Cropwat 8.0 Application to Investigate Water Availability for Crops in Nawungan Agricultural Land, Imogiri

Umi Mar Atus Sholihah[1(✉)], Nur Ainun H. J. Pulungan[2], and Fathi Alfinur Rizqi[2]

[1] Student of Soil Department, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia
umisholihah05@mail.ugm.ac.id

[2] Soil Department, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract. The evaluation of water availability is crucial in planning and managing irrigation system. Rainfall is a climatic element having a very important role to provide crop water requirement. However, the amount of rainfall also depends on other climatic factors such as air temperature, humidity, wind speed, and solar radiation. Based on this problem, this study aimed at analysing the temporal pattern of climate factors at the research location and evaluating water availability for irrigation through calculating the reference evapotranspiration (ETo). The descriptive quantitative analysis approach was used. The research carried out by collecting the data through field survey taking primary and secondary data. Data tabulation from Cropwat version 8.0 software was used to analyse water availability from climatic data. The results showed that the reference evapotranspiration (ETo) ranged from 4.28 mm/day to 5.73 mm/day. The peak of ETo is in January to May. The maximum ETo value is in April, while the minimum ETo value is in September. The highest average maximum temperature occurs in November, which is 27.8 °C. The highest average minimum temperature occurred in April at 26.1 °C. The highest solar radiation duration is in November of 12.5 h. The highest wind speed is in November, which is 71 km/day. The highest relative humidity of 88% occurs in January and February. The high monthly rainfall in January is 287.0 mm/month with an effective rainfall of 197.9 mm/month.

Keywords: ETo · evapotranspiration · cropwat · climate · Nawungan

1 Introduction

Water resources are important in the practice of agriculture. This is also regulated in Law No. 17/2019 concerning Water Resources. Water resources are one of the main aspects considered in the development of the agricultural sector [1]. This is because water is a fundamental aspect for plants. Water is needed by plants for photosynthesis [2, 3], growth and development [4, 5], mineral nutrient transport [6].

J. Sumantyo et al. (Eds.): ICoSIA 2022, ABSR 29, pp. 229–241, 2023.
https://doi.org/10.2991/978-94-6463-122-7_20

The main input of water in an area generally comes from rainfall. However, the amount of rainfall also depends on other climatic factors such as air temperature [7, 8], air humidity [7, 8], solar radiation [9, 10], wind speed [7, 11], and air pressure [12]. In Indonesia, agricultural activity is strongly influenced by the amount of rainfall. This is in line with Nganji and Simanjuntak [13] stated that the planning and suitability of cropping patterns is highly dependent on the intensity of rainfall in a particular area. Setting cropping patterns is part of planning agricultural activities to aimed minimizing the risk of crop failure. For example, Rahayu [14] states that to adjust the rainy period, in the rice planting period, short-lived rice varieties can be selected. Nawungan agricultural land has problems in terms of continuity water availability. In fact, the availability of water is one of the factors that determine land productivity, where the main water source is highly dependent on rainfall. Shallots are one of the leading commodities in Nawungan Hamlet and its surroundings. The problem of water availability for shallot farming is a crucial problem in this area. The general rainfall in the Selopamioro area is 1,564 mm/year [15]. According to Idjudin and Marwanto [16], dry land has rainfall ranging from 1200–3000 mm/year. Thus, Nawungan is a dry land area.

The availability of water in an area determines the level of land suitability for the cultivation of certain plants [17]. This is because each crop commodity has different water requirements. Therefore, it is necessary to analyze the climate during the rainy season and during the dry season in order to determine the availability of water during the rainy season and during the dry season and to meet agricultural water needs, especially during the dry season.

CROPWAT is a computer program-based decision support system developed by the FAO's Land and Water Development Division based on the Penman-Monteith method to calculate the crop water requirements and irrigation requirements based on soil, climate, and crop data (FAO, 2022). The Penman-Monteith method recommended by FAO 56 is the method that has the best results in determining the rate of evapotranspiration, compared to other methods [18–23]. CROPWAT application used is expected to be able to analyze climate factors during the rainy season and during the dry season which can then be used to calculate crop evapotranspiration (ETc), reference evapotranspiration (ETo), irrigation water needs for one type of crops or several types of crops. Based on background as described above, this study aims to: (1) analyze the temporal pattern of climate factors at the research location and (2) evaluate water availability based on climatic data in the research location.

