



## **SOYBEAN CULTIVATION PROSPECT BASED ON CROP WATER REQUIREMENTS AND THE AGROCLIMATIC ZONE IN JAMBI PROVINCE**

### **PROSPEK BUDIDAYA KEDELAI BERDASARKAN KEBUTUHAN AIR TANAMAN DAN ZONA AGROKLIMAT DI PROVINSI JAMBI**

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#### **ABSTRAK**

*Kedelai (*Glicine max*) berpotensi untuk dikembangkan karena tidak hanya dapat diolah menjadi bahan pangan tetapi juga menjadi pakan ternak. Selain pemanfaatan teknologi, peningkatan produksi tanaman kedelai dapat dilakukan dengan memperhatikan ketersediaan air dan faktor cuaca terutama untuk meningkatkan intensitas tanaman. Penelitian ini bertujuan untuk mengetahui kebutuhan air tanaman berdasarkan zona agroklimat. Analisis deskriptif kuantitatif dan pengolahan data dilakukan dengan model Cropwat. Model ini dibuat oleh FAO untuk menentukan perhitungan evapotranspirasi dan perhitungan kebutuhan air tanaman di seluruh dunia secara otomatis. Cropwat merupakan salah satu model perangkat lunak yang mudah untuk dioperasikan dan dapat meminimalisir kesalahan manusia. Klasifikasi iklim diidentifikasi berdasarkan data curah hujan di Provinsi Jambi yaitu di Kabupaten Muaro Jambi di Stasiun Sultan Thaha, Palmerah Jambi, dan Depati Parbu. Zona agroklimat untuk setiap wilayah tersebut berturut-turut adalah D1, D2, dan E2. Berdasarkan curah hujan, ketiga kabupaten tersebut layak untuk budidaya kedelai karena memiliki curah hujan rata-rata 127,11 mm - 192,51 mm per bulan. Banyaknya kebutuhan air tanaman juga menjadi faktor esensial dalam pembudidayaan tanaman agar air dapat tertata sesuai dengan kebutuhan tanaman dan dapat memberikan produksi yang optimal. Berdasarkan neraca air, surplus di Kabupaten Muaro Jambi Provinsi Jambi terjadi pada bulan Januari, Februari, Maret, April, September, Oktober dan Desember. Kabupaten Tanjung Jabung Timur mengalami surplus pada bulan Januari, Februari, Maret dan April. Kabupaten Tanjung Jabung Barat surplus terjadi pada bulan Januari, Februari, Maret, Oktober, November dan Desember. Hasil perhitungan ini menunjukkan bahwa Provinsi Jambi berpotensi untuk dibudidayakan tanaman kedelai karena memiliki ketersediaan air yang cukup.*

**Kata kunci:** *Cropwat, Klasifikasi Oldeman, neraca air, evapotranspirasi, kebutuhan air tanaman, ketersediaan air*

#### **ABSTRACT**

Soybean (*Glicine max*) has the potential to be developed because it cannot only be processed into foodstuffs but also become livestock feed. In addition to using technology, enhancement of crop production can be done by looking at water availability and pay attention to the weather factors, especially to increase crop intensity. This research aims to determine the crop water requirements based on the agroclimatic zone. The quantitative descriptive analysis and data processing were conducted using the Cropwat model. This model was created by FAO specialists to provides an opportunity for automation of all the necessary calculations for evapotranspiration determination. Cropwat is an easy-to-operate software that can minimize human error. Climate classification was identified based on precipitation data in Jambi province respectively in Muaro Jambi Regency at Sultan Thaha Station, Jambi Palmerah, and Depati Parbu. The agroclimatic zone for those areas, respectively, are D1, D2, and E2. Based on the rainfall, all three districts are feasible for soybean cultivation with average rainfall between 127.11 mm – 192.51 mm per month. The amount of crop water requirements is also an essential factor for cultivating a plant so that the water can be administered according to the needs of plants and can provide optimal production. Based on water balance, the surplus in Muaro Jambi Regency Jambi Province occurs in January, February, March, April, September, October and December. East Tanjung Jabung Regency surplus is in January, February, March and April. West Tanjung Jabung Regency surplus occurs in January, February, March, October, November and December. The results of this calculation indicate that Jambi Province has the potential to cultivate soybean plants because they have sufficient water availability.

