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Estimating Water Demand and Plant Evapotranspiration Using the Cropwat App

Moh. Syahrul Munir[1], Marcus dos Santos Soares[2*], Abdul Jalil1[1]
[1]University of Jember; Indonesia
[2]Universitas Nasional Timor Lorosae'e; Timor Leste

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*Correspondence: Marcus dos Santos Soares
Email: soaresmarcus29@gmail.com

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Abstrak: Water management is very important for plants and good water management can increase the productivity of rice, corn and soybeans, hereinafter referred to as PAJALE. This paper aims to estimate the water requirements of PAJALE plants using the cropwatt model. The results of the analysis show that each plant has different water requirements in each growth phase which was analyzed using cropwatt application throughout the year with medium textured soil types. Rice, corn and soybeans are the main food commodities in Indonesia. Corn and soybeans are generally planted after rice in irrigated and rainfed rice fields, making them susceptible to drought. Therefore, information using cropwatt applications, especially rainfall, temperature, Air humidity and solar radiation are very important in determining the time of planting and the right water requirements for plants. The purpose of the study was to determine the planting time and water requirements of rice, corn and soybeans, based on the results of cropwatt 8.0 analysis, and to compile a time map of Indonesian food crops so that the risk of production failure due to drought can be avoided.

Keywords: *Water Demand, Cropwat, Evapotranspiration, Plant.*

INTRODUCTION

The agricultural sector is one of the mainstays of the economy because it is able to run the Indonesian economic system and play a role in domestic development to all corners of Indonesia. The role of agriculture can be seen from its contribution to the formation of gross domestic product, job creation and export of superior food commodities in Indonesia. The determination of planting time greatly affects the continuity of agricultural cultivation because it is able to minimize the loss of nutrients needed by plants, especially when the dry season changes to the rainy season. Because of that, informationrainfall, temperature, air humidity and basic solar radiationneeded as a start in determining the time from planting to harvesting, when to water and how much water volume is needed. Some of the leading food commodities other than rice are corn and soybeans, hereinafter referred to as PAJALE.

[1] Corn is useful as a substitute for staple food. Soybeans can be used by the community to be used as raw material for tempeh, besides that soybean meal is used as pet food. Soybeans and corn will usually be cultivated after rice is planted in paddy fields, therefore information on climatic conditions is very useful in determining the right planting time and also to determine the water needs of PAJALE plants. The purpose of this study was to determine the water needs of PAJALE plants.

CROPWAT is a Windows based program used to calculate crop water requirements and irrigation requirements based on soil, climate and crop data. CROPWAT can be used to calculate potential evapotranspiration, actual evapotranspiration, irrigation water requirements for one type of plant or several types of plants in one stretch, as well as planning for irrigation water supply. From several studies it was found that the Penmann-Monteith model provides an accurate estimate so that the FAO recommends its use for estimating the standard evapotranspiration rate in estimating water requirements for plants [2].

METHOD

Data analysis of irrigation plant water needs is carried out using secondary data that can be obtained from data from the Meteorology, Climatology and Geophysics Agency at Juanda Station Indonesia in 2013-2014. Meteorological data arerainfall, temperature, humidity and solar radiation. A number of empirical formulas are used to calculate crop water requirements, reference evapotranspiration (ETo), ETcrop and planting time based on climatological data using the Cropwat 8.0 computer application which is a decision support tool developed by the FAO Land and Water Development Division for use in commodities. rice, corn and soybeans, hereinafter referred to as PAJALE

RESULTS AND DISCUSSION

The Juanda climate station is in the southern part of the city at 7.3806 °S and 112.7861 °E. Juanda climate station covers the cities of Surabaya and Sidoarjo.In general, the determination of the planting time begins with the type of rice plant and each type of plant is given a rest period of one week as listed in table 1.