2 Methodology

The research is located on the Shallot Farm Area in Nawungan, Imogiri, Bantul Regency, Special Region of Yogyakarta (7°57′46.29″ S, 110°24′42.40″ E). The climate parameters that have been observed in this study are data from the Nawungan Selopamioro Weather Station for 3 years from April 2019–March 2022. The reference evapotranspiration value data and effective rainfall are then compared with various climatic factors or factors that influence it.

2.1 Materials

The tools used are as follows:

1. Computer, used to process data.
2. Microsoft Excel software is used to process climatological data sourced from AWS and NASA POWER Web.
3. CROPWAT 8.0 software, used to process and analyze the data.
4. Calculator, used for data calculation.

2.2 Data Collecting

This research used secondary data as the main source of information to obtain climatological information and the potential for evaporation that occurs. The data needed are as follows:

1. Climatological data, such as air temperature, duration of sunlight, humidity, rainfall, and average wind speed for the periode of 2022, sourced from private Automatic Weather Station (AWS) in Nawungan.
2. Climatological data, such as length of sunlight, rainfall, and average wind speed for the period of 2019–2021, sourced from the Automatic Weather Station (AWS) of the Faculty of Agricultural Technology UGM.
3. Climatological data, such as the average air temperature and humidity for the period of 2019–2021, sourced from online data of NASA POWER.

2.3 Data Analysis

CROPWAT software version 8.0 used to data analysis. The data processing carried out in this software is in the form of the pattern of climate data, ETo (actual evaporation), and the relation between ETo and each of climate parameters (air temperature, duration of sunlight, humidity, rainfall, and average wind speed).

3 Result and Discussion

3.1 Maximum and Minimum Temperatures

The study area has a small annual range of minimum and maximum temperatures. The difference in mean temperature between the warmest and the coldest month is mostly less than 4 °C [24]. This is also illustrated in research [25] regarding temperatures in several cities in the tropics which shows that the minimum and maximum temperatures do have values that are not too much different. The maximum temperature range at the research site ranges from 25–29 °C with an average maximum temperature throughout the year of 27.3 °C and the highest maximum temperature during measurements occurred in November 2019 of 29.14 °C.

The observed average minimum temperature and lowest minimum temperature were 24.68 °C and 23.10 °C in November, respectively. The minimum temperature range is

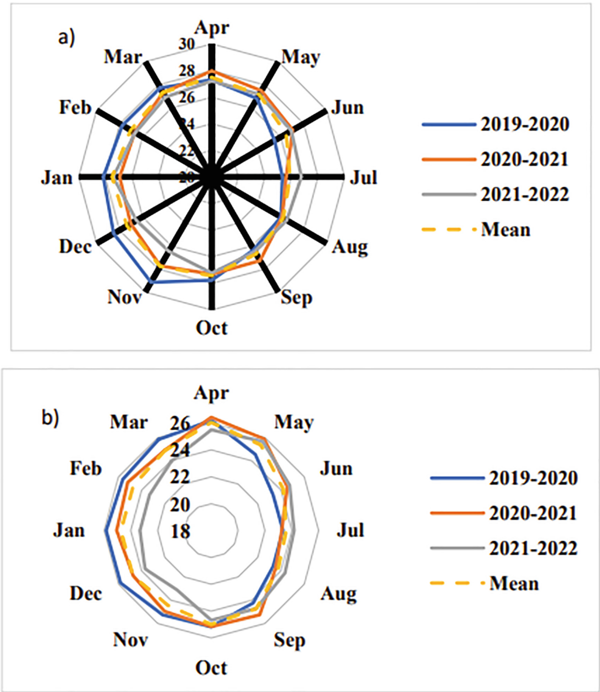

Fig. 1. (a) Maximum and (b) Minimum temperature from April 2019 to March 2020 in the study area

between 23–26 °C. In the tropics, the temperature doesn't change much along the year [26]. The minimum and maximum temperatures, with an average value of temperature in the study area for a period of three years between April 2019 and March 2022, are shown in Fig. 1.

3.2 Humidity

The study area is generally characterized by a relative constant humidity (Fig. 2). There is no significant differences of humidity during a year. The maximum average air humidity is (88%) and the minimum average air humidity is about 77%. Air humidity in the tropics is relatively high, can reach 90%. Thirakomen [27] stated that in the tropical climate, humidity stays high most of the time. The high humidity phenomenon is in line with high temperature in the tropics. The tropical mean humidity increases with temperature [28]. This is in line with Sobel's [26] research that the higher the temperature, the more water to evaporate into the air, as an impact the atmosphere becomes very humid.

