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Estimation of the Reference Evapotranspiration in Sumbawa District, West Nusa Tenggara, Indonesia

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***Abstract* – The study aimed to estimate the reference evapotranspiration (ETo) using the Cropwat Model. The Cropwat Model is a Penman-Monteith Model (FAO 56-PM) as a method for determining ETo with monthly meteorological data input from 2005-2016 in Sumbawa District. Results showed that the minimum and maximum ETo values fluctuated around 3.04-4.17 mm/ day. The highest values were observed in September and the lowest in February. The value of ETo in Sumbawa Regency fluctuated during the period 2005-2016.**

***Keywords* – Evapotranspiration, Penman-Monteith, Water Management, Agriculture.**

I. Introduction

Evapotranspiration (ET) included evaporation and transpiration processes in atmospheric system [1]. Understanding the evapotranspiration mechanism is essential in efficient irrigation management based on ecosystem models [2] [3]. Evapotranspiration of reference plants (ETo) is an important agrometeorological parameter for hydrological studies, for planning and management of irrigation [4], these ETo values reflect the impact of atmospheric evaporative capacity on crop water requirements in different regions and periods, and are strongly associated with local weather conditions [5][6].

The ETo is difficult to observe directly because it depends on several meteorological parameters observed at the main climatic station [7], has dependence on weather data and climate types [8] [9] [10] [11]. "Cropwat for Windows" is an application program that uses the Penman-Monteith Model in the evapotranspiration of reference crops and plant water requirements (Etm) and irrigation needs [12].

The Penman-Monteith Model (FAO 56-PM) as a method for determining ETo [13] [14] [15]. The FAO 56-PM method integrates climate variables including temperature, solar radiation, relative humidity and wind velocity that may be affected by climate change [16].The results of [17] suggest that the use of plant water is estimated by multiplying the reference evapotranspiration with the specified plant-specific coefficients. Evapotranspiration sensitivity analysis is a way to improve understanding of the relationship between climatic conditions and ETo variability, and identification of predominant climatic variables in estimating evapotranspiration [18]. The study aimed to estimate the reference evapotranspiration using Cropwat Model in Sumbawa District which was used for irrigation scheduling in order to increase the production of food crops.

II. Materials and Method

The study was conducted in Unter Iwes Sub-district, Sumbawa District, West Nusa Tenggara Province (NTB), Indonesia. Geographically, it is in a position of 8°32.5.5 'LS to 8°32.315' LS and 117°24.51.8 'BT to 117°26.312' BT. This research was conducted in March 2015-December 2017, in Unter Iwes Sub-district, Sumbawa Regency, West Nusa Tenggara Province, Indonesia. The data used in the research are meteorological data covering the maximum temperature, minimum temperature, relative humidity, wind speed and sunshine data collected for the period of 2005-2016 from Center of meteorology, climate and meteorology (BMKG) of Sumbawa district.

Estimates of evapotranspiration were analyzed using FAO-PM in Cropwat 8.0 model. FAO-PM is the standard method for estimating reference evapotranspiration, requiring climatic variables such as temperature, radiation, wind speed and relative humidity [19]. The temperature data is expressed in celcius (˚C), humidity in percent (%), wind velocity (m^{-1} s), and long solar irradiance (hours). All parameters were analyzed using Cropwat 8.0 model (Table 1). The calculation formula for evapotranspiration of reference plants by the Penman-Monteith method is [20] in Cropwat 8.0:

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \dfrac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where ET0 = reference evapotranspiration (mm/day), Rn = net radiation at the crop surface (MJ·m−2·day−1), G = soil heat flux density at the soil surface (MJ·m−2·day−1), T = mean daily air temperature at 2 m height (˚C), u_2 = wind speed at 2 m height (m·s−1), es = saturation vapor pressure (kPa), ea = actual vapor pressure (kPa), $e_s - e_a$ = saturation vapor pressure deficit (kPa), Δ = slope of saturation vapor pressure versus air temperature curve (kPa·˚C−1) and γ = psychometric constant (kPa·˚C−1).

II. Results and Discussion

Estimated evapotranspiration (ETo) estimates were estimated using the Cropwat model with climatological data input, consisting of maximum and minimum temperatures, relative humidity, wind speed, solar radiation (Figure 1).