**Keyword:** *Cropwat, Oldeman Classification, water balance, evapotranspiration, crop water requirement, water availability*

## I. INTRODUCTION

The increasing of crop production currently occupies a top priority in agricultural development. One of the most important crops is soybean. Soybean can be processed into various foodstuffs, including fermented soybean, tofu, soy sauce, soy milk, soybean oil, and *tauco* (traditional food). Furthermore, it can also be processed into livestock feed. One of the most important areas for soybean production is Jambi Province. This province has very supportive geographical conditions for soybean production. Among the 11 districts in this province, East Tanjung Jabung Regency is the most productive area with the fourth-highest productivity level, namely 12.92 quintals/hectare/year with a harvest area of 976 hectares and a production of 1,261 tons (Dinas Pertanian Tanaman Pangan, 2015). To further enhance productivity and cropping patterns, the development should consider the water availability, weather factors, and technology.

Water becomes one of the factors in plant cultivation and is needed since the beginning of growth. Water availability is a limiting factor that most determines the agricultural activities, especially on dry land. Without available water, an area cannot be planted, although the soil and biological condition are suitable (Musa, 2012). Water is important for crop production because it is used to transport plant nutrients from the soil to the photosynthesis site, distribute the results of photosynthesis, and metabolism of plants. Water balance analysis should be conducted by considering the water availability and the crop water requirements so that water can be administered efficiently according to plants' needs. This analysis is helpful to identify the soil water content dynamics and water use of plants for the planting planning of each cultivar, which can increase the productivity of the agroecosystems. Productivity is influenced by land subsystems, water, and cropping patterns for certain periods (Munir, 2012). The water balance information can be used in deciding the appropriate time for the cropping pattern to achieve high productivity.

One way to conduct water balance and crop water requirement analysis in an agricultural area is by using Cropwat. Cropwat is a software developed by the FAO that refers to the empirical equation of Penman-Monteith that can calculate the evapotranspiration, irrigation schedule, and the water requirements in different cropping patterns. In some studies, it is well-known that the model of Penman-Monteith provides accurate results so that FAO recommends its use for

estimates of the standard evapotranspiration in determining the need for water tanks (Manik, Rosadi, & Karyanto, 2012). Cropwat was created by FAO specialists to provides an opportunity for automation of all the necessary calculations for evapotranspiration determination. It is widely used to define crop water requirements worldwide (Surendran, Sushanth, Mammen, & Joseph, 2015). Cropwat is an easy-to-operate software that can minimize human error.

Weather factors are a primary factor that affects the growth and development of plants. Thus, appropriate weather factors should be identified to obtain a high production. In agricultural development, the analysis can be conducted by estimating the agro-climatological zone. The agro-climatological zone is very important to be identified in determining the main strategic decisions in preparing land use and cropping patterns. Climate change immensely affects the agro-climate zone which has an impact on changing cropping patterns in the field. Therefore, identify changes in agro-climatological zones and crop pattern directions based on the identification of rain patterns is very important to do. The Oldeman climate classification is quite useful, especially in the classification of agricultural land for food crops in Indonesia. Oldeman made and classified climate types in Indonesia based on the criteria of wet months and dry months, respectively. With the changing climate in an area, with Oldeman classification, the area can determine the actions and time when farmers can cultivate crops accordingly. (Fadholi & Supriatin, 2012) stated that the Oldeman classification system is very useful in the classification of agricultural land for food crops in Indonesia using the elements rainfall. The criteria are based on the calculation of wet months and dry months, respectively, which the limits consider the chance of rain, effective rain, and water requirements for plants. With this understanding, the optimal cropping pattern in an area can be determined.

These factors should be studied comprehensively in the development of soybean estate in Jambi Province so that optimal production can be achieved. Thus, this study was conducted to determine the soybean cultivation area by considering crop water requirements based on agro-climatological zone. The analysis was done using Cropwat (version 8.0) in Muaro Jambi Regency, East Tanjung Jabung Regency, and West Tanjung Jabung Regency.

## II. METHOD

### 2.1. Study Area

The research was conducted in April 2016 to December 2016 in Muaro Jambi Regency, East Tanjung Jabung Regency and West Tanjung Jabung Province of Jambi (Figure 1). This research flowchart can be seen in Figure 2.

### 2.2. Secondary Data Collection

Hydrological conditions were identified to determine the condition of water availability, rainfall type, the water requirements for soybean plants, and the water balance for soybean cultivation to identify the surplus and deficit conditions. The identification began with collecting rainfall data and climate data at the Muaro Jambi Regency, West Tanjung Jabung Regency, and East Tanjung Jabung Regency. Data collected were rainfall, minimum and maximum temperature, moisture data, duration of bright sunshine, wind speed, radiation, and evapotranspiration. Due to the availability of consistent and high-quality data, the analysis was conducted using the data from 2005 to 2014.