3.3 Sunshine

Sunshine hour is also the main parameter used for estimation of evaporation. Mostly, tropics has a constant sunshine hour which is 12 h/day. In further, the sun shines more

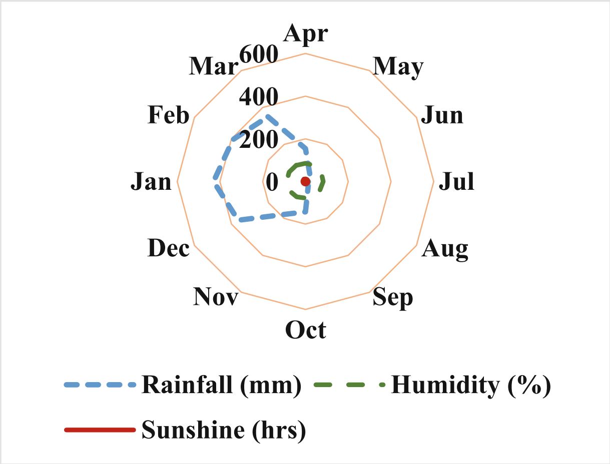

Fig. 2. Monthly rainfall, humidity, and sunshine hours in the study area

directly on the tropics than on higher latitudes that causes the tropics warm [29]. As a consequence, the pattern of sunshine hour affects significantly to the pattern of humidity along the year as shown in the Fig. 2.

3.4 Rainfall

The rainfall pattern over the study area shows the dominant rainfall occurred in the period of wet season (December to March), with a high rainfall average of 350 mm to 430 mm monthly. However, Tropics is characterized with rain occurred all the year [24] even though the intensity is getting lower during the dry season. The variability of rainfall in Indonesia is highly dependent on the variability of the monsoon and the movement of the ITCZ [30]. The respective data on air humidity, sunshine hours, and rainfall in the study area are shown in Fig. 2.

3.5 Relation of ETo with Climate Parameters

Reference evapotranspiration or ETo is the amount of evapotranspiration with an unlimited amount of available water to meet the optimum growth of the reference crop surface that grows with sufficient irrigation [31]. The current method of estimating the evapotranspiration rate can be determined by various evapotranspiration methods [32]. However, the most widely applied evapotranspiration method is the Penman-Monteith method [23], as developed in the CROPWAT model. This has been proven by many studies that use the Penman-Monteith method in measuring reference evapotranspiration rates such as Steduto et al. [18] tested the Penman-Monteith method in the southern part of Italy which has a semi-arid Mediterranean climate with the results showing that this method is the best in predicting daily evapotranspiration rates, Temesgen et al. [20] also tested the Penman-Monteith method in California, USA which was measured at 37 climate stations in this region and the results showed a good correlation with evapotranspiration

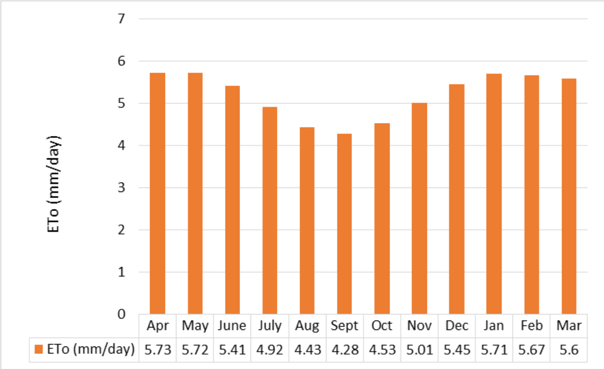

Fig. 3. The reference evapotranspiration (ETo) from April 2019 to March 2022

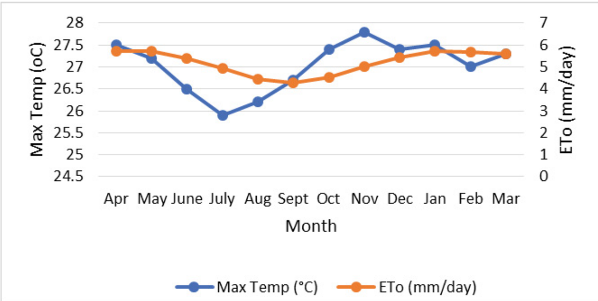

Fig. 4. ETo VS maximum temperature from April 2019 to March 2022

rates; also reinforced by Saidah et al. [22] where the Penman-Monteith method is used as a calibration against the Thornthwaite equation and Evaporation Pan for a limited area in Indonesia.

