Journal of Oil Palm Research Vol. 33 (2) June 2021 p. 278-288
DOI: https://doi.org/10.21894/jopr.2020.0094

QUANTITATIVE APPROACH FOR IRRIGATION REQUIREMENT OF OIL PALM: CASE STUDY IN CHUPING, NORTHERN MALAYSIA

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ABSTRACT

The right decision is needed before the irrigation project starts because it is risky, costly and required a site-specific approach. The study aims to estimate oil palm irrigation water demand by using FAO-CROPWAT model. Study was conducted in Chuping Region, Northern Peninsular of Malaysia. Four points were selected to represent North, East, West and South for soil sampling. The samples were sent to a laboratory to measure the water content after pressure applied at 0, 1, 10, 33 and 1500 kPa. Total available water holding capacity was found at 105-227 mm for 100 cm soil depth and the lowest value was selected to be used in FAO-CROPWAT model, developed by Land and Water Development Division of Food and Agriculture Organisation of the United Nations (FAO). Prior to that, history of 14 years of monthly meteorological data were collected and serve as climatic data for potential evapotranspiration calculation. Based on the simulation, crop evapotranspiration (ETc) and irrigation requirement (IR) was 1175 and 255.2 mm yr^{-1} respectively. Total net irrigation was concluded at 132 mm yr^{-1} with the assumption of 80% irrigation efficiency and 5.0 mm of irrigation input. Through this study, FAO-CROPWAT found to be a suitable approach to estimate crop water requirement (CWR) for oil palm and simulate irrigation scheduling for the entire year. It can help to strategise the management plan prior to any irrigation project design and increase potential for good economic return.

Keywords: available water content, FAO-CROPWAT, irrigation water supply, soil-water relation, water allocation budget.

Received: 23 December 2019**; Accepted:** 7 September 2020**; Published online:** 27 October 2020.

INTRODUCTION

Oil palm (*Elaeis guineensis*) is categorised as a commodity crop and it contributes a lot to the improvement of the living standard of Malaysian, especially in the rural area. It has been shown that oil palm's yield can reach up to 37 t ha^{-1} yr^{-1} (Goh, 1994). Results from other field trials has demonstrated better yield that can go up to 35-42 t ha^{-1} yr^{-1} during peak season (Kee *et al*., 1998). However, the national average yield for Malaysia was still below 20 t ha^{-1} yr^{-1} for the last 15 years (Kushairi *et al*., 2018).

Many factors contribute to this low yield, which includes plantation management, nutrient uptake, soil, topography, pest, disease and water. Water specifically in the form of moisture will maintain the functional growth of oil palm. This element plays important roles in photosynthesis and is also kept in the soil to make nutrient available for uptake by the palm. Water shortage will affect sex ratio index whereby, it is, lowering the number of female flowers at approximately 22-24 months before harvesting. During fruiting activity, any

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water shortage at 9-10 months or 4-5 months before harvest is damaging to the palm as it affects anthesis process and cause bunch failure.

Globally, industrial-scale oil palm is estimated at 18.7 million hectares as October 2017 (Meijaard *et al*., 2018). Whereas in Malaysia, oil palm planted area further expanding up to 5.74 million hectares in 2016 (MPOB, 2017). Additional area means oil palm is going to be cultivated in marginal areas. In Peninsular Malaysia, land conversions to cultivate oil palm within marginal and moderate oil palm suitability classes have been increasing and about 30% of all conversions in 2012 were in areas with low oil palm suitability (Shevade and Loboda, 2019). Marginal soil classified as having at least one serious limitation to crop growth in the form of acute nutrient deficiencies, very poor drainage, steep slopes, massive laterites, acid peat, sandy texture, strong compaction, acid sulphate and saline conditions (Mohd Arif, 2005). Several of these limitations are highly related to the water deficit problem. Most oil palm plantations rely on the rainfall as the main water supply to oil palm. However, uneven rainfall distribution throughout the year and specific area (temporal and spatial distributions) has affected the yield. On top of that, *El-Nino* events sometimes occurs and worsen the situation (Amirul Hadi *et al*., 2016; Nadia and Fatimah, 2016).

Irrigation is one of the ways to reduce the impact of water deficit and support oil palm functional growth. Irrigation was firstly demonstrated to increase yield of oil palm up to 225% as reported by Ochs and Daniels (1976). In Thailand, trials have been done which cover different type of irrigation and rate, and it has been shown that an irrigated plot gave extra yield up to 6 t ha^{-1} yr^{-1} (Palat, 2000). Whilst a study in different location has shown that drier area can give better palm response of up to 56% compared to non-irrigated palm (Lee and Izwanizam, 2013). Therefore, selection of an area for irrigation project is a very critical process in order to get high return on investment in the future.