Table 1. Cropping pattern PAJALE

No.	crop name	Planting date	harvest date	Area %
1	Rice	05/01	04/05	100
2	Maize	12/05	13/09	100
3	soybean	21/09	14/12	100

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

The planning for rice planting started on January 05, 2014 and harvesting will be done on May 04, 2014, then corn was planted on May 12, 2014 and harvested on September 13, 2014, planted soybeans on September 21, 2014 and harvested on December 14, 2014.

Table 2. Average Climatological Data at Juanda Station in 2014

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sun (hours)	Rain (mm/day)	ETo (mm/day)
January	24.6	31.3	82	2.0	3.0	24.0	3.55
February	24.4	31.9	83	2.0	2.0	31.4	3.86
March	24.7	32.3	82	2.0	5.1	39.8	4.13
April	25.1	32.4	82	2.0	5.7	27.2	4.04
May	26.0	32.4	78	2.0	6.8	10.5	4.11
June	25.5	32.0	78	2.0	7.9	20.1	4.12
July	24.0	31.1	77	2.0	6.8	4.9	3.9
August	23.3	31.3	74	2.0	8.2	0.0	4.57
September	22.3	31.9	69	2.0	8.5	0.0	5.15
October	24.0	33.4	67	2.0	9.3	0.0	5.78
November	25.4	34.2	69	2.0	7.3	6.2	5.36
December	25.2	32.8	81	2.0	3.9	24.8	3.93
Average	24.5	32.3	77	2.0	6.2	15.7	4.38

Source: BMKG, 2014.

The analysis of water requirements that need to be applied to PAJALE plants based on Table 2 for the types of rice, corn and soybeans are listed in Table 3, while the graph of data based on rainfall, temperature, humidity and solar radiation in 2014 is listed in Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5. Reference evapotranspiration (ETo) was analyzed using Cropwat 8.0 software with input data in the form of temperature, humidity, rainfall and duration of solar radiation for the Juanda station area in 2014. Muamar et al. (2012) reported the results of their research that the total ETo during the study was 143.29 mm and the total evapotranspiration of maize for 100 days on a tarpaulin plot was 659.5 mm and on a plot of land without tarpaulin was 614.29 mm. Wahyuni et al.'s research results.

Table 3. Water Needs, Schedule and Amount of Irrigation for Rice Plants

Date	Day	stage	rain	Percol.	Net Gif
			mm	mm	mm
16-Dec	-19	PrePu	0.0	0.0	49.5
31-Dec	-4	Puddl	0.0	0.0	98.0
02-Jan	-2	Puddl	0.0	15.0	52.7
10-Jan	6	Init	0.0	3.4	95.9
24-Jan	20	Init	0.0	3.4	101.7
07-Feb	34	Dev	2.9	3.4	97.1
22-Feb	49	Dev	0.0	3.4	101.2
10-Mar	65	Mid	0.0	3.4	98.3
25-Mar	80	Mid	0.0	3.4	103.1
06-Apr	92	End	0.0	3.4	98.5
20-Apr	106	End	0.0	3.4	101.0
04-May	End	End	0.0	0.0	

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

Plant water requirement is the amount of water needed by plants to grow optimally which can also be interpreted as the amount of water used to meet the plant evapotranspiration process [3]. The water needs of rice plants must be adjusted to the growth phase of rice plants and the right time of planting. The growth phase of the rice plant is divided into several phases, whereas when viewed from the stage of the rice plant growth cycle, the water needed by the rice plant is starting from the need for soil processing, seeding, planting to primordia, primordia to flowering, 10% interest to full, full flower. until ripening then cooking until harvesting, each of which requires different water. The water requirement at the time of inundation was 49.5 mm, the puddle process was carried out twice with a water requirement of 150.7 mm, the initial phase of rice occurred twice, starting on January 10 and 24 with a water requirement of 197.6 mm, the development phase started on 7 and 22 February 34 days and 49 days with a water requirement of 198.3 mm, the middle phase occurred twice, namely on 10 and 25 March 65 days and 80 days with a water requirement of 201.4 mm and the last phase until the end of growth in April 6 and 20, 92 days and 106 days required 199.5 mm of water, so when calculated from the initial phase (flooding-mudding) to harvesting, the total water requirement for rice plants total net irrigation was 997.0 mm. The highest water demand is in the Mid-season phase of 201.4 mm, which is on March 10-25. The results of the study [1] the results of the analysis of water needs showed that rice plants in East Nusa Tenggara Province needed irrigation of 4.9 mm day-1 in the May-August planting period. This percolation is influenced, among others, by soil texture, soil with a fine texture has a low percolation rate, while soil with a coarse texture has a large percolation rate. Soil permeability and topsoil thickness, the thinner the topsoil the lower the percolation rate, the total percolation from the initial phase to harvest is 27.2 mm.