There are three data required for CROPWAT analysis to measure irrigation water requirement, i.e. climatic data, soil data, and crop data. In specific, climatic data is important to analyze the reference evapotranspiration (ETo) of the study area. Climatic data needed include humidity, minimum and maximum temperature, wind speed, rainfall, and sunshine hours.

Based on the results of Cropwat 8.0's analysis of climatological data from April 2019 to March 2022, it shows that the ETo value is volatile, with the peak of the graph being in January to May. The reference evapotranspiration (ETo) was calculated from the Penman–Monteith equation. The reference evapotranspiration ranged from 4.28 mm/day to 5.73 mm/day (Fig. 3). The mean reference evapotranspiration (ETo) is 5.21 mm/day with a total annual ETo of 62.46 mm/day. The maximum ETo value is in April, which is 5.73 mm/day, while the minimum ETo value is in September, which is 4.28 mm/day. Fibriana et al. [21] stated that the rate of evapotranspiration is strongly influenced by factors of temperature, solar radiation, and wind speed.

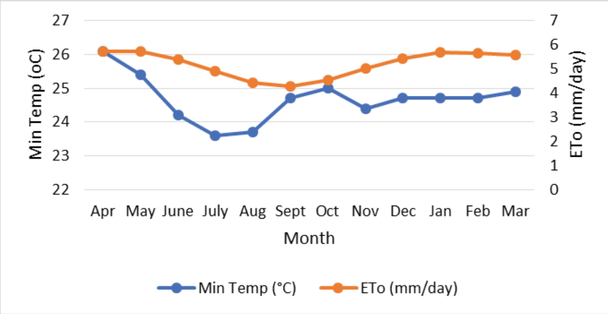

Fig. 5. ETo VS minimum temperature from April 2019 to March 2022

The graph of the relationship between the value of ETo and the maximum temperature shows a relatively uniform pattern (Fig. 4). The highest average maximum temperature occurred in November at 27.8 °C, followed by an increase in the ETo value from the previous month to 5.01 mm/day. The graph of the evapotranspiration value tends to move with changes in the maximum temperature. This concludes that the temperature and ETo values have a straight comparison. In addition, Safitri [33] states that for tropical areas where the temperature is relatively high, the daily average ETo value will range from 5–7 mm/day (see Fig. 5).

The graph of the relationship between the ETo value and the minimum temperature shows a relatively uniform pattern, although it is not as significant as the maximum temperature pattern. Almost all the decrease and increase in the minimum temperature was followed by a decrease and increase in the value of ETo (Fig. 5). The ETo value moves following the fluctuations in the minimum temperature value where the lowest minimum average temperature occurs in July at 23.6 °C followed by a decrease in the ETo value from the previous month to 4.92 mm/day. The highest average minimum temperature occurred in April of 26.1 °C followed by the highest ETo value of 5.73 mm/day. It was observed that ETo is higher starting from the transition period of wet into dry season (January-February). It is due to the high temperature. It then decreases in the transition period of dry into wet season (June-July) due to the low temperature. A decrease in temperature accompanied by an increase in relative humidity can result in a decrease in evapotranspiration [34].

The value of ETo and the duration of solar irradiation has a directly proportional relationship. The longer the sunshine in a day, the higher the ETo value in the area, and vice versa. Further, it was seen that an increase in radiation value brings an increase in the ETo value, with the direct relation shown in Fig. 6. The annual mean ETo was calculated as 7.49 mm. The low relative humidity, high temperatures, and high wind increased evapotranspiration during the dry season [31]. The differences in ETo values reflect the variation in weather parameters in the study area. The average length of sunshine in a day is 12.2 h with the highest value being in October and November of 12.5 h with an increase in ETo in the previous month, while the lowest value is in June of 11.7 h followed by a decrease in ETo from the previous month which is 5.41 mm/day (see Fig. 7).