The rainfall data of each district was obtained from the different stations which were the closest to the city. Rainfall data of Muaro Jambi Regency was obtained from the Sultan Thaha, Palmerah, and Depati Parbu Meteorological station. Data for East Tanjung Jabung Regency was from Sungai Durian Meteorological station. Data for West Tanjung Jabung Regency was from Senyerang Meteorological station.

### 2.3. Agro-Climatological Zone Classification

The agro-climatological zone classification was based on the Oldeman classification system. Oldeman classification was determined from rain information based on the number of wet months and dry months that occurred. Arrangement of climate types by number consecutive wet months. The categories are (Tjasyono, 2004):

- Wet months if the average rainfall is more than 200 mm;
- Humid months if the average rainfall is 100-200 mm;
- Dry months if the average rainfall is less than 100 mm.

These values were determined based on crop water requirements of common commodities in Asia i.e. rice and *palawija* (Oldeman & Syarifuddin, 1977). The crop water requirement for rice is about 150 mm/month whereas for *palawija* is about 70 mm/month. The assumption that the water requirements of rice crop is 150

mm/month which is required rainfall at 220 mm/month. Meanwhile, to provide sufficient water requirement for *palawija*, it requires rainfall of 120 mm/month.

Rainfall has a vital role in plant growth and production. Effective rainfall is rainfall that is thought to be used by plants. In this study, monthly rainfall is used to calculate effective rainfall. Climate and rainfall data will be processed by the Cropwat automatically and the resulting output data is reference evapotranspiration (ET<sub>o</sub>), crop evapotranspiration (ET<sub>c</sub>), effective rainfall, soil moisture availability, crop coefficient for each growth phase, crop water needs, water needs. actual irrigation and irrigation scheduling and soil moisture balance.

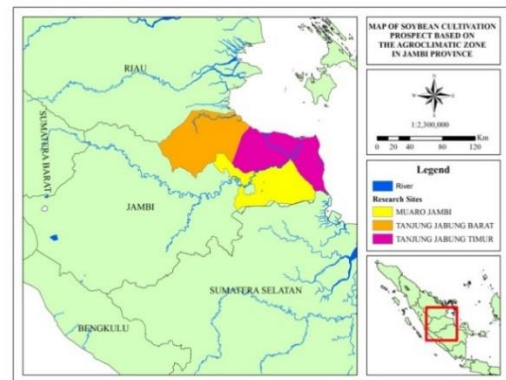


Figure 1 Research Location

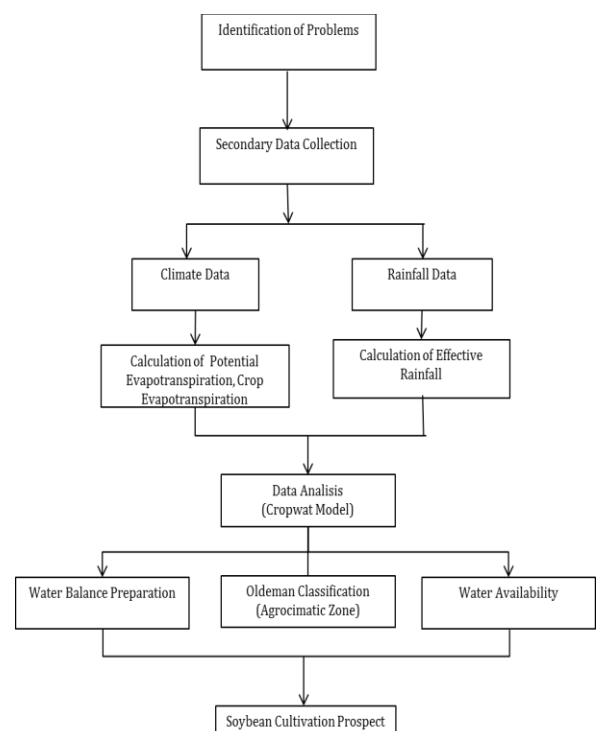


Figure 2 Research Flowchart

## 2.4. Data Analysis

Data analysis was conducted using the Cropwat for Windows 8.0 program which was developed by the Land and Water Development Division of the Food and Agriculture Organization (FAO). Cropwat used the Penman-Monteith (FAO) method in estimating the evapotranspiration and crop water requirements. Cropwat model could be used to calculate the potential evapotranspiration, actual evapotranspiration, the need for irrigation water in mono or multi-cropping pattern.

