2.57	0.46	0.026
			3		24.20	2.42	0.43	0.024
7		July						
8		August						
9		September	1	Landprep	57.80	5.78	1.03	0.058
			2	Initial	44.60	4.46	0.79	0.044
			3		32.20	3.22	0.57	0.032
10		October	1		13.60	1.36	0.24	0.014
			2	Development	0.00	0.00	0.00	0.000
	Pattern 2		3		5.60	0.56	0.10	0.006
11		November	1		5.80	0.58	0.10	0.006
			2	Mid	7.10	0.71	0.13	0.007
			3		7.20	0.72	0.13	0.007
12		Desember	1		5.00	0.50	0.09	0.005
			2	Late	3.90	0.39	0.07	0.004
			3		14.10	1.41	0.25	0.014
Maximum Crop Water Requirement					59.00	5.90	1.05	0.06
Minimum Crop Water Requirement					0.00	0.00	0.00	0.00
Average Crop Water Requirement					23.41	2.34	0.42	0.02
Total Crop Water Requirement					561.90	56.19	10.01	0.56

It can be shown that the most significant crop water need occurs during the land preparation stage, with planting periods 1 and 2 requiring 0.059 m^3/second and 0.058 m3/second, respectively. Low effective rainfall influences the value of the maximum crop water needed. Water is also required for land preparation since it is necessary during flood and puddle times.

Fig 14. Crop water requirements for citrus (Cropwat 8.0, 2022)

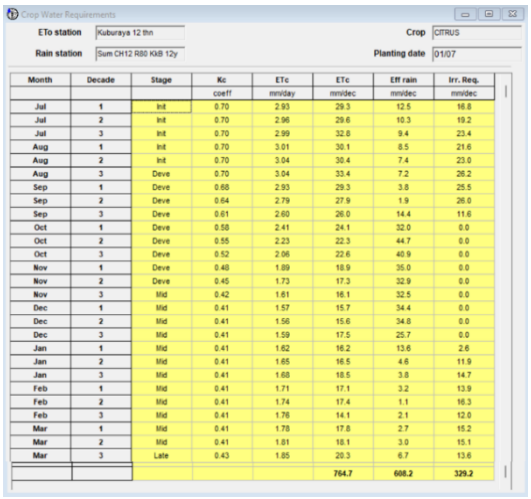


Table 3. Recapitulation of crop water requirements for citrus (Research, 2022)

No	Month	Period	Stage	NFR		DR	
				mm/sec	mm/day	l/dt/ha	m3/sec
1	July	1	Initial	16.80	1.68	0.30	0.0014
		2		19.20	1.92	0.34	0.0016
		3		23.40	2.34	0.42	0.0020
2	August	1		21.60	2.16	0.38	0.0018
		2		23.00	2.30	0.41	0.0020
		3		26.20	2.62	0.47	0.0022
3	September	1		25.50	2.55	0.45	0.0022
		2		26.00	2.60	0.46	0.0022
		3		11.60	1.16	0.21	0.0010
4	October	1	Development	0.00	0.00	0.00	0.0000
		2		0.00	0.00	0.00	0.0000
		3		0.00	0.00	0.00	0.0000
5	November	1		0.00	0.00	0.00	0.0000
		2		0.00	0.00	0.00	0.0000
		3		0.00	0.00	0.00	0.0000
6	Desember	1		0.00	0.00	0.00	0.0000
		2		0.00	0.00	0.00	0.0000
		3		0.00	0.00	0.00	0.0000
7	January	1	Mid	2.60	0.26	0.05	0.0002
		2		11.90	1.19	0.21	0.0010
		3		14.70	1.47	0.26	0.0013
8	February	1		13.90	1.39	0.25	0.0012
		2		16.30	1.63	0.29	0.0014
		3		12.00	1.20	0.21	0.0010
9	March	1		15.20	1.52	0.27	0.0013
		2		15.10	1.51	0.27	0.0013
		3		13.60	1.36	0.24	0.0012
10	April	1		8.70	0.87	0.15	0.0007
		2		5.40	0.54	0.10	0.0005
		3		0.30	0.03	0.01	0.0000
11	May	1	Late	0.00	0.00	0.00	0.0000
		2		0.00	0.00	0.00	0.0000
		3		0.00	0.00	0.00	0.0000
12	June	1		0.00	0.00	0.00	0.0000
		2		2.20	0.22	0.04	0.0002
		3		4.10	0.41	0.07	0.0003
Maximum Crop Water Requirement				26.20	2.62	0.47	0.00
Minimum Crop Water Requirement				0.00	0.00	0.00	0.00
Average Crop Water Requirement				9.15	0.91	0.16	0.00
Total Crop Water Requirement				329.30	32.93	5.86	0.03

It can be seen that the maximum crop water requirement occurs at the initial stage of 0.0022 m^3/second which is influenced by low effective rainfall. The minimum water requirement reaches 0 m^3/second because rainfall has effectively fulfilled the crop water requirements.

f. Validation of crop water requirements

Validation of crop water demand computation using Cropwat 8.0 software may be performed on paddy water requirements. If the results of the discharge of water requirements of paddy in the software are by the discharge of water requirements in the field in the same month, then the validation is correct. In September Period 3, it was found that the crop water requirement on Cropwat 8.0 software was 32.2 mm/day for ten days, while the measurement of plant water level in the field in late September was 3 mm for one day. This shows that the calculation of water

requirements for paddy using Cropwat 8.0 Software has been validated.

4. Conclusion

Based on the analysis results, it can be concluded that the maximum water requirement for paddy occurred in March period one at 5.90 mm/day/ha, while the minimum water requirement for paddy happened in the October period at 0 mm/day/ha. The maximum water need for citrus was 2.62 mm/day/ha in August for period 3, while the lowest water requirement was 0 mm/day/ha from October to December and May to June for period 1. The estimation of plant water demands using Cropwat 8.0 software has been confirmed based on field findings, which are 3 mm for one day in September 3.

5. Acknowledgment

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6. Author's Note

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