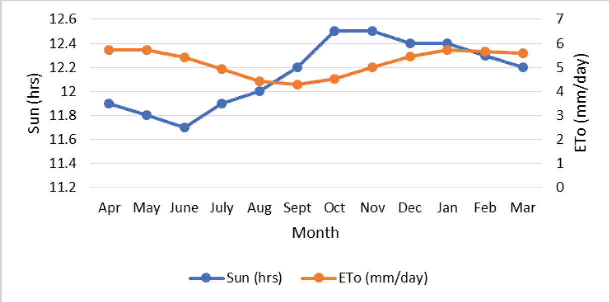

Fig. 6. ETo VS sunshine duration from April 2019 to March

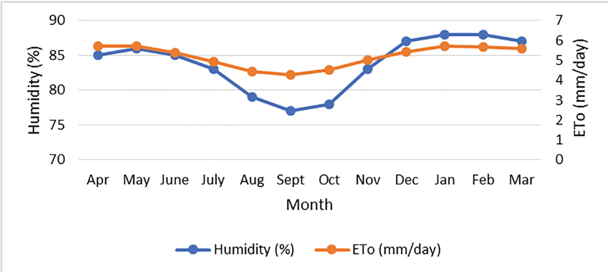

Fig. 7. ETo VS relative humidity from April 2019 to March 2022

Based on the graph above, the relative humidity value has a uniform pattern with the ETo value. When the relative humidity had the highest value of 88% which occurred in January and February, the ETo value also increased to 5.71 and 5.67 mm/day. Meanwhile, the lowest value occurred in September at 77%, followed by a decrease in the lowest ETo value at 4.28 mm/day. This is not in accordance with the theory, where basically low relative humidity can lead to an increase in evapotranspiration during the dry season of the year [3]. Conversely, if the relative humidity value is high, the air will become saturated with water vapor so that the air temperature will decrease and the evapotranspiration rate will also decrease or even stop [35]. The increase in the value of evapotranspiration when the relative humidity value is high indicates that what affects the ETo value is not only relative humidity but also wind speed (Fig. 8), temperature (Figs. 4 and 5), and duration of sunlight (Fig. 6).

Based on the graph above, the relative humidity value has a uniform pattern with the ETo value. When the relative humidity had the highest value of 88% which occurred in January and February, the ETo value also increased to 5.71 and 5.67 mm/day. Meanwhile, the lowest value occurred in September at 77%, followed by a decrease in the lowest ETo value at 4.28 mm/day. This is not in accordance with the theory, where basically low relative humidity can lead to an increase in evapotranspiration during the dry season of the year [3].

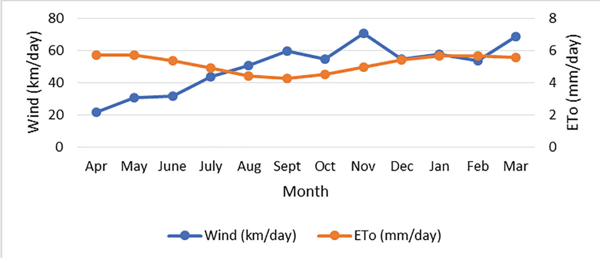

Fig. 8. ETo VS wind speed from April 2019 to March 2022

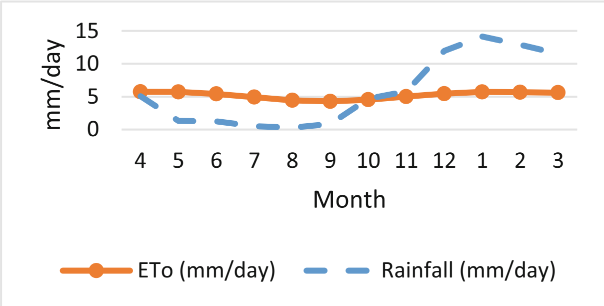

Fig. 9. ETo VS rainfall from April 2019 to March 2022

On the other hand, if the relative humidity value is high, the air will become saturated with water vapor so that the temperature variation of the wind speed value is inversely proportional to the ETo value. The picture above shows the higher the wind speed value, the lower the ETo value is. The Nawungan area has an average wind speed of 50 km/day and has the lowest value in April of 22 km/day in which month ETo occurs with the highest value of 5.73 mm/day. The highest wind speed is in November, which is 71 km/day. The Nawungan area can be said to have a humid climate based on FAO guidelines No. 56/1990 which describes an area as having a humid climate if the relative humidity is high, ranging from 45–70%, but the wind speed is low below 1 m/s [31]. Fig will decrease and the rate of evapotranspiration will also decrease or even stop [35]. The increase in the value of evapotranspiration when the relative humidity value is high indicates that what affects the ETo value is not only relative humidity but also temperature, wind speed, and duration of sunlight.