Table 4. Plant Water NeedsRice During Life Based on Growth Phase and Climatological Data at Juanda Station 2014

Growth Phase	Time (day)	Water Needs		
		Kc	ETo(mm)	ETC(mm)
Initial (germination)	20	1.10	7.20	7.92
Development	30	1.20	27.56	33.07
Mid-season (Stem Extension)	40			
Late-season (Cooking)	30	1.05	12.51	13.14
Total	120	3.35	47.27	54.13

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

Note. : Plant coefficient (kc), reference evapotranspiration (ETo), consumptive water demand (ETc)

Based on the data in Table 4, the highest water demand is in the Mid-season phase or the stage of stem elongation of rice plants in February in the third decade to March in the second decade, based on high Kc and ETc values.

Table 5. Plant Water NeedsCorn During Life Based on Growth Phase and Climatological Data at Juanda Station 2014

Growth Phase	Time (day)	Water Needs		
		Kc	ETo(mm)	ETC(mm)
Initial (germination)	20	0.30	8.05	2.42
Development	35			
Mid-season (Stem Extension)	40	1.20	30.57	36.68
Late-season (Cooking)	30	0.35	13.83	4.84
Total	125	1.85	52.45	43.94

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

Note. : Plant coefficient (kc), reference evapotranspiration (ETo), consumptive water demand (ETc)

Based on the data in Table 5, the highest water demand is in the Mid-season phase or the stage of corn stalk elongation in the first decade of June to August of the first decade based on high Kc and ETC values. The results of the study [4] that the total evapotranspiration of corn plants during 4 planting periods was 1026.18 mm/year and had very sufficient water availability and every month had a surplus value throughout the year in the Tarakan City area.

Table 6. Water Needs, Schedule and Amount of Irrigation for Corn Plants

Date	Day	stage	Rain	Net Irr
			Mm	mm
19-July	69	mid	0.0	163.6
13-Sep	end	end	0.0	0.0

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

The water requirement for Mid-season corn plants is 163.5 mm, namely July 19 at the critical phase in the Mid-season 69 days, with a total gross irrigation of 233.7 mm. (Sirait et al., 2020) The average water requirement of corn plants in the initial phase is 23.45 mm, the crop development phase is 90.72 mm, the mid-season phase is 128.55 mm and the Late season phase is 13.83 mm. During one period of planting corn plants require an average of 256.55 mm of water.

Table 7. Water Demand, Schedule and Amount of Soybean Plant Irrigation

Date	Day	stage	Rain	Net Irr
			Mm	mm
01-Nov	42	mid	0.0	177.1
14-Dec	end	end	0.0	0.0

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

The water requirement of plants for one clump of soybeans is the same as the number of plants water lost due to the evapotranspiration process in one unit of time [5]. Irrigation water requirements in the production area can be calculated, if the water requirements of soybean plants are known. Mid-season soybean crop water requirement is 177.1 mm, namely November 1 at the critical phase in the Mid-season 42 days, with a total gross irrigation of 253.0 mm.