FAO-CROPWAT 8.0 simulation model was developed by Food and Agriculture Organisation of the United Nations (FAO) to estimate Crop Water Requirement (CWR) especially for food crop. This model allows the development of irrigation schedules which cover different management options and also the calculation scheme of water supply for varying crop patterns. Studies were done on various crops such as maize and sorghum (Demba, 2014), rice, coconut, banana, areca nut, vegetables, pulses, rubber, tea, coffee and cotton (Surendran *et al*., 2015). Nevertheless, this model has not been widely used for oil palm yet, and is now starting to draw some attention. A study done by Isa *et al*. (2016) has demonstrated the capability of this model to estimate CWR and irrigation requirement (IR) for oil palm in South West Nigeria. Other than that, this model has been widely used to calculate water usage for water footprint evaluation in oil palm plantation (Mungkalasiri *et al*., 2015; Zulkifli *et al*., 2014; Muhammad Muaz and Marlia, 2014). Therefore, usage of FAO-CROPWAT into the oil palm plantation is justified. The objective of this study was to predict the crop and irrigation water requirement to help decision maker for irrigation planning in the oil palm plantation.

MATERIALS AND METHODS

Location and Soil Properties

An area located at FGV Agri Services Sdn. Bhd. (FGVAS) Chuping Estate (6°33′10.73″N, 100°18′19.15″E) was selected for this study with total of 28.8 ha. This place is located at a dry region and the highest maximum temperature ever recorded was 41°C. For the last 40 years, this area was cultivated with sugarcane and now being replanted with oil palm. Four points were selected for sampling purposes to represent North, East, South and West of the research plot. A semi-detailed soil survey of the area including the research plot was carried out by the relevant authorities. Basically, it is consists of two main parent materials dominated by pediments and small part of sub-recent alluvium. Topography is undulating with slope class from 4%-12%. Soil developed over pediment parent material (reworked lateritic soil) was shallow and gravelled within 100 cm soil horizon. Topsoil was fine sandy loam and gravels consist of fine rounded petroplinthite. Particle class size ranging from loamy-skeletal to clayey skeletal with more than 35% gravels. Meanwhile, soil developed over sub-recent alluvium was deep, friable and fine sandy clay loam (Paramananthan, 2012; Jabatan Pertanian, 2008).

Total Available Water Holding Capacity (AWHC) Estimation

Soil samples were taken using bulk density ring at each layer. For each point, differences in soil layers were decided based on its physical and colour changes as shown in *Figure 1*. The thickness of each layer was recorded for Total AWHC calculation as in *Table 1*. These soil samples were sent to the laboratory for determination of water content at several pressure applications of 0, 1, 10, 33 and 1500 kPa using a pressure plate apparatus (Richards, 1947; Teh and Jamal, 2006). AWHC for each layer was calculated using the formula in Equation 1.

$$\text{Total AWHC} = \Sigma\text{AWHC for all depth of horizontal layer} \quad \text{Equation (1)}$$

$$\text{AWHC} = \text{BD} \times \left(\frac{\text{FC - PWP}}{100}\right) \times \text{D}$$

where;
AWHC - available water holding capacity (mm)
BD - bulk density (g cm^{-3})
FC - field capacity (% in weight)
PWP - permanent wilting point (% in weight)
D - depth of horizontal layer (mm)

Examination of horizontal layer was done up to 1 m depth except for Point 1. It is because, high gravel proportion with dense horizontal layer beyond 60 cm become hindrance and making soil sampling by ring is nearly impossible. The value of each layer was added to get the total readings of Total AWHC (Equation 1). The lowest Total AWHC value was selected and used in FAO-CROPWAT software for simulation of crop water requirement and irrigation scheduling.

Collection of Historical Climatic Data

Weather data used in FAO-CROPWAT model was purchased from the Malaysian Meteorological Department. These data consists of 14 years collection from 2000-2013 (*Table* 2). Sunshine hours data was collected from Felda Chuping B Meteorological Station (06°30′13″N, 100°20′53″E) while the other data was from Chuping Meteorological Station (06°28′55″N, 100°14′4″E). The amount of rainfall, minimum temperature, maximum temperature, solar radiation and wind speed were used in the FAO-CROPWAT model to estimate the value of reference evapotranspiration (ET_o) in Equation 2 as described by Allen *et al*. (1998). Effective rainfall calculation was based on FAO method and the calculation is shown in Equation 3. ET_o and effective rainfall estimation were automatically calculated by the software.

$$ET_o = \frac{0.408\Delta (Rn - G) + \gamma\frac{900}{T + 278} U_2 (e_s - e_a)}{\Delta + \gamma(1+0.34U2)} \quad \text{Equation (2)}$$

where;
ET_o - reference evapotranspiration (mm day^{-1})
Rn - net radiation at the crop surface (MJ m^{-2} day^{-1})
G - soil heat flux density (MJ m^{-2} day^{-1})
T - air temperature at 2 m height (°C)
U_2 - wind speed at 2 m height (ms^{-1})
e_s - saturation vapour pressure (kPa)
e_a - actual vapour pressure (kPa)
$e_s - e_a$ - saturation vapour pressure deficit (kPa)
Δ - slope vapour pressure curve (kPa $°C^{-1}$)
γ - psychrometric constant (kPa $°C^{-1}$)

