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Crop coefficient and water requirement for oil palm (*Elaeis guineensis* Jacq.) on the nursery based on radiation evaporation method

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Abstract. Water requirements of oil palm close to crop evapotranspiration (ET_c). The objectives of this research were to know the value of crop coefficient for the age of oil palm 4, 5 and 6 month and predicted water requirements of oil palm based on net radiation evaporation method. The result showed the value of oil palm for 4, 5, and 6 months were 0.50, 0.52, and 0.54. The value of reference evaporation (net radiation, ET_o) range 2.89-4.25 mm.day⁻¹. Moreover, from predicted crop evapotranspiration showed that water requirements of oil palm range 1.44-3.70 mm.day⁻¹. Water requirements increasing based on the age of oil palm, however, it will decrease in the rainy season.

1. Introduction

Experts have made several observations about evaporation using earth observation [1-2, 4-5, 8]. Earth observation as a discipline, rather than specific to the field of hydrology, focusing on some of the critical data needs and knowledge gaps per water cycle variable, such as precipitation, evaporation, soil moisture, runoff, groundwater and terrestrial water storage, vegetation, snow and permafrost, water vapor, water quality [4].

There are hydrological variables that can be retrieved from space, i.e. rainfall, snowfall, evaporation, runoff, snow cover, snow density, depth or water equivalent; surface soil moisture, deep soil moisture, surface water elevation, terrestrial water storage change, vegetation/land cover/irrigated area, vegetation stress, photosynthesis, water vapor, but not water consumption, water quality, depth to groundwater, total groundwater storage, and integrated water budget yet [4].

The oil palm plantation industry is one of the economic wheels of the Indonesian, especially the community of North Sumatera Province. Oil palm nurseries require the supply of irrigation water which is in accordance with water requirements and the time. Crop water requirements are closely related to the rate of evapotranspiration [7]. The effect of the crop characteristic on crop water requirements is given by the crop coefficient (K_c) which presents the relationship between reference evaporation (ET_o) and crop evapotranspiration (ET_c) [3]. The four methods presented for ET_o, i.e. The Blaney-Criddle, Radiation, Penman and Pan Evaporation-method, are modified to calculate ET_o using the mean daily climatic data [3]. Crop coefficient for age of oil palm from 7 until 12 month are 0.80; 0.81; 0.83; 0.84; 0.85; 0.87 [6].



The objectives of this studies were to known the value of crop coefficient for the age of oil palm 4, 5 and 6 month and predicted water requirements of oil palm based on net radiation evaporation method.

2. Materials and Methods

2.1. The experimental design

The research was conducted from April to July 2018 were placed on greenhouse laboratory, Agricultural Faculty, Universitas Sumatera Utara. The material that was used in the experiment including oil palm seeds Tenera Variety at 4 months old from Indonesian Oil Palm Research Institute (IOPRI).

2.2. Observation the meteorological data

Observation of meteorological data using monthly data in the last 5 years (2013, 2014, 2015, 2016, and 2017) obtained from Meteorological, climatological, and Geophysical Agency (BMKG) Sampali's Station in Medan, North Sumatera Province. The data that were used including the average of temperature, relative humidity, Sunshine duration, solar radiation and the amount of radiation received on the atmosphere.

2.3. Calculating reference evaporation (ET_o) with Radiation Evaporation Method

The radiation method is essentially an adaptation of the Makkink formula. Relationship are given between the presented radiation formula and reference crop evapotranspiration (ET_o) [3], expressed as:

$$ET_o = c(WR_s)mm.day^{-1} \quad (1)$$

Where, ET_o = Reference crop evapotranspiration (mm.day⁻¹)
 R_s = solar radiation in mm.day⁻¹
 W = Weighting factor which depends on temperature and altitude
 c = adjustment factor which depends on mean humidity and daytime wind conditions

The amount of radiation received at the top atmosphere (R_a) is dependent on latitude and the time of year only, and part of R_a dependent is absorbed and scattered when passing through the atmosphere. R_s can be measured directly, R_s can be obtained from measured Sunshine duration records.

$$R_s = (0.25 + 0.50 n/N)R_a \quad (2)$$

Where n/N is Ration between daily actual (n) and daily maximum possible (N).