The calculation stages of water requirements with Cropwat were conducted in two steps. Firstly, Climate data i.e. temperature, humidity data, wind speed, and daily duration of bright sunshine were analyzed to obtain the value of evapotranspiration. Afterwards, the estimated total rainfall value and the monthly effective rainfall were calculated.

## 2.5. Water Balance Calculation

The information about the availability and water requirements of plants in each research place became a reference in the calculation of water balance as a recommendation for soybean cultivation in Muaro Jambi Regency, East Tanjung Jabung Regency, and West Tanjung Jabung Regency. The potential for soybean cultivation in each district can be determined by knowing the ratio between water availability and plant water needs (water balance).

## III. RESULT AND DISCUSSION

### 3.1. Hydrological Condition

Data collection was done directly to the field at the nearest meteorological or rainfall station to

the research location. The location and data availability can be seen in Table 1. The monthly average rainfall data for each district can be seen in Table 2 and climate Data in Jambi Province can be seen in Table 3.

Table 2 shows that rainfall occurs in Muaro Jambi Regency in the ranges from 103.5 mm to 251.1 mm. Maximum rainfall occurs in April and the minimum is in June. The average rainfall in the area of 190 mm per month. The rainfall data is monthly rainfall data from Sultan Thaha station in 2005-2014. The rainfall ranges of East Tanjung Jabung Regency are from 120.2 mm to 262.8 mm with the maximum rainfall in November and the minimum in June. The average rainfall is 192.49 mm per month. The rainfall data uses monthly rainfall data which is obtained from Sungai Durian station in 2004-2015. West Tanjung Jabung Regency shows the rainfall occurring between 113.8 mm to 290.2 mm with maximum rainfall in March and the minimum in September. The average rainfall is 169.23 mm per month. The rainfall data uses the average monthly rainfall data of 2011-2015 which is obtained from Senyerang station.

Table 3 shows the climate data of Jambi province which is collected in the form of minimum and maximum temperature, humidity, wind velocity, and daily bright sunshine duration. The radiation and ETo are the results of the analysis in Cropwat. This data was obtained from Sultan Thaha Jambi station.

**Table 1** Rainfall Station in Jambi Province

Regency	Station	Coordinate			Data Availability (Year)
		Latitude	Longitude	Elevation (msl)	
Muaro Jambi	Sultan Taha	-1.63524	103.64275	28	2005-2014
	Palmerah Jambi	-1.63544	103.6/3917	28	1980-1989
	Depati Parbu	-2.09117	101.46236	4	2005-2014
East Tanjung Jabung	Sungai Durian	-1.15184	104.07829	5	2005-2014
West Tanjung Jabung	Senyerang	-0.82059	103.13779	4	2011-2015

**Table 2** Average Monthly Rainfall Data (mm) of Muaro Jambi Regency, East Tanjung Jabung Regency and West Tanjung Jabung Regency

Month	Muaro Jambi	East Tanjung Jabung	West Tanjung Jabung
January	155.3	174.3	181.8
February	177.0	191.2	257.6
March	230.0	216.4	290.2
April	251.1	240.4	120.4
May	191.6	179.2	121.6
June	103.5	120.2	118.0
July	162.5	138.8	145.0
August	169.7	154.7	114.6
September	139.8	175.3	113.8
October	215.3	215.4	150.6
November	241.1	262.8	223.4
December	250.6	241.2	193.8
Total	2287.5	2309.9	2030.8
Average	190	192.4	169.2

Source: Sultan Thaha Station, Jambi (2005-2014)

**Table 3** Climate Data of Jambi Province (2005-2014)

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Humidity (%)	Wind Velocity (km/day)	Sunshine Hour (Hours)	Radiation (MJ/m <sup>2</sup> /day)	ET <sub>o</sub> (mm/day)
January	23.7	30.6	84	404	3.3	14.2	3.61
February	23.3	31.3	83	337	3.9	15.6	3.68
March	23.2	31.8	84	413	4.2	16.1	3.72
April	23.4	32.8	84	431	4.5	16.0	3.82
May	23.6	32.1	84	395	5.5	16.4	3.48
June	23.5	28.8	83	311	5.3	15.5	3.36
July	22.9	31.7	83	302	5.1	15.5	3.39
August	22.7	32.0	82	297	5.4	16.8	4.02
September	23.0	32.1	81	475	4.7	16.5	4.72
October	23.3	32.1	83	346	3.8	15.3	4.29
November	23.3	31.8	85	355	3.8	15.0	3.99
December	23.3	30.0	85	382	3.0	13.6	3.58
Average	23.3	31.4	83	371	4.4	15.5	3.8