$$P_{eff} = (0.6 \times P_{month}) - 10 \quad \text{for } P_{month} \leq 70 \text{ mm}$$
$$P_{eff} = (0.8 \times P_{month}) - 24 \quad \text{for } P_{month} > 70 \text{ mm} \quad \text{Equation (3)}$$

where;
P_{eff} - effective rainfall
P_{month} - rainfall at particular month

FAO-CROPWAT Setting

In Crop Module, the crop coefficient (Kc) value of 0.80 was used as referred on the study conducted by Henson and Harun (2005). Suggestion by Tailiez (1971) stated the greatest quantity of rooting zone are within 20-60 cm from the ground level and has been used as rooting depth in the model. For the fourth module which is soil properties, two important inputs were the Total Available Moisture which is same meaning as Total AWHC and the other one is Maximum Rain Infiltration Rate (MRIR). In this study, MRIR was set to default value which is 30 mm day^{-1} (Smith, 1992).

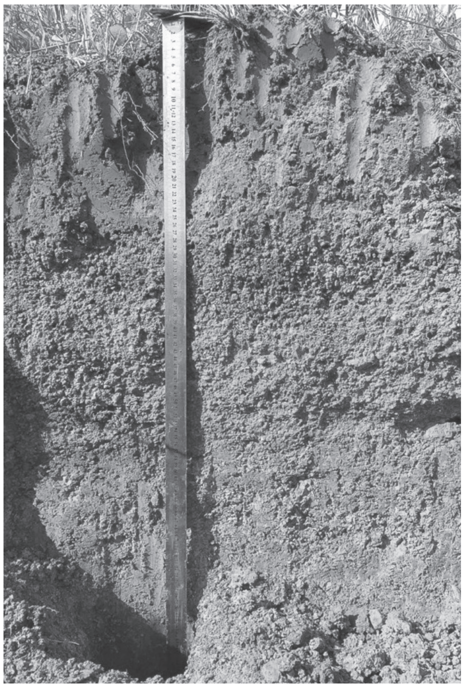


Figure 1. Different soil layers through soil horizon (Point 2).

Then, scheduling criteria such as irrigation timing and application depth were set accordingly in the 'Schedule' module. These inputs will have an impact on the determination of irrigation scheduling table and it is generally calculated by using soil water balance concepts. For this case, timing for irrigation was set when the deficits reached Critical Depletion (CD). The term CD refers to fraction of available moisture to be depleted before plant experience moisture stress affecting plant ET_o and plant production. The value for this fraction for broad range of crop has been presented by Allen *et*

TABLE 1. SOIL WATER RETENTION PROPERTIES AT DIFFERENT POINT OF SAMPLING ACCORDING TO EXAMINED DEPTH

Point	Depth (cm)	Bulk density (g cm^{-3})	Gravimetric water content (%)					AWHC (mm)	
			0 kPa	1 kPa	10 kPa	33 kPa	1 500 kPa		
1	0-15	1.73	26.34	19.28	15.47	8.83	8.07	19.22	±3.51
	15-30	1.77	25.27	22.32	17.56	8.53	5.83	31.11	±0.49
	30-45	1.45	33.84	28.13	19.10	12.07	10.05	19.68	±1.21
	45-60	1.19	24.36	14.86	12.14	8.09	7.40	8.47	±0.62
2	0-25	1.61	27.37	17.67	14.01	6.84	5.74	33.35	±1.69
	25-60	1.20	15.81	12.65	9.59	8.07	7.28	9.66	±0.05
	60-100	1.22	43.88	31.32	29.18	22.76	16.43	62.34	±24.05
3	0-30	1.50	24.41	18.13	16.56	8.48	6.16	46.97	±1.27
	30-100	1.51	28.45	20.21	16.69	11.90	9.43	76.85	±39.10
4	0-100	1.70	24.01	20.15	17.17	4.57	3.81	227.17	±3.43
	Mean	1.49	27.37	20.47	16.75	10.01	8.02		

Note: AWHC - available water holding capacity.

TABLE 2. AVERAGE MONTHLY CLIMATIC DATA FROM NEAREST WEATHER STATION AT FGVAS CHUPING ESTATE FOR 14 YEARS (2000-2013)

Month	Minimum temp. (°C)	Maximum temp. (°C)	Humidity (%)	Wind speed (m s^{-1})	Sunshine (hr)	Estimated by FAO-CROPWAT	
						Radiation (MJ m^{-2} day^{-1})	ET_o (mm day^{-1})
January	23.6	32.6	76	2.0	7.3	18.9	4.40
February	23.8	34.5	73	2.0	8.3	21.4	5.15
March	24.1	34.4	78	1.4	7.1	20.4	4.72
April	24.4	34.1	81	1.0	7.0	20.2	4.54
May	24.5	33.3	84	0.8	5.5	17.4	3.88
June	24.1	32.7	84	0.8	5.7	17.2	3.79
July	23.7	32.2	85	0.8	5.1	16.5	3.60
August	23.7	32.2	85	0.9	5.3	17.3	3.77
September	23.6	31.9	86	0.8	5.0	17.0	3.68
October	23.7	31.8	86	0.9	5.2	16.8	3.63
November	23.8	31.9	85	1.3	5.2	16.0	3.52
December	23.7	31.5	82	1.6	5.6	16.1	3.60
Average	23.9	32.8	82	1.2	6.0	17.9	4.02