2.4. Calculating crop coefficient (K_c)

Crop coefficient of Oil Palm obtained according to the relationship between reference evaporation (ET_o) and crop evapotranspiration that determined according to volumetric soil moisture [7], expressed as:

$$ETc = \frac{1}{2} \frac{\theta h}{t} \quad (3)$$

and,

$$\theta = \frac{Mc \rho b}{\rho w} \quad (4)$$

Hence,

$$Kc = \frac{ETc}{ET_o} \quad (5)$$

Where, ET_c = Crop evapotranspiration (volumetric method, mm.day⁻¹)
 ET_o = Reference evaporation (pan evaporation, mm.day⁻¹)
 θ = Volumetric soil moisture (%)

- h = soil depth (cm)
 t = time (day)
 Mc = soil water content in dry basis (%)
 ρ_b = bulk density of soil (g.cm^{-3})
 ρ_w = water density (1 g.cm^{-3})

2.5. Predicting water requirements of oil palm/ crop evapotranspiration (ET_c)

Crop evapotranspiration (ET_c) can be predicted using the appropriate crop coefficient (K_c), expressed as:

$$ET_c = ET_o \cdot K_c \quad (6)$$

Where, ET_c = Crop evapotranspiration (mm.day^{-1})
 ET_o = Reference evapotranspiration (mm.day^{-1})
 K_c = Crop coefficient

3. Results and Discussion

3.1. Meteorological Data for 5 years duration

The meteorological data showed in figure 1 below.

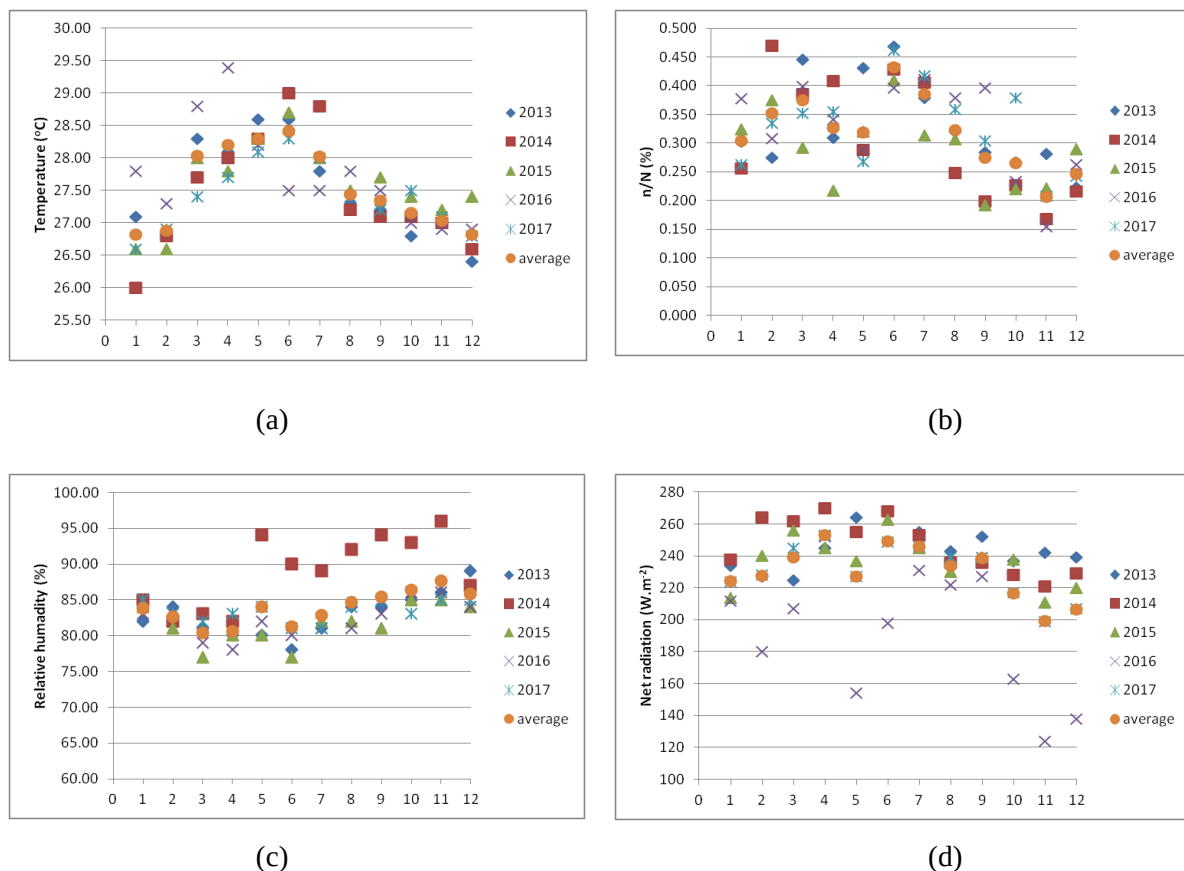


Figure 1. The meteorological data for 5 years duration: a) temperature, b) sunshine duration, c) relative humidity, d) solar radiation

Figure 1 shows the average data from meteorological data. The data applies to surround area of Medan city, Deli Serdang district, and Langkat district. Sunshine duration range is 0.1-0.5% which categorize is low, the wind range is 2-5 m.s⁻¹ which categorize is moderate, and relative humidity of area categorize is high, with RH>70%. Meteorological data is needed to make observations, including evaporation observation [4].

3.2. Reference evaporation (net radiation, E_{To})

The results of reference evaporation observation shown on table 1 below.