Estimates of reference evapotranspiration (ETo) from meteorological data using Penman Monteith model requires maximum and minimum temperature parameters, relative humidity, wind speed and solar radiation and solar radiation duration [21] [22] [23]. Penman-Monteith (ETo FAO-PM) has been recommended by FAO for standard methodology in all climatic variability [19] [24], integrated in climatic variable : temperature, solar radiation, humidity and wind speed [16]. Overall increases in ETo occurrence beginning in January and declining in November (Figure 2). Increased ETo occurs in January-May, ranging from 3.04-4.03 mm mm / day, then in June down (3.93 mm / day) and in July increased to a maximum in September (4.17 mm / day). The increase in ETo values during March-September is explained by changes in temperature, humidity, wind speed, solar irradiance and radiation. Temperature inflated in March and peaked in October (36.5 ^{0}C), followed by long sunshine exposure.

The longest sunshine occurred in September (7.6 hours). Average annual temperatures show an increasing trend, and relative humidity has decreased. Wind speed is slightly stable at first, then fluctuates downward and fluctuates up and high value, then decreases. The duration of solar radiation fluctuates up and high value, then falls following the trend with radiation and ETo trends. There is linear correlation between ETo and meteorological factor [25] [26] [27] [28] [29] [30].

Decreased humidity occurred in January-September with the lowest humidity value (68%), and highest humidity (86%) with moisture increase occurred in November-February. Variations in solar radiation and temperature have a sensitivity to evapotranspiration [31].The estimate results show that the minimum and maximum ETo values fluctuate around 3.04 and 4.17 mm / day. The highest values were observed in September and the lowest in February. The value of ETo fluctuated during the period 2005-2016. Temperature variables, solar irradiance, wind speed, and solar radiation are the main climatic variables affecting ETo in Sumbawa district.

Estimates of evapotranspiration are important by measuring temperature or solar radiation during summer rather than winter [32]. Wind speed parameters, and solar radiation are sensitive parameters in calculating ETo [33].Temperatures are more sensitivity during summer than during winter [34].

Evapotranspiration has been used to identify areas susceptible to drought, and is an important area of climate-related research [35], primarily to estimate the need and support of irrigation and drought scheduling plant water supply [36], can provide the required informations in decision making in the planting calendar [37].

Similar findings were also found in previous studies in various research sites [38] [39] [40] [41] [42]. Reduced duration of solar irradiance, wind speed causes a decreasing trend of ETo. Evapotranspiration is more sensitive to each variation of solar radiation, maximum temperature and wind speed [43] [44]. Maximum temperature and solar radiation are FAO-PM ETo in the Senegal River Delta. Wind speeds in semi-arid climates are highly sensitive to evapotranspiration changes [45] [46] [47].

IV. Conclusion

The main climate variables affecting ETo in Sumbawa District are temperature, wind speed, and solar radiation. Reduced duration of solar radiation, wind speed causes a decreasing of ETo.

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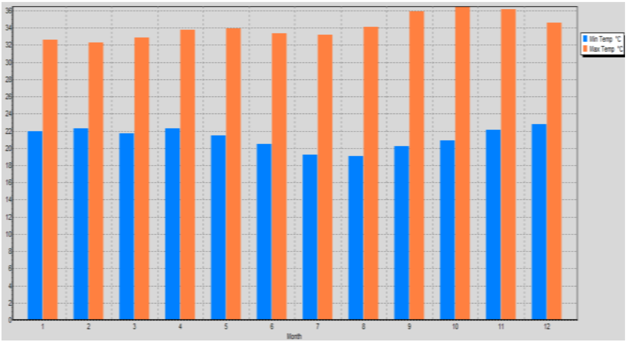
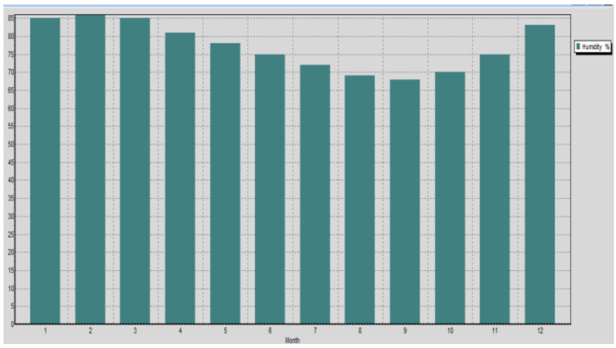
Table 1. Estimation of ETo FAO-PM Period Year 2005-2016 in Sumbawa District