Table 8. Plant Water NeedsSoybean During Life Based on Growth Phase and Climatological Data at Juanda Station 2014

Growth Phase	Time (day)	Water Needs		
		Kc	ETo(mm)	ETC(mm)
Initial (germination)	15	0.40	13.72	5.49
Development Mid-season (Stem Extension)	15 40	1.15	32.43	37.29
Late-season (Cooking)	15	0.50	10.02	5.01
Total	85	2.05	56.17	47.79

Source: The results of the Cropwat 8.0 computer application with climatological data of Juanda station

Based on the data in Table 8, the highest water demand is in the Mid-season phase or the stage of stem elongation of soybean plants in October of the second decade to November of the second decade based on high Kc and ETc values.

The results of the study [6] the time required for the Tanggamus variety in the early growth phase, vegetativeactive, fertilization, and seed maturity were 15 days, 15 days, 35 days and 13 days, respectively. Based on observations made during the study (4 November 2013 – 17 January 2014), the ETo value during the soybean growing period was 658.82 mm water or 8.45 mm water per day, with the total ETo per stage was 167.9; 104.5; 254.7; 131.6 mm of water with a daily average of 11.2 respectively; 6.9; 7.3;10.1 mm/day. From the calculations that have been carried out [6], the ETc values according to the phase of the soybean plant, namely the early growth phase, active vegetative, fertilization and seed maturity were 50.38; 73.17; 280.22 and 92.12 mm of water with a total evapotranspiration of 495.9 mm of water or 6.4 mm per growth required more water than the FAO predicted.

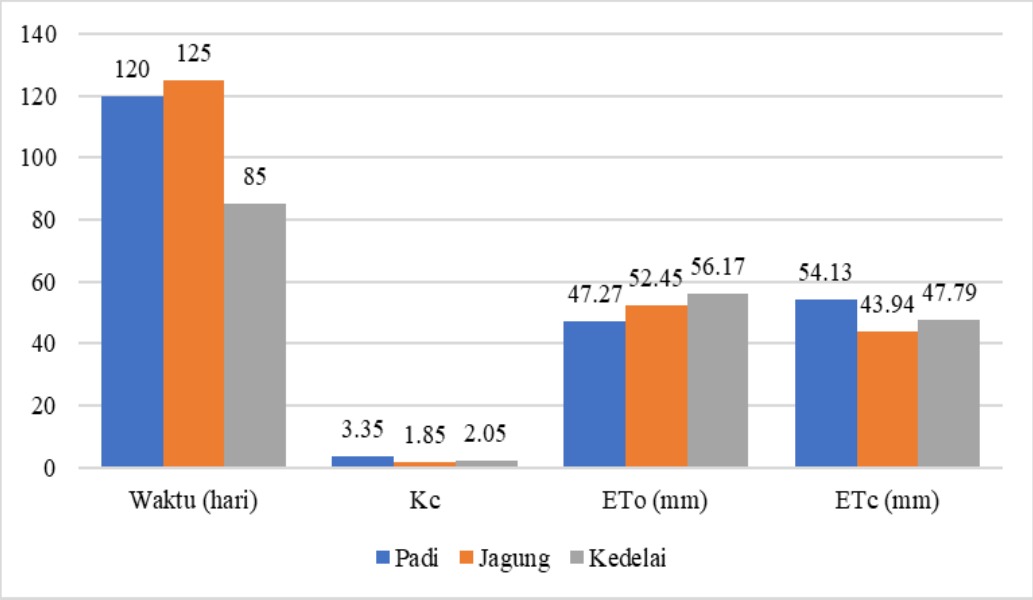

Figure 1. ETcrop PAJALE

The results of cropwatt 8.0 analysis show that the highest water requirement is for rice plants which can be seen from the ETC of 54.13 mm and ETo of 47.27 mm with the highest Kc value of 3.35. Soybean has an ETC value of 47.79 mm and ETo with the highest value of 56.17 mm, a Kc value of 2.05. Then the corn plant has an ETC value of 43.94 then an ETo of 52.45 mm and a Kc value of 1.85. From Figure 1 it can be seen that when compared to corn and soybeans, rice plants need the most water, then corn plants need the least water with a planting time of 125 days after planting in the area.