Based on Fig. 9, the graph shows a linear relationship between actual rainfall and ETo. During the wet season in December–March, the ETo increased almost constant. High rainfall in the wet season is able to supply the water needs for evapotranspiration or even exceed it. Excess rainfall, according to Adiningrum [31], tends to fill soil moisture and becomes a water surplus. During the dry season, excess rainfall in the previous wet season will affect the ET value more than the rain that occurs during the dry season itself [36]. This concludes that soil moisture during the dry season can be maintained and sufficient to keep the ET rate equal or even higher than the rainy season. This is

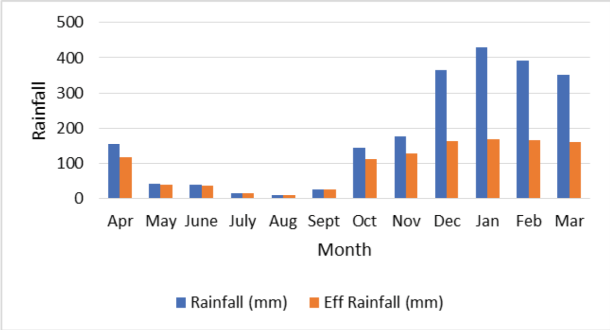

Fig. 10. Rainfall VS effective rainfall from April 2019 to March 2022

consistent with the graph for the dry month in May–September which has almost the same ETo value during the wet season. Zhao et al. [37], explained that evapotranspiration is responsible for about 50% of the annual rainfall in humid areas.

Effective rainfall has a uniform pattern with monthly rainfall (Fig. 10). The total rainfall for the last 3 years that has been observed is 2136.9 mm and the effective rain is 1127.6. Effective rain is the amount of rainfall that can be absorbed and utilized effectively by plants to meet the crop water requirement [38]. Based on the graph above, the months of December–March have high rainfall, with the peak of rainfall occurring in January. High monthly rainfall in January of 287.0 mm/month resulted in an effective rainfall of 197.9 mm/month, while the minimum monthly rainfall occurred in August of 66.0 mm/month with an effective rainfall of 46.2 mm/month. The total effective rainfall is 1062.10 mm/year.

The large difference between rainfall and effective rain in months with high rainfall indicates a lack of effective use of water in agriculture due to high rainwater losses such as run-off. Meanwhile, in months with low rainfall, the difference between rainfall and effective rain is relatively small, which means that the use of rainwater for agricultural activities will be more effective. The calculation of effective rainfall for input into the Cropwat program uses the average rainfall data of R80% per month [23]. Moreover, the gap of actual rainfall and effective rain is potential to be stored in water harvesting activities.

Rainfall is a climatic element that very important role to provide crop water requirement. The temporal distribution of rainfall will affect the appropriate commodities to be applied as an effort to increase agricultural production. Especially since the territory of Indonesia has two seasons, the temporal distribution of rainfall will greatly affect the application of cropping patterns [39]. The temporal distribution of rainfall or rainfall patterns in a year can be determined using the criteria of wet months and dry months according to the Oldeman Classification. The pattern of rain data can help on regulating cropping patterns and the water management in Nawungan area.

4 Conclusion

Climatic factors have a strong influence on the formation of the peak of the reference evapotranspiration (ETo). The most controlling climatic factors were maximum temperature, solar radiation, and wind. It was supported based on the results of research the Penman-Monteinth method through Cropwat 8.0 software that:

1. Each climate factor has a different effect on the formation of the reference evapotranspiration (ETo).
2. The reference evapotranspiration (ETo) shows a uniform annual pattern with maximum temperature, minimum temperature, solar radiation, humidity, and wind factors. Variation in pattern occurs in the relationship of the reference evapotranspiration (ETo) to rainfall.
3. The study area has the minimum and maximum temperature that are not too much different, the high values of humidity in line with high temperature and in line with a humid climate with medium to high rainfall.

Acknowledgments. We would like to thank to Matching Fund Grant 2022, for the research opportunity and research funding support.