Source: Sultan Thaha Station, Jambi

### 3.2. Agro-Climatological Zone Classification

The agro-climatological zone classification was conducted with the Oldeman classification system. Oldeman classification was based on the number of wet months in succession. The division of climate type of Oldeman in each district can be seen in Table 4.

Tabel 4 shows a climate classification based on precipitation data that occurs in Jambi province. Each of them is included in the classification of climate D1, D2, and E2. East Tanjung Jabung Regency of the Sei Durian station includes in the classification of D1 and West Tanjung Jabung Regency at E1 station includes in the climate classification of E1. If it is viewed from the rainfall, all three districts are fulfilled for soybean cultivation with average rainfall between 127.11 mm - 192.51 mm/month.

### 3.3. Potential Evapotranspiration, Crop Evapotranspiration, and Crop Water Requirement

Evapotranspiration is a combined process between evaporation and transpiration. Evaporation is water that is lost from the soil around plants, leaf surfaces, and water surfaces. Transpiration is water that enters the roots of plants and is used by plants or water that is lost through the leaves into the atmosphere (Hansen, Israelsen, & Stringham, 1979).

The value of the potential evapotranspiration in Jambi province showed in the range of 3.46 mm/day to 4.56 mm/day. Crop water requirements could be described from the fluctuation of potential evapotranspiration distribution (ET<sub>o</sub>). The pattern of ET<sub>o</sub> value in Jambi province is obtained from the climate data in table 3 which is presented in Figure 3.

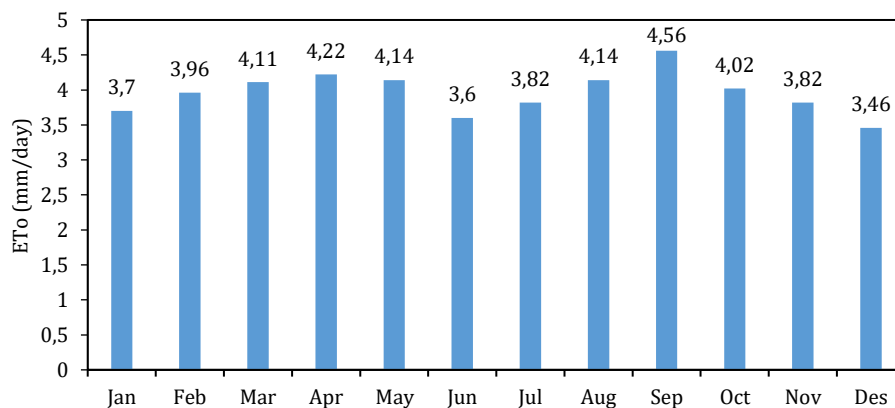
Data on the water requirements of soy plants in Muaro Jambi Regency, East Jabung and West Tanjung Jabung are presented in Table 5. The pattern of distribution of the evapotranspiration of plants (ETc) and the water requirement of soybean in each regency, Muaro Jambi Regency, can be seen in Figure 4, East Tanjung Jabung Regency can be seen in Figure 5, and West Tanjung Jabung Regency can be seen in Figure 6.

It is essential to know the water requirement so that irrigation can be provided efficiently. The right amount of water will stimulate plant growth and increase the efficiency of water use so that it can increase the area of plants that can be irrigated. In designing an irrigation system, crop water requirements are calculated using empirical

estimation methods based on certain formulas (Direktorat Irigasi dan Rawa, 2013; Purba, 2011). The availability of water is a factor that significantly affects water delivery in rice fields. Insufficient water causes imperfect rice growth and can even cause rice to die from drought (Rizal, Alfiansyah, & Rizalihadi, 2014). The amount of irrigation water needs in this field can be verified with the help of a computer model for calculating irrigation water needs, based on the parameters that affect, including planting patterns and schedules, effective rainfall, percolation, efficiency, group, and so on based on the irrigation network planning criteria (Direktorat Irigasi dan Rawa, 2013). One of the models that is easy to use for calculating crop water requirements is the cropwat model.