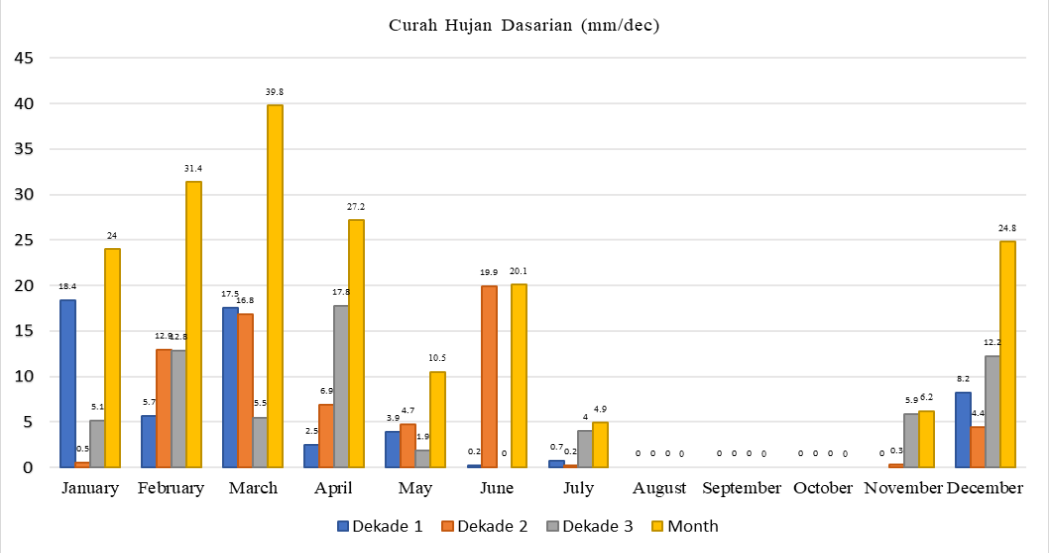

Figure 2. 2014 Dasarian Rainfall

Information on the 2014 basic rainfall trend at Juanda station is shown in Figure 2. Based on this figure, the highest rainfall trend occurred in March of the third decade of 39.8 mm, and the trend of decades without rainy days occurred for ten decades, starting in August. the first decade to end in November of the first decade. The lowest rainfall trend occurred in November in the second decade of 0.3 mm.