Note: ET_o - reference evapotranspiration.

al. (1998). Unfortunately, there are no exact figures demonstrated for oil palm yet and in this case, 50% has been selected to be inserted in the model. Based on practical point of view, 4 mm was selected as an irrigation application amount. Irrigation efficiency was set at 80% based on the average percentage proposed by Pocaides (2000) for micro irrigation method. Therefore, the depth of irrigation will be 5 mm considering losses up to 20%.

Evaluating Different Sources of ET_o Data Sources

Several studies by researchers have quantified the accuracy of FAO-CROPWAT model based on water deficit impact to the crop yield (Etissa *et al*., 2016; Bekele and Tilahun, 2009) but this is not covered in this article due to several reasons including insufficient climatic data for 2014 and onward. In addition, the palms were replanted in March 2014 and started yielding two years later. Consequently, data sources as requisite input for ET_o calculation emphasised and put into evaluation.

Climatic data for years of 2013, 2012, 2011 and 2010 was served as 'observed' years. Then, climatic data for previous years (PY), average of last five years (5Y), average of last 10 years (10Y) and data from FAO-CLIMWAT (Climwat) was served as 'predicted'. All the data was loaded into FAO-CROPWAT for determination of monthly ET_o value. Data from Climwat was downloaded by selecting nearest station with the research area namely as Kangar (6°25'48"N, 100°12'0"E). Comparison of ET_o value between 'observed' and 'predicted' was accessed by using mean absolute error (MAE) and root mean squared error (RMSE) based on 1:1 line (Equation 4).

$$\mathrm{MAE} = \frac{1}{n}\Sigma_{n}^{t=1}|O_t - P_t|$$

$$\mathrm{RMSE} = \sqrt{\frac{\Sigma|O_t - P_t|^2}{n}} \qquad \text{Equation (4)}$$

where;
n - numbers of observation
O_t - 'Observed' data
P_t - 'Predicted' data

RESULTS

Soil-water Retention Properties

The results of soil water retention properties are shown in *Table 1*. Variations in soil layer can be observed for every sampling point. Point 1 consists of four main layers of up to 60 cm depth. Sampling process cannot go further beyond that level because of the existence of hard plinthite layer. Point 2 consists of three layers followed by Point 3 consists of two layers. There are no variations observed for Point 4 and the layers are in the same characteristic from ground level to 1 m depth.

The graph was plotted to represent average value of sampled layers and mirror S-curve shape was observed (*Figure 2*). Each area shows a saturated value ranged from 38.9%-42.1% and percentage of volumetric water content (VWC) reduce with the increasing of pressure applied. Points 1, 2 and 3 were located at the same parent material for soil origin, therefore the curve is likely to be the same trend and close to each other. Eventually, trend curve for Point 4 have a greater variation and much lower permanent wilting point (PWP) which is only 6.5%.

Using Equation 1, the value of Total AWHC according to the sample point is as shown in *Table 3*. The highest value was Point 4, which is 227 mm then followed by Point 3 and 2, which are 124 and 105 mm, respectively. Point 1 has a value of 78 mm but it is only represent for 60 cm depth.

TABLE 3. TOTAL AVAILABLE WATER HOLDING CAPACITY (AWHC) VALUE ACCORDING TO THE SAMPLING POINT

No.	mm m^{-1}	cm cm^{-1}
1	78.48*	0.131
2	105.35	0.105
3	123.82	0.124
4	227.17	0.227

Note: * only for 60 cm.

Crop Water Requirement (CWR)

Once the data is loaded into FAO-CROPWAT, the CWR properties could be generated and the result is shown in *Table 4*. A decade indicated 10-days value of CWR, and it was calculated using linear interpolation in FAO-CROPWAT (Smith, 1992). Total estimation of crop evapotranspiration (ETc) is 1175.0 mm yr^{-1} and effective rainfall is 1117.8 mm yr^{-1}. For each of IR calculations, the deficit will only be applied if the ETc value exceeds the effective rainfall which total is 255.2 mm yr^{-1}.