**Table 4** Climate Criteria of Oldeman in Jambi Province

Regency	Station	Zone	Annual Amount (mm)	Wet Month	Dry Month
Muaro Jambi Regency	Sultan Taha	D1	2,287.77	3	0
Muaro Jambi Regency	Palmerah Jambi	D2	2,112.5	4	3
Muaro Jambi Regency	Depati Parbu	E2	1,525.33	0	2
East Tanjung Jabung Regency	Sei Durian	D1	2,310.13	3	0
West Tanjung Jabung Regency	Senyerang	E1	2,008.8	2	0

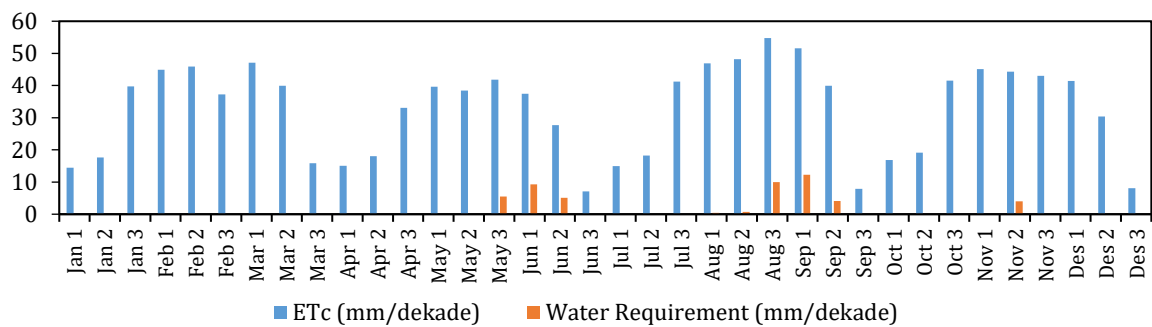


**Figure 3** ETo Value Fluctuations Pattern in Jambi Province

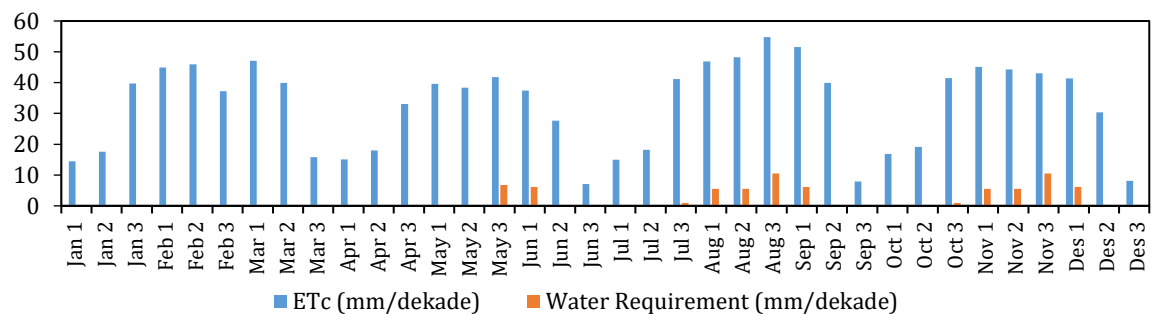
**Table 5** Water Requirements of Soybean Plant in Muaro Jambi Regency, East and West Tanjung Jabung Regency

Month (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Muaro Jambi	0	0	0	0	5.5	14.4	11.1	16.4	0	0	4	0
East Tanjung Jabung	0	0	0	0	6.8	6.1	0.9	21.5	6.1	0.9	21.5	6.1
West Tanjung Jabung	0	0	0	8	42.2	9.9	1.9	49.6	27	0	0	0