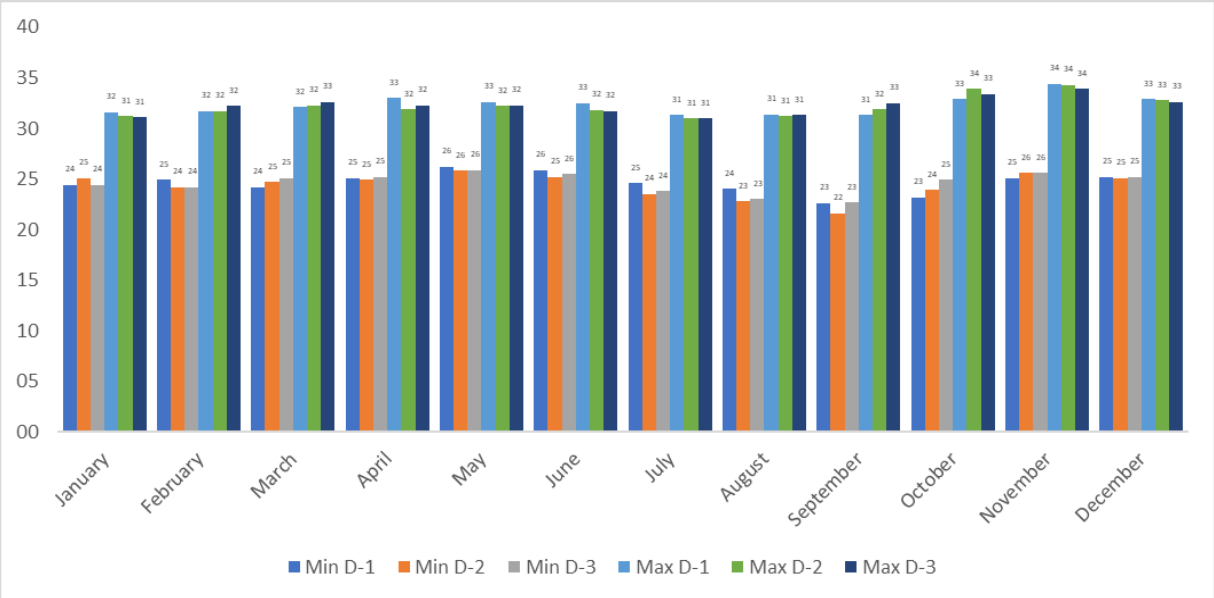

Figure 3. 2014 Dasrian Temperature

The analysis of the air temperature trend at Juanda Station is shown in Figure 3. At the station, it can be seen that the highest air temperature occurred in November the first decade of 34.4°C, changes in air temperature in the decade showed a varied trend. In the trend of minimum air temperature, there is a relatively small increase in air temperature per decade and a decrease in minimum temperature occurs in October of the first decade by 23.2°C. Meanwhile, the trend of maximum air temperature shows a significant increase with the range of low and high air temperatures between decades showing a relatively large distance. The trend of average air temperature does not show a significant upward trend although it is not as big as the trend of maximum air temperature in November. Based on Wordclim data, the minimum and maximum average air temperatures in Surabaya are 22^{O}C and 34^{O}C.

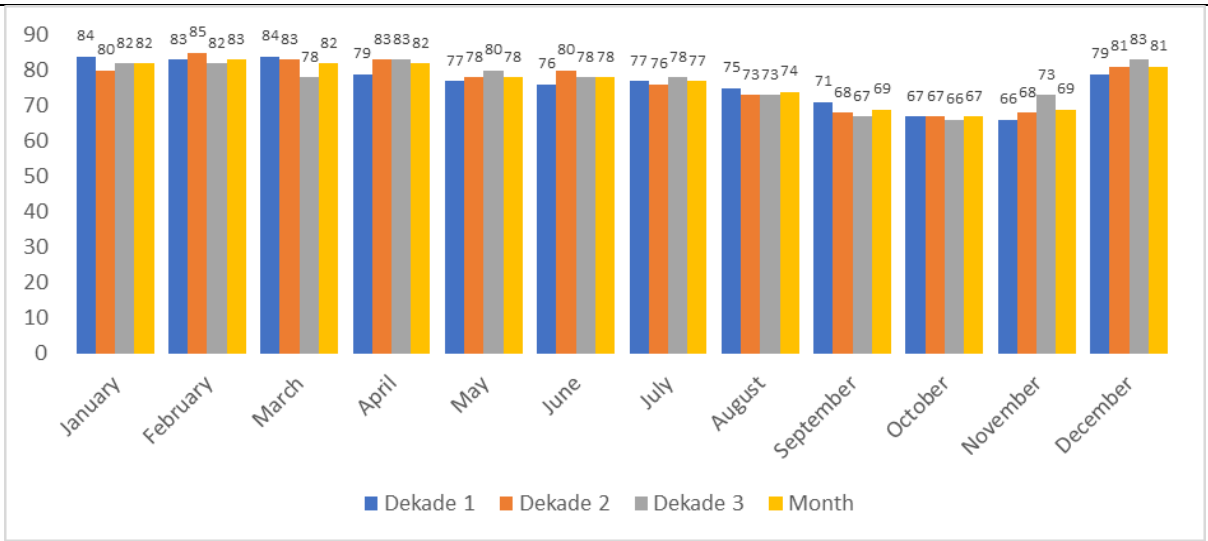

Figure 4. Dasrian Air Humidity 2014

Juanda Station, which is located in the tropics, causes relatively moderate variations in temporal air humidity. The range of air humidity per decade is between 67 – 84%. Low humidity tends to occur in dry months (September and October) while moderate air humidity occurs in January, February, April and December with values above 80%.Dissemination of Extreme Weather Information which includes extreme categories, among others, ranges from 92 - 100%.