Irrigation Scheduling

However, looking solely at *Table 4* does not reflect daily irrigation input. Therefore, 'Schedule' module calculates daily irrigation input based on soil water balance concept. In this case, value of 105 mm m^{-1} was used besides the pre-defined

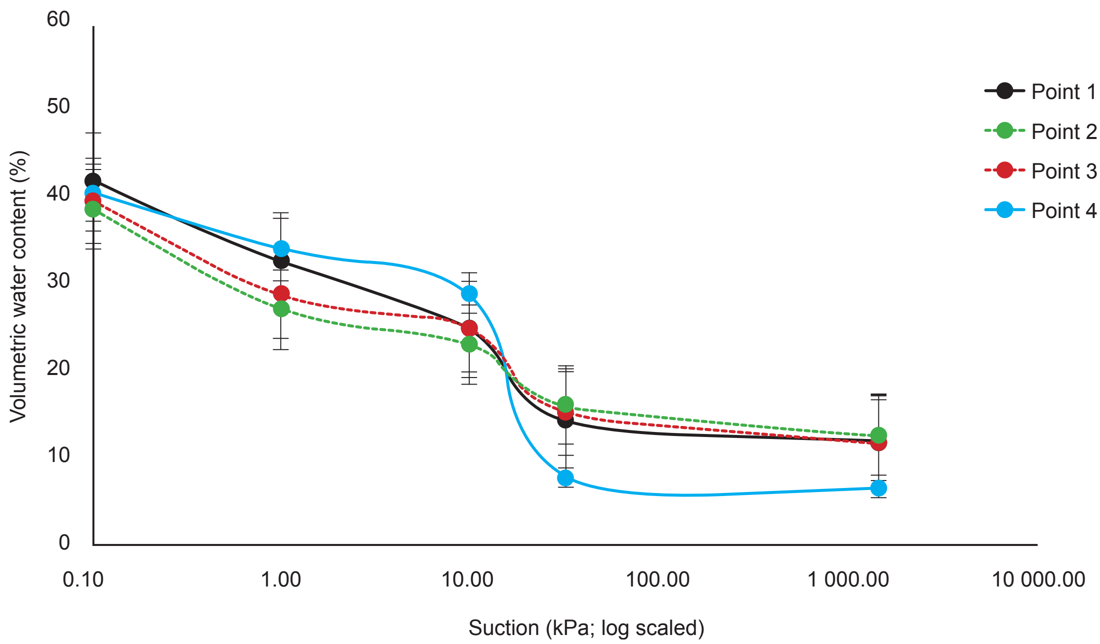


Figure 2. Soil water retention curves for each location.

requirement such as initial soil moisture, irrigation timing and irrigation depth as mentioned before. Simulation for daily irrigation schedule is shown in *Figure 3*. Two lines depicted by green and red colour indicate available water for 60 cm root zones and the latter is for water availability after considering root zone and CD (for this case is 50%). The results showed that Total Net Irrigation (TNI) was 132 mm for the entire year.

Evaluation of Various Dataset

It has been found that MAE value ranged from 0.10-0.32 (*Figure 4*). The lowest MAE value was represented by 2013-5Y data which is only 0.10. Surprisingly, 5Y generated lower MAE value compared to 10Y for all tested year. Moreover, PY also generates lower MAE than 10Y for years of 2013, 2012 and 2011. Overall, Climwat dataset has shown better MAE than 10Y.

TABLE 4. CROP WATER REQUIREMENT (CWR) FOR OIL PALM PLANTED AT FGVAS CHUPING ESTATE

Month	Decade	Kc	ETc (mm day^{-1})	ETc (mm dec^{-1})	Effective rainfall (mm dec^{-1})	IR (mm dec^{-1})
Jan	1	0.8	3.3	33.1	10.2	22.8
Jan	2	0.8	3.5	35.2	2.0	33.3
Jan	3	0.8	3.7	40.9	5.4	35.6
Feb	1	0.8	4.0	39.8	8.6	31.2
Feb	2	0.8	4.2	42.0	9.9	32.1
Feb	3	0.8	4.1	32.5	18.2	14.3
Mar	1	0.8	3.9	38.9	28.5	10.4
Mar	2	0.8	3.8	37.8	36.6	1.1
Mar	3	0.8	3.7	41.0	39.0	2.0
Apr	1	0.8	3.7	36.8	43.2	0.0
Apr	2	0.8	3.6	36.3	47.5	0.0
Apr	3	0.8	3.5	34.5	40.1	0.0
May	1	0.8	3.3	32.8	29.8	3.0
May	2	0.8	3.1	31.0	22.9	8.1
May	3	0.8	3.1	33.9	23.5	10.4
Jun	1	0.8	3.1	30.6	24.9	5.7
Jun	2	0.8	3.0	30.3	24.6	5.7
Jun	3	0.8	3.0	29.8	24.6	5.2
Jul	1	0.8	2.9	29.3	24.0	5.3
Jul	2	0.8	2.9	28.8	23.7	5.1
Jul	3	0.8	2.9	32.2	26.2	6.0
Aug	1	0.8	3.0	29.7	28.2	1.5
Aug	2	0.8	3.0	30.2	30.0	0.2
Aug	3	0.8	3.0	32.9	35.5	0.0
Sep	1	0.8	3.0	29.7	42.5	0.0
Sep	2	0.8	3.0	29.5	48.1	0.0
Sep	3	0.8	2.9	29.3	48.8	0.0
Oct	1	0.8	2.9	29.2	49.7	0.0
Oct	2	0.8	2.9	29.0	51.2	0.0
Oct	3	0.8	2.9	31.6	49.8	0.0
Nov	1	0.8	2.9	28.5	49.5	0.0
Nov	2	0.8	2.8	28.2	49.2	0.0
Nov	3	0.8	2.8	28.4	41.7	0.0
Dec	1	0.8	2.9	28.6	33.5	0.0
Dec	2	0.8	2.9	28.8	26.9	1.9
Dec	3	0.8	3.1	34.0	19.9	14.2
Total				1 175.0	1 117.8	255.2

Note: ETc – crop evapotranspiration; IR – irrigation requirement.