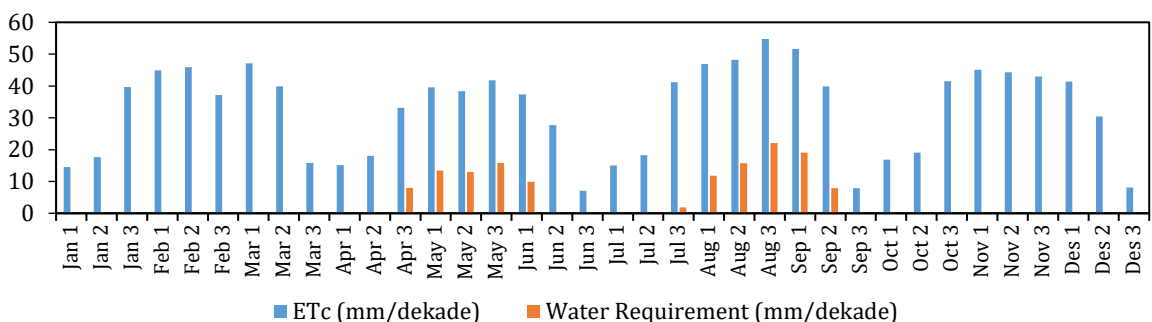
Source: Processing Data using Cropwat



**Figure 4** Comparison of the value of fluctuations ETC and the water requirement of soybean in Muaro Jambi Regency



**Figure 5** Comparison of Fluctuation Value ETC and the Water Requirement of Soybean in East Tanjung Jabung Regency



**Figure 6** Comparison of fluctuation value ETC and the Water Requirement in West Tanjung Jabung Regency

### 3.4. Water Availability

The water availability of each regency in Jambi Province can be found from the monthly rainfall based on Table 2. Water availability in Jambi province and the water requirements of soybean plants from each regency in Muaro Jambi Regency, East Tanjung Jabung Regency, and West Tanjung Jabung Regency can be seen in Table 6. Availability of rainwater is calculated based on precipitation Weibul rain opportunity 80%.

### 3.5. Water Balance Calculation

Water balance is defined as the difference between the amount of water received by plants and the loss of water and soil through evapotranspiration. In the calculation, the water

height unit (mm or cm) is used for all elements. The time unit used can be selected either daily, weekly, decade, monthly or yearly as needed (Munir 2012). The water balance is arranged climatologically and is useful for knowing agroclimatic conditions, especially the dynamics of groundwater content and the use of plant water for planting planning for each cultivar.

The water balance for inputs, outputs and changes in the amount of water deposits in this study is calculated using Cropwat. Water balance in Muaro Jambi Regency, East Tanjung Jabung and West Tanjung Jabung is known by comparing the availability of existing rainwater with water requirements for soybean crop. Water balance is analyzed to determine the surplus and water

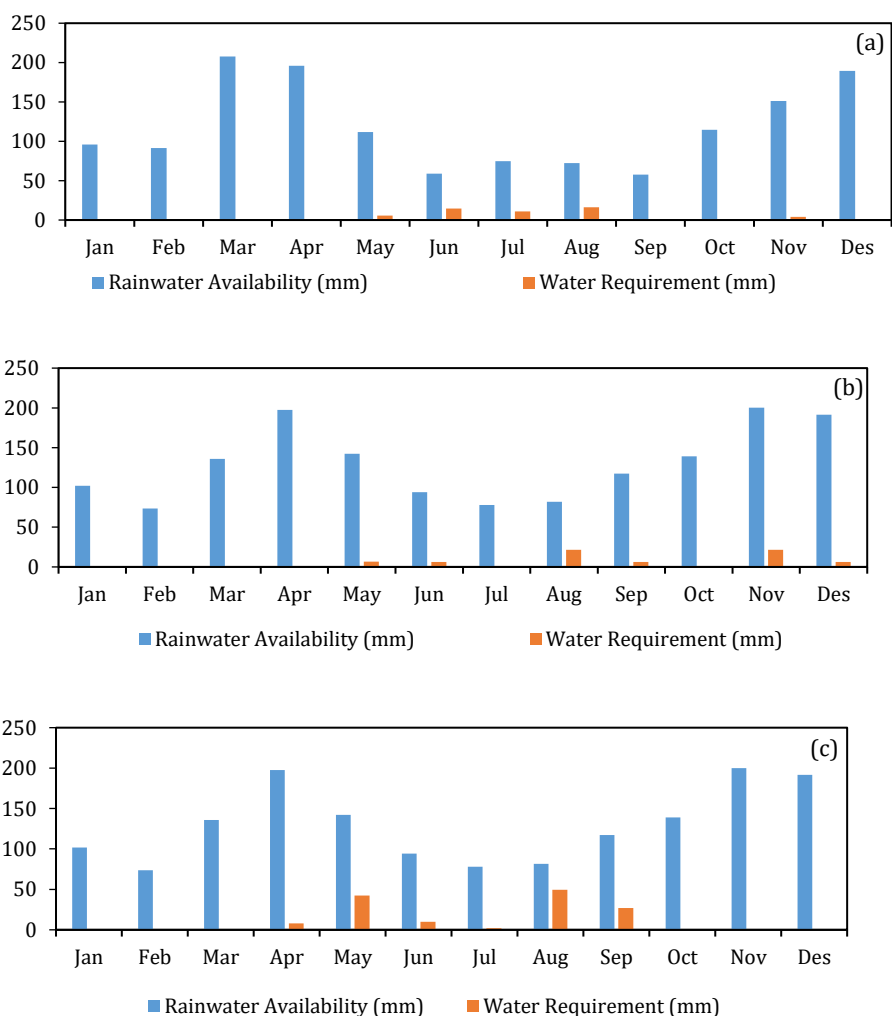
deficit of an area for the cultivation of a commodity and in this research is soy. The comparison between the availability of rainwater