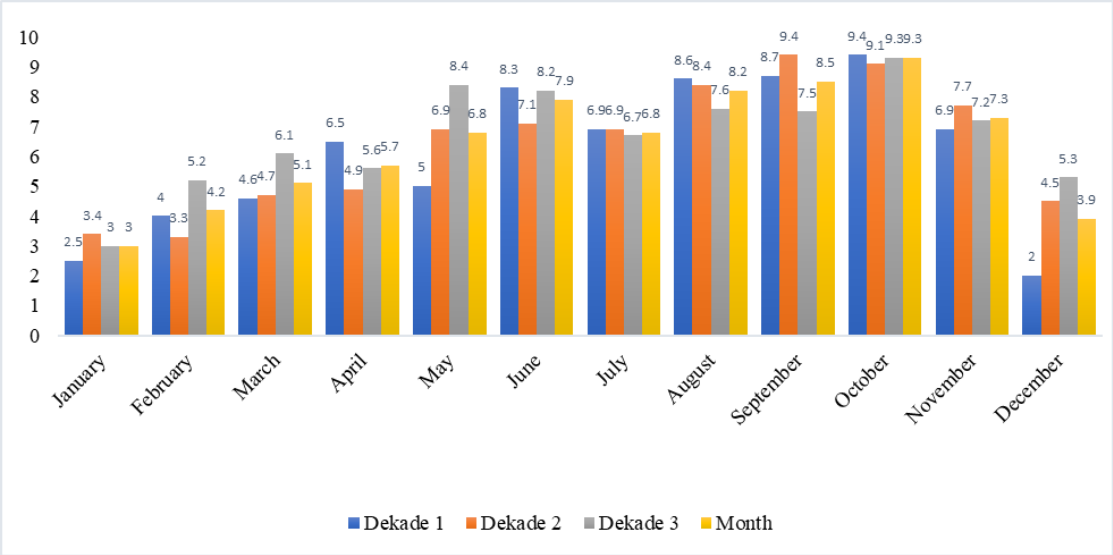

Figure 5. Solar Radiation Dasrian 2014

The analysis of the trend of solar radiation at Juanda Station is shown in Figure 5. At the station, it can be seen that the highest solar radiation occurred in September of the second decade of 9.4 hours and in October of the first decade of 9.4 hours, this is in line with humidity conditions. the air that affects the dry months there is no rain in that decade. Changes in decade solar radiation show varied trends. The trend of low solar radiation occurs in January of the first decade to May of the second decade, and in December of 3.9 hours.