RMSE is likely to be same as MAE but is not identical since it will amplify large error to become more visible. As an example, MAE for 2013_10Y has relatively same value compared to 2012_Climwat data source. However, RMSE for former data source was higher, 0.452 compared to 0.360 as shown in *Figure 5*. It is likely due to two data which are far deviated from 1:1 line. Similarly for 2011-PY, the bar was increased and become the same level as 2011-5Y and 2011-10Y (*Figure 4*).

DISCUSSION

Total AWHC reflect the availability of water content between field capacity and PWP. PWP refers to the water content under high soil retention that affects the plants to withering and loose turgidity even in humid atmosphere (Briggs and Shantz, 1912). Normally, PWP is straight forward and directly represented by -1500 kPa pressure level. But it actually differ between crop species, developmental stage, soil condition and climate (Carlesso, 1995; Romano and Santini, 2002). In best situation, the field capacity needs to be measured in the field where the soil is undisturbed. But, this can be hampered by practical difficulties, laborious, time consuming and lateral losses through horizontal flow (Reichardt, 1988; Van Lier, 2002). Although 33 kPa is often used as estimation for field capacity, there are some arguments rised by Kirkham (2004). He stated that soil scientists realised that field capacity was an imprecise term and it was not a unique value, because equilibrium is never reached. Field capacity is usually determined by applying tension from 0.05-0.15 bar for sandy to loamy soils (McCarty *et al*., 2016). Therefore, 10 kPa or 0.10 bar was selected as a field capacity point since the result was comparable to available water content suggested by Raveendra *et al*. (2017) (*Table 5*).

Crop water and irrigation demand are dependent on climate and location. There are no attempt being made in the Malaysian context to use FAO-CROPWAT for irrigation scheduling. As comparison, potential ET_o ranged from 3.60-5.15 mm day^{-1} (*Table 1*) is relatively high compared to study done by Isa *et al*. (2016). ET_o for his study in South West Nigeria ranged from 2.92-4.49 mm day^{-1} although similar annual rainfall amount was observed.

Generally, soil profiles in the study area are compacted and has high bulk density. This might be due to the previous sugarcane cultivation that lasted for almost 40 years. Long-terms sugarcane cultivation altered soil physical properties in term of higher bulk density, lower structural stability and an increased proportion of fine pores (Barzegar *et al*., 2005). Variability among Total AWHC values shows there are need for variable rate of irrigation in the field but such irrigation concepts are still in an infancy level with inadequate trial results. Furthermore, sluggish price of crude palm oil for the last two years (MPOC, 2019) has also become major hindrance for planters to invest on huge capital cost project such as irrigation.

The others important information available shown in FAO-CROPWAT is peak demand for water sources and for this case concentrated in January to February. Normally, estates water source depends on stream or river for oil palm irrigation. For this example, high evaporation and low rainfall will greatly impact water level and irrigation attempt might be impossible. Irrigation input of 5.0 mm day^{-1} was almost equivalent to a 1440 m^3 of water day^{-1} for a total of 28.8 ha area. Therefore, it is expected that the adjustment will be made to suit with water availability such as by reducing input of irrigation despite increasing irrigation interval. Another option is to have groundwater as an alternative water source, but this might