References

1. Noer H 2011 optimalisasi pemanfaatan sumberdaya air melalui perbaikan pola tanam dan perbaikan teknik budidaya pada sistem usahatani Indonesian Journal of Agricultural Economics (IJAE) 2 ISSN 2087–409X
2. Zlatev Z and Lidon F C 2012 An overview on drought induced changes in plant growth, water relations and photosynthesis Emirates Journal of Food and Agriculture 24
3. Astutik D, Suryaningndari D, Raranda, U 2019. Hubungan pupuk kalium dan kebutuhan air terhadap sifat fisiologis, sistem perakaran dan biomassa tanaman jagung (Zea mays). J. Citra Widya Edukasi 11 pp 67–76
4. Turner N C and Burch G J 1983 The Role of Water in Plants, Chapter 3: Crop Water Relations, Editors: Iwan Teare and Mary Peet, John Wiley and Sons pp 73–126
5. Ahanger M A, Moradtalab N, Allah E F A, Ahmad P 2016 Plant growth under drought stress: significance of mineral nutrients Water Stress and Crop Plants: a sustainable approach 2 pp 649–668 https://doi.org/10.1002/9781119054450.ch37
6. Zunzunegui M., Díaz-Barradas M C, Jáuregui J, Rodríguez H, Álvarez-Cansino L 2016 Season-dependent and independent responses of Mediterranean scrub to light conditions Plant Physiology and Biochemistry 102 pp 80–91 https://doi.org/10.1016/j.plaphy.2016.02.004
7. Rohmana S F, Rusgiyono A, Sugito S 2019 Penentuan factor-faktor yang mempengaruhi intensitas curah hujan dengan analisis diskriminan ganda dan regresi logistic multinominal (studi kasus: data curah hujan Kota Semarang dari stasiun meteorology Maritim Tanjung Emas periode Oktober 2018 – Maret 2019) J. Gaussian 8 pp 398–406 https://doi.org/10.14710/j.gauss.v8i3.26684

8. Azkia M W A, Hitayuwana N, Khusna Z A, Widodo E 2019 Analisis temperature dan kelembaban terhadap curah hujan di Kabupaten Sleman Provinsi Daerah Istimewa Yogyakarta Prosiding Konferensi Nasional Penelitian Matematika dan Pembelajarannya (KNPMP) IV
9. Zhao J, Yan-Ben H, Zhi-An L 2003 The effect of solar activity on the annual precipitation in the Beijing Area Journal of Beijing Normal University (Natural Science) 35
10. Hiremath K M 2005 Influence of solar activity on the rainfall over India Astrophysics Journal 27 pp 367–372.
11. Simbolon C D L, Ruhiyat Y, Saefullah A 2022 Analisis arah dan kecepatan angin terhadap sebaran curah hujan di Wilayah Kabupaten Tangerang J. Teori dan Aplikasi Fisika 10
12. Ardhitama A 2013 simulasi prakiraan jumlah curah hujan dengan menggunakan data parameter cuaca (study kasus di Kota Pekanbaru tahun 2012) Jurnal Sains & Teknologi Modifikasi Cuaca 14 p 111–117
13. Nganji M U and Simanjuntak B H 2020 Penentuan pola tanam tanaman pangan berdasarkan neraca keseimbangan air di Kecamatan Umbu Ratu Nggay Barat, Kabupaten Sumba Tengah, Provinsi Nusa Tenggara Timur **Jurnal Ilmiah Teknologi Pertanian Agrotechno** 5 pp 67–75 ISSN 2548–8023. https://doi.org/10.24843/JITPA.2020.v05.i02.p04
14. Rahayu S P 2011 Pola curah hujan menentukan pola tanam padi, BB Litbang Sumberdaya Lahan Pertanian, Bogor 2007, Agroklimat dan Hodrologi, 2009, Balai Besar Litbang Sumberdaya Lahan Pertanian, Badan Litbang Pertanian Jurnal Tanah dan Iklim
15. Kurniawan R 2020 Analisis neraca air pada lahan sirsak (Annona muricata l.) dengan pemanen air hujan di Kebun Buah Nawungan, Desa Selopamioro, Kecamatan Imogiri, Kabupaten Bantul (Doctoral dissertation, Universitas Gadjah Mada).
16. Idjudin A A and Marwanto S 2008 Reformasi pengelolaan lahan kering untuk mendukung swasembada pangan Jurnal Sumberdaya Lahan 2
17. Lestiana H, Mulyono A, Maria R, Mulyadi D 2019 Kesesuaian lahan berdasarkan indeks konservasi secara spasial di DAS Ciasem Hulu, Subang Limnotek: perairan darat tropis di Indonesia 26
18. Steduto P, Todorovic M, Caliandro A, Rubino P 2003 Daily reference evapotranspiration estimates by the penman monteith equation in Southern Italy constant vs. variabel canopy resistance J. Theor. Appl. Climatol 74 pp 217–225
19. Berengena J and Gavilán P 2005 Reference evapotranspiration estimation in a highly advective semiarid environment Journal of Irrigation and Drainage Engineering 131 pp 147–163
20. Temesgen B, Eching S, Davidoff B, Frame K 2005 Comparison of some reference evapotranspiration equations for California. Journal of Irrigation and Drainage Engineering 131 pp 73–84
21. Fibriana R, Ginting Y S, Ferdiansyah E, Mubarak S 2018 Analisis besar atau laju evapotranspirasi pada daerah terbuka Agrotekma 2 pp 130–137
22. Saidah H, Sulistyono H, Budianto M B 2020 Kalibrasi persamaan thornthwaite dan evaporasi panci untuk memprediksi evapotranspirasi potensial pada daerah dengan data cuaca terbatas J. Sains Teknologi &Lingkungan 6 pp 72–84
23. Adlan, Setiawan B I, Arif C, Saptomo S K 2021 Evaluasi metode pendugaan laju evapotranspirasi standar (ETo) menggunakan bahasa pemograman visual basic microsoft excel di Kabupaten Nagan Raya Aceh Jurnal Teknik Sipil dan Lingkungan 06 pp 35–48 https://doi.org/10.29244/jsil
24. Trewin B 2014 The Climates of the Tropics and How they are changing, Report, State of the Tropics (Australia: James Cook University)
25. Marcotullio P J, Keßler C, Quintero G R, Schmeltz M 2021 Urban growth and heat in tropical climates J. Front Ecol 9 p 616626 https://doi.org/10.3389/fevo.2021.616626
26. Sobel A H 2012 Tropical weather Nature Education Knowledge 3 p 2
27. Thirakomen K 2001 Humididty Control for Tropical Climate (Thailand: Ashrae)