Table 1. Observation of reference evaporation based on net radiation method

Parameters	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
n	3.62	4.21	4.51	3.97	3.90	5.33	4.72	3.95	3.33	3.18	2.46	2.93
N	11.87	11.94	12.03	12.17	12.25	12.32	12.25	12.25	12.1	12.03	11.94	11.87
n/N	0.30	0.35	0.38	0.33	0.32	0.43	0.39	0.32	0.28	0.26	0.21	0.25
Ra	14.34	15.03	15.51	15.48	14.87	14.38	14.57	15.08	15.3	15.12	14.53	14.13
Rs	5.769	6.406	6.786	6.394	6.087	6.704	6.449	6.202	5.929	5.781	5.132	5.275
W	0.759	0.760	0.773	0.775	0.773	0.777	0.775	0.765	0.764	0.762	0.761	0.759
(W.Rs)	4.381	4.867	5.247	4.955	4.707	5.210	4.867	4.747	4.531	4.408	3.905	4.006
C	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.74	0.74	0.74	0.74
E_{To}	3.55	3.94	4.25	4.01	3.81	4.22	3.94	3.84	3.35	3.26	2.89	2.96

Table 1 shows reference evaporation (E_{To}) value based on net radiation. In January E_{To} is 3.55 mm.day⁻¹, than increasing for February and March, until May, and decreasing until December. Generally, January to June is summer, and July to December is the rainy season. In the rainy season, the duration of sunshine is low compared to the summer season. It is caused by cloudy more than sunshine. Surely, evaporation will decrease compared with the summer season.

3.3. Crop coefficient (K_c) oil palm

The measurement result showed in table 2 below

Table 2. Crop coefficient for 4-6 month age of oil palm

Age of oil palm (month)	Month of plant	E_{Tc} (mm.day ⁻¹)	E_{To} (mm.day ⁻¹)	K_c
4	April	0.60	1.19	0.50
5	May	0.66	1.26	0.52
6	June	0.64	1.19	0.54

Table 2 shows crop coefficient value of oil palm for 4-5 month age of oil palm. The value of oil palm crop coefficient was 0.50 for 4 months, 0.52 for 5 months, and 0.54 for 6 months. This shows that the bigger the plant, the higher crop coefficient. Crop coefficient is increasing with the growing age of oil palm [7].

3.4. Water requirements on oil palm nursery

Water requirements of oil palm shown in table 3 equal with evapotranspiration of oil palm.

Table.3. Crop evapotranspiration of oil palm

Age of oil palm (month)	Table 1: Crop evapotranspiration of oil palm												
	Kc	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
		Reference Evaporation (Eto, mm.day ⁻¹)											
		3.55	3.94	4.25	4.01	3.81	4.22	3.94	3.84	3.35	3.26	2.89	2.96
		Crop Evapotranspiration (ETc, mm.day ⁻¹)											
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-
4	0.5	1.77	1.97	2.12	2.01	1.91	2.11	1.97	1.92	1.68	1.63	1.44	1.48
5	0.52	1.85	2.05	2.21	2.09	1.98	2.19	2.05	2.00	1.74	1.70	1.50	1.54
6	0.54	1.92	2.13	2.29	2.17	2.06	2.28	2.13	2.08	1.81	1.76	1.56	1.60
7	0.8	2.84	3.15	3.40	3.21	3.05	3.38	3.15	3.08	2.68	2.61	2.31	2.37
8	0.81	2.87	3.19	3.44	3.25	3.09	3.42	3.19	3.11	2.72	2.64	2.34	2.40
9	0.83	2.95	3.27	3.53	3.33	3.16	3.50	3.27	3.19	2.78	2.71	2.40	2.46
10	0.84	2.98	3.31	3.57	3.37	3.20	3.54	3.31	3.23	2.82	2.74	2.43	2.49
11	0.85	3.02	3.35	3.61	3.41	3.24	3.59	3.35	3.27	2.85	2.77	2.46	2.52
12	0.87	3.09	3.43	3.70	3.49	3.32	3.67	3.43	3.35	2.92	2.84	2.51	2.58

Table 3 shows crop evapotranspiration of oil palm, close to water requirement of oil palm. The greater age of oil palm, the greater crop coefficient value. Generally, oil palm water requirements will increase in accordance to the age of oil palm. However, table 3 shows that water requirement decreasing in the rainy season depends on evaporation value. Hence, water requirement affected by sunshine duration, solar radiation, wind velocity, relative humidity, temperature and altitude.

4. Conclusion

Crop coefficient of oil palm for 4,5, and 6 month are 0.50; 0.52; and 0.54. Reference evaporation (Eto) range 2.89 – 4.25 mm.day⁻¹, depends on summer season or rainy season. Water requirement is increasing based on the age of oil palm, but it will decrease in the rainy season

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