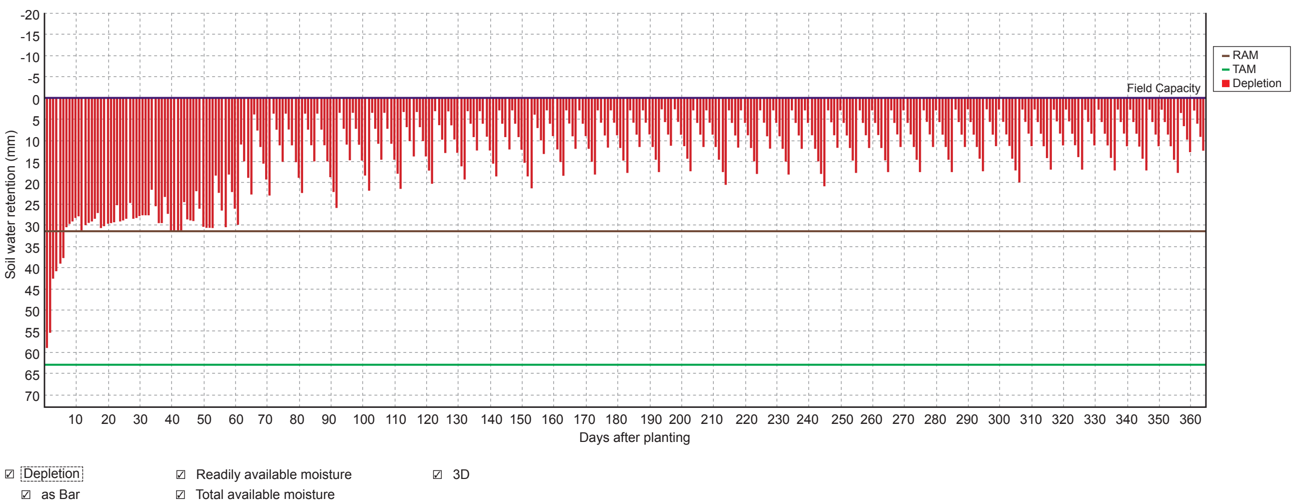
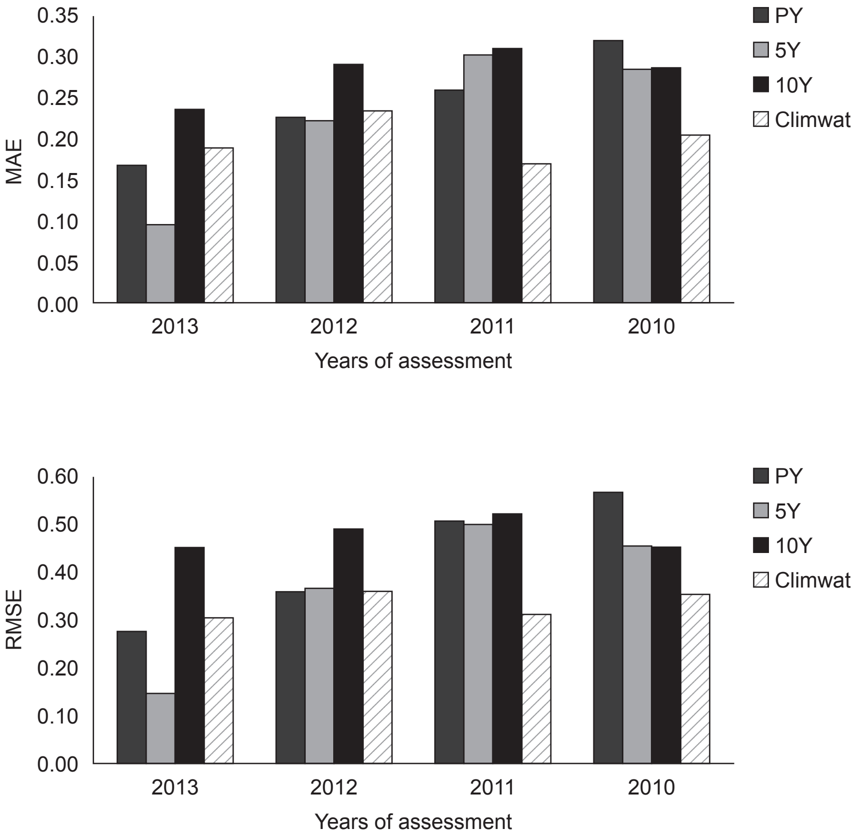
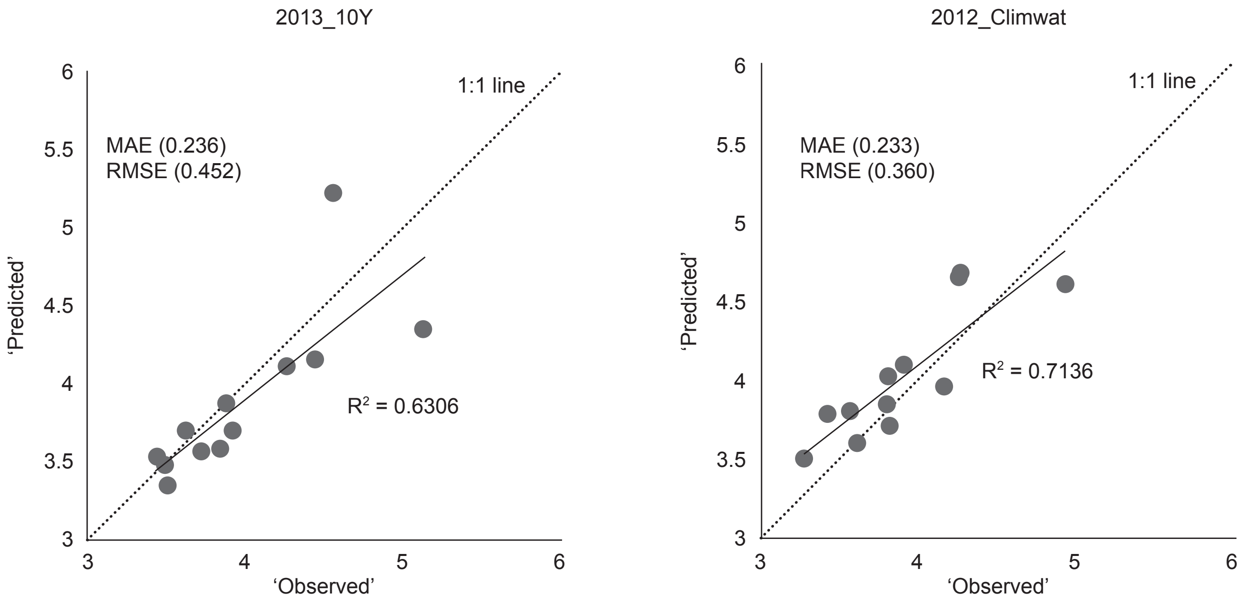


Figure 3. Irrigation schedule suggested by FAO-CROPWAT.