28. Sun D and Oort A H 1995 Humidity-Temperature relationships in the tropical troposphere Journal of Climate 8 pp 1974–1987 https://doi.org/10.1175/1520-0442(1995)008<1974:HRITTT>2.0.CO;2
29. Stevens A 2011 Introduction to the basic drivers of climate Nature Education Knowledge 2
30. Hermawan E 2010 Pengelompokkan pola curah hujan yang terjadi di beberapa kawasan P. Sumatera berbasis hasil analisis teknik spektral Artikel Puslitbang 11 p 169
31. Adiningrum C 2015 Analisis perhitungan evapotranspirasi aktual terhadap perkiraan debit kontinyu dengan Metode Mock J. Teknik Sipil 13 pp 135–147
32. Runtunuwu E and Kondoh A 2008 Assessing global climate variability under coldest and warmest periods at different latitudinal regions Indonesian Journal of Agricultural Science 9 pp 7–18
33. Safitri, L 2019 Manajemen irigasi pembibitan sawit (Elaeis guineensis) presisi dengan Cropwat 8.0. J.of Agricultural Engineering 8 pp 97–106
34. Onyancha D M, Gachene C K K, Kironchi G 2017 FAO-CROPWAT model-based estimation of the crop water requirement of major crops in Mwala, Machakos County Research Journal's Journal of Ecology 4
35. Yustiana F dan Sitohang G A 2019 Perhitungan evapotranspirasi acuan untuk irigasi di Indonesia RekaRacana: Jurnal Teknil Sipil 5 p 39
36. Silva R O, Souza E B, Tavares A L, Mota J A, Ferreira D, Souza-Filho P W, Rocha E J D 2017 Three decades of reference evapotranspiration estimates for a tropical watershed in the eastern Amazon Anais da Academia Brasileira de Ciencias 89 pp 1985–2002
37. Zhao L, Xia J, Xu Cy, Wang Z, Sobkowiak L, Long C 2013 Evapotranspiration estimation methods in hydrological models J Geogr Sci 23 pp 359–369
38. Prastowo D R, Manik T K, Rosadi R A B 2015 Penggunaan model cropwat untuk menduga evapotranspirasi standar dan penyusunan neraca air tanaman kedelai di Dua Lokasi Berbeda Jurnal Fakultas Pertanian Universitas Lampung 5 pp 1–12
39. Sarvina Y 2019 Climate change impact and adaptation srategy for vegetable and fruit crops in the Tropic Region Jurnal Penelitian dan Pengembangan Pertanian 38 pp 65–76.