Month	Min Temp(°C)	Max Temp(°C)	Humidity (%)	Wind (km)	Sun (hours)	Rad (MJ/m2/day)	ETo (mm/day)
Jan	22.0	32.6	85	10	4.5	14.6	3.04
Feb	22.3	32.3	86	10	5.1	16.4	3.39
Mar	21.7	32.9	85	10	4.6	16.4	3.44
Apr	22.3	33.8	81	8	6.0	18.7	3.91
May	21.5	33.9	78	8	6.9	19.6	4.03
Jun	20.5	33.4	75	10	7.2	19.6	3.93
Jul	19.2	33.2	72	10	7.2	19.7	3.86
Augt	19.1	34.1	69	11	7.5	20.7	4.02

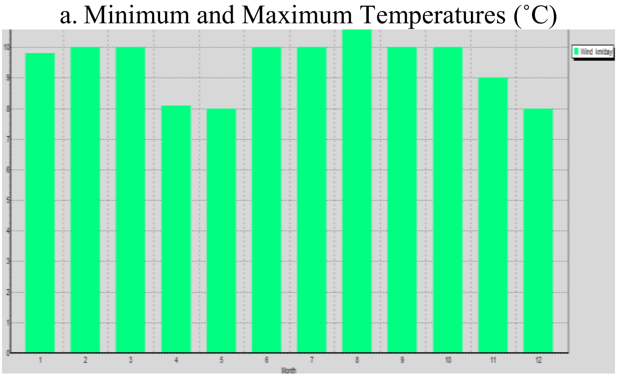
Sept	20.2	35.9	68	10	7.6	21.0	4.17
Oct	20.9	36.5	70	10	7.5	20.1	4.07
Noc	22.1	36.2	75	9	6.8	18.0	3.71
Dec	22.8	34.6	83	8	5.2	15.2	3.23
Average	21.2	34.1	77	9	6.3	18.3	3.73



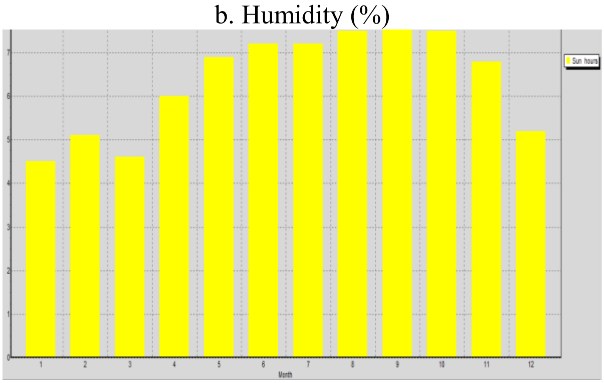
a. Minimum and Maximum Temperatures (˚C)



b. Humidity (%)



c. Wind speed ($m^{-1}\cdot s$)



d. Solar Radiation (hours)

Figure 1. Variable Climate Variable Using Cropwat 8.0 Model

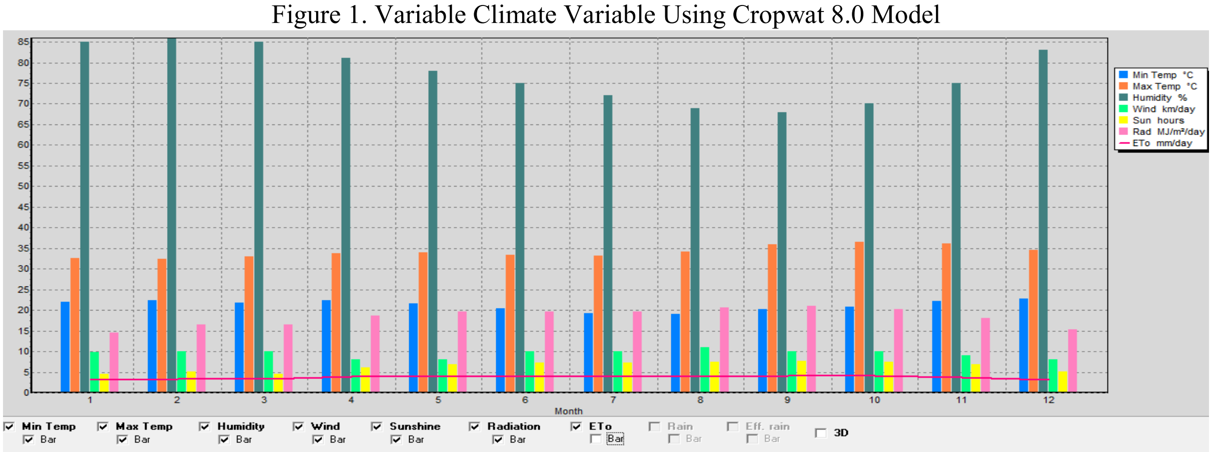


Figure 2. Graph of Climate Variables and Value of ETo Period Year 2005-2016

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