Note: MAE – mean absolute error; RMSE – root mean squared error.

Figure 4. Comparison between different datasets using MAE and RMSE statistical indices.



Note: MAE – mean absolute error; RMSE – root mean squared error.

Figure 5. Graphical representation of 'observed' (x-axis) and 'predicted' (y-axis) with their respective MAE and RMSE.

incur additional cost besides uncertainties of water quality and groundwater recharge rate.

In general, long-term historical data will be used to feed the module in FAO-CROPWAT model. Therefore, it makes sense to suggest that the longer data is collected or averaged, the closer it is to the expected value. However, the question that arises is how long the data should be required to obtain an accurate estimation of ET_o. Two statistical indices namely MAE and RMSE usually applied to make an assessment of modelling accuracy. Based on their objective, it is reasonable to use them and look into 'observed' - 'predicted' closeness.

ET_o generated from 5Y was found to be more close to the observed value in terms of MAE for 2012 and 2013. To certain extent, PY also gave lower value than 10Y for 2011, 2012 and 2013. This put into contexts that longer data period does not necessarily give better ET_o estimation. Result has shown that Climwat gave consistent results and sometimes better than the others. Thus, making Climwat dataset a good option to be used when local data are partially invalid or not available. It is freely available with more than 5000 stations worldwide (43 stations for Malaysia) and 15-30 years compilation makes it very handy and reliable resources (FAO, 2020).

CONCLUSION

Chuping region is well known as a dry area and has a relatively higher temperature than other parts of Peninsular Malaysia. Soil formation was classified from two types which are pediments and sub-recent alluvium. However, Total AWHC varied greatly within examined soil layer. Based on climate, rainfall, crop and soil input the calculated IR is 255.2 mm yr^{-1}. However, TNI is only amounted to 132 mm yr^{-1} and most irrigation events suggested are concentrated in January to February. This estimation will helps to design proper irrigation project and make a decision whether it could be profitable or not. MAE and RMSE showed climatic data from Climwat could be the good option if localise data

TABLE 5. SOIL MOISTURE AT FIELD CAPACITY (θ FC), PERMANENT WILTING POINT (θ PWP), AVAILABLE WATER CONTENT (AWC) AND BASIC INFILTRATION RATE (*F*)

Soil type	θ FC (%v)	θ PWP (%v)	*F* (mm day^{-1})	AWC (cm cm^{-1})
Sand	9	4	1 200	0.05
	(6-12)	(2-6)	(600-6 000)	
Coarse sand	3.2	1.2	11 200	0.02
Medium coarse sand	9.5	1.7	3 000	0.078
Medium fine sand	15.5	2.3	1 100	0.132
Fine sand	19.6	4.2	500	0.154
Sandy loam	14	6	600	0.08
	(10-18)	(4-8)	(312-1 824)	
Sandy loam	19.5	6.1	165	0.134
Light loamy medium (coarse sand)	24.2	10	23	0.142
Loamy medium coarse sand	18.1	2.1	3.6	0.16
Loamy fine sand	14.6	6	265	0.086
Fine sandy loam	27.3	8.7	120	0.186
Loam	22	13	192	0.09
	(18-26)	(8-12)	(192-480)	
Silt loam	33.8	9.2	6.5	0.246
Loam	29.3	9.8	50	0.195
Clay loam	27	13	192	0.14
	(23-31)	(11-15)	(60-360)	
Sandy clay loam	31.7	18	235	0.137
Silty clay loam	34.5	18.5	15	0.16
Clay loam	39.3	25.5	9.8	0.138
Silt clay	31	15	60	0.16
	(27-35)	(13-17)	(7.2-120)	
Clay	35	17	12	0.18
	(31-39)	(15-19)	(2.4-120)	
Light clay	34	21.5	35	0.125
Silty clay	44.7	25.7	13	0.19
Basin clay	49.8	32.1	2.2	0.177

Source: Raveendra *et al*. (2017).

are not available. Through this study, it has been found FAO-CROPWAT can be used as a tool to simulate crop water requirement which was previously developed for water management of food crops.

ACKNOWLEDGEMENT

We would like to thank the FGV Agri Services Sdn. Bhd. for providing research grant for this project. Special thanks also given to the FGV Research and Development Sdn. Bhd. which allows this article to be published. Last but not least, special thanks goes to anyone who contributes towards this project during the data collection and field work.

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