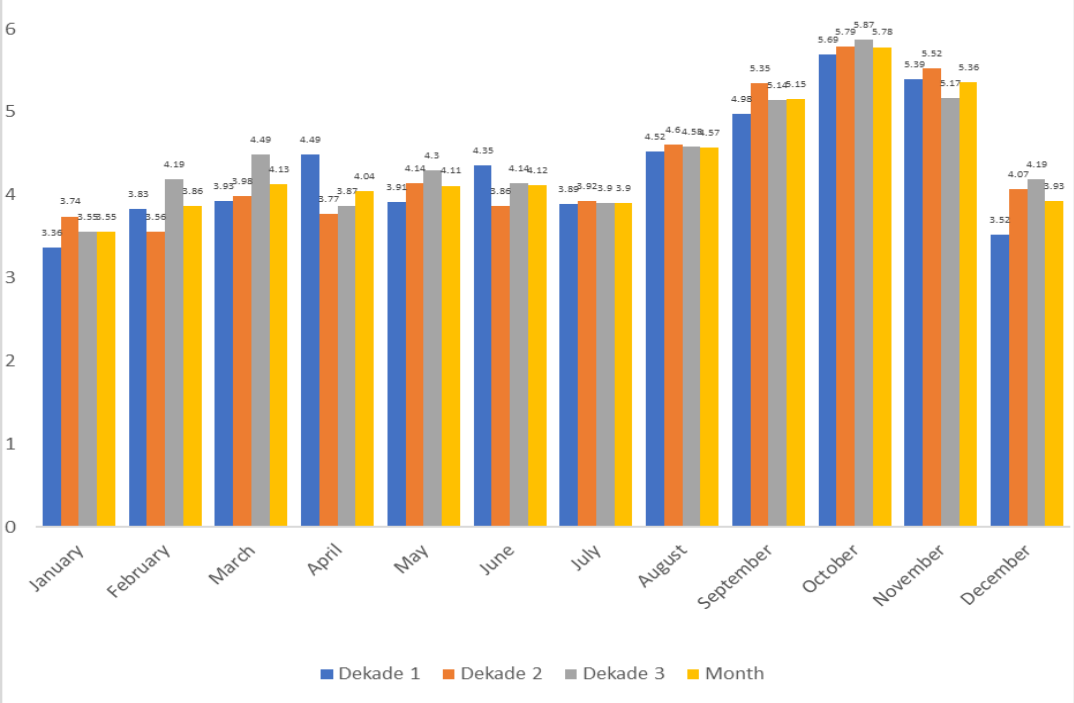

Figure 6. Reference evapotranspiration (ETo) Dasrian 2014

Potential evapotranspiration can be calculated using the Cropwat 8.0 computer application based on climate data such as maximum and minimum temperature, humidity, wind speed, solar radiation and rainfall. Potential evapotranspiration in the Juanda Station area is presented in Figure 6. During the rainy season until the beginning of the dry season, the potential evapotranspiration in the Juanda Station area ranges from 3.36-5.87 mm/decade, evapotranspiration has increased from August the first decade to November in the third decade with a range of 4.52 -5.17 mm/decade along with increasing maximum temperature, solar radiation intensity and dry decade (dry month).

CONCLUSION

1. PAJALE planting with an interval of one week starting with rice planting on January 5, 2014 and harvesting on May 4, 2014 for approximately three months, then corn commodity starting on May 12 2014 and harvesting on September 13 2014 and finally soybean on September 21 2014 and harvest on December 14, 2014.
2. The highest water requirement for rice plants and the lowest for corn plants:
    a). The total gross irrigation of rice is 1424.2 mm with a total net irrigation of 997.0 mm. The initial season is 197.6 mm, the Development period is 198.3 mm, until the Mid-season is 201.4 mm and the final growth period is 199.5 mm. The inundation period was 49.5 mm and the puddling was carried out twice at 150.7 mm.
    b). Corn gross irrigation total of 233.7 mm with a total net irrigation of 163.6 mm. Mid-season by 163.6 mm on July 19 69 days.
    c). Soybean gross irrigation total of 253.0 mm with a total net irrigation of 177.1 mm. Mid-season was 177.1 mm on November 1, 42 days.
3. From the results of the analysis, it is known that the water needs of the three commodities, rice plants need the most water, namely total net irrigation of 997.0 mm, then soybeans with total net irrigation of 177.1 mm and the least need for corn is 163.6 mm.
4. The highest water requirement is in rice plants which can be seen from the ETC of 54.13 mm and ETo of 47.27 mm with the highest Kc value of 3.35. Soybean has an ETC value of 47.79 mm and ETo with the highest value of 56.17 mm, a Kc value of 2.05. Then the corn plant has an ETC value of 43.94 then an ETo of 52.45 mm and a Kc value of 1.85.
5. The highest rainfall trend occurred in March of the third decade of 39.8 mm, and the trend of decades without rainy days occurred for ten decades, starting in August in the first decade to ending in November in the first decade.

6. During the rainy season until the beginning of the dry season, the potential evapotranspiration in the Juanda Station area ranges from 3.36-5.87 mm/decade. intensity of solar radiation and dry decade (dry months).

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