and water requirement of each district in Jambi Province can be seen in Figure 7.

**Table 6** Availability of Raindrops (mm) in Muaro Jambi Regency, East, and West Tanjung Jabung Regency

	Water Availability (mm)		
	Muaro Jambi	East Tanjung Jabung	West Tanjung Jabung
January	95.9	101.84	127.6
February	91.26	73.52	147.2
March	207.6	135.98	179.4
April	195.86	197.54	92.8
May	111.6	142.32	83.8
June	58.76	94.18	62.4
July	74.42	78.02	52.8
August	72.14	81.74	75
September	57.8	117.2	19.8
October	114.74	139.04	51.4
November	151.12	200.12	93.4
December	189.28	191.58	112.6

Source: Data Processing



**Figure 7** Comparison of Rainwater Availability and Water Requirements of Soybean Plant in Muaro Jambi Regency (a); East Tanjung Jabung Regency (b); and West Tanjung Jabung Regency (c)



A comparison of the rainwater availability to crop water requirements may indicate surplus conditions and water deficits for soybean cultivation. The surplus in Muaro Jambi Regency Jambi Province occurs in January, February, March, April, September, October and December. East Tanjung Jabung Regency surplus is in January, February, March and April. Then, West Tanjung Jabung Regency surplus occurs in January, February, March, October, November and December. The best month for cultivating soybeans is in months with surplus water conditions. Plants will get sufficient water needs which will give good yields. Therefore, in months with a water surplus condition, soybean cultivation can be planned in that area. The results of this calculation indicate that Jambi Province has the potential to cultivate soybean plants. With sufficient water, soybean cultivation will give high yields. This result are inline with data from (Pusat Pendidikan dan Pelatihan Sumber Daya Air dan Konstruksi, 2017) which imply that Jambi is one of the areas with a surplus of water availability conditions.

The presence of irrigation infrastructures to deliver water can also help increase crop yields and water use efficiency. Irrigation water use efficiency and evapotranspiration water use efficiency were determined to assess the effectiveness of irrigation on soybean yield. Irrigation enhanced soybean yields from rainfed yield baselines of 4.04 ton/ha in 2007 and 4.82 ton/ha in 2008 (Irmak, Specht, Odhiambo, Rees, & Cassman, 2014).

The potential in soybean cultivation is not only seen from the water balance factor, therefore it is also very important to pay attention to other factors. Daily operations need to be carried out based on observations of plant conditions and actual rainfall to maintain soil moisture content within the appropriate range for plant growth (Susanawati & Suharto, 2018).

#### IV. CONCLUSIONS

Cropwat model is very good and useful to be used in planning water use in agriculture because Cropwat model can estimate the water needs of plants precisely. Cropwat model is able to explain agro-climate zone well because the results of data analysis using this model can predict cropping patterns for soybean cultivation based on crop water requirements and also water availability in an area. Climate classification (Oldeman Classification) based on precipitation data which occurs in Jambi province respectively in Muaro Jambi Regency is included in the classification of climate D1, D2, and E2. East Tanjung Jabung

Regency includes in the classification of D1 and West Tanjung Jabung Regency includes in the climate classification of E1.

The best month for cultivating soybeans is in months with surplus water conditions. Plants will get sufficient water needs which will give good yields. The surplus in Muaro Jambi Regency Jambi Province occurs in January, February, March, April, September, October and December. East Tanjung Jabung Regency surplus is in January, February, March and April. Then, West Tanjung Jabung Regency surplus occurs in January, February, March, October, November and December.

The results of water balance calculations using the cropwat model in several districts in Jambi Province indicate the potential of soybean cultivation because they have sufficient water availability.

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