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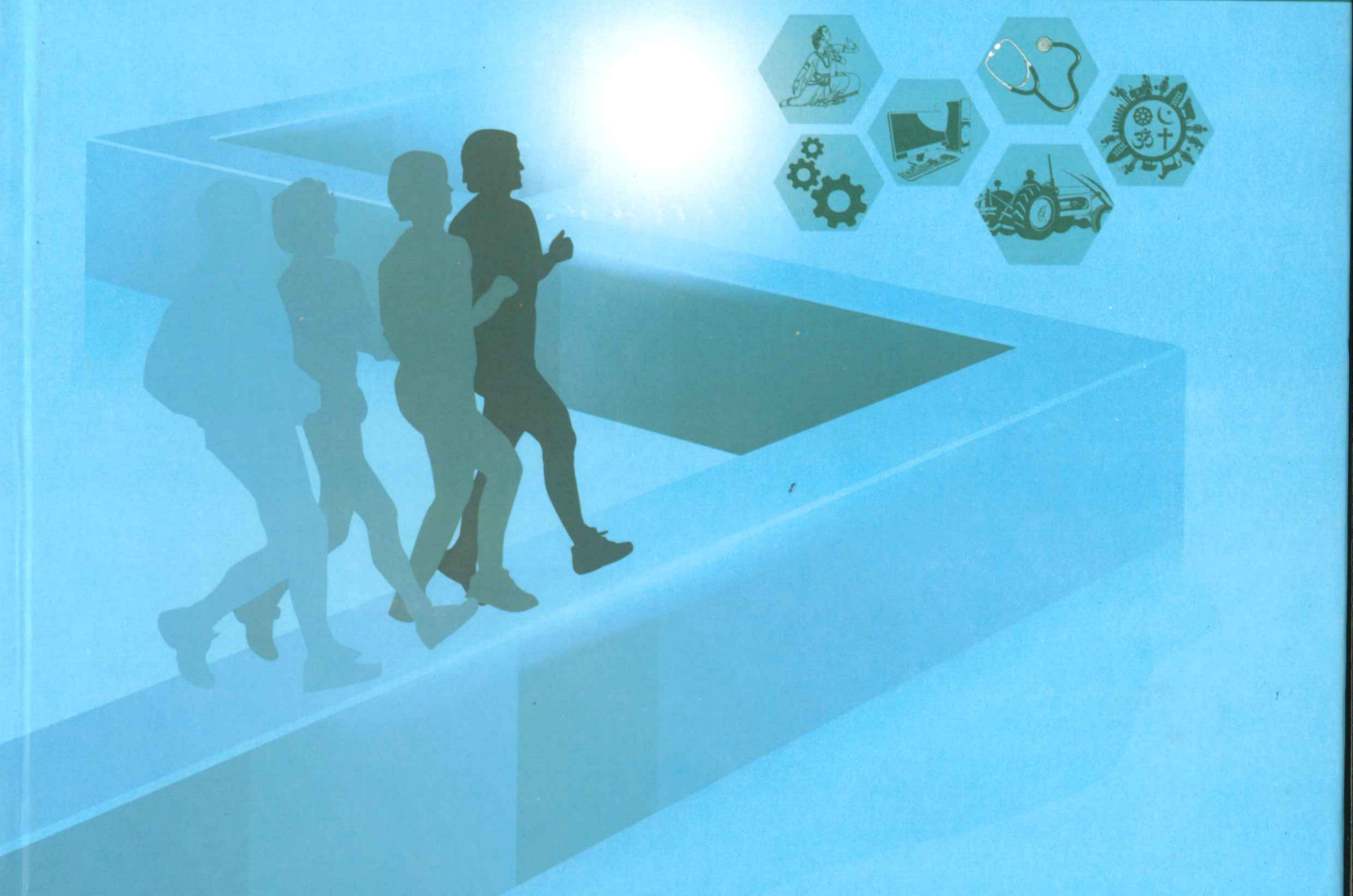

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Modelling the Crop Water Requirement in Batticaloa District, Sri Lanka: FAO-Cropwat Modelling for Rice

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***Abstract*— Agriculture still the leading source of livelihood and contributes a great percentage to national income for most developing countries around the world. Since agriculture is the major user of water, improving agricultural water management is essential to any irrigation management approach specially to apply the exact amount of water to the field in order to meet crop water requirement. This study aims to estimate water requirement of rice by using the model CROPWAT. In this study, water requirement of rice for the two seasons were studied. The results show that, Batticaloa district receives around 1060mm effective rainfall per year. ET_O value ranged between 3.07 and 4.57mm/day during December to April respectively. ET_C value recorded as 1.76 to 3.66 mm/day during November to January respectively. In Maha season, crop water requirement of rice increases at the rate of 1.85 mm/day at initial stage to 3.3 mm/day in the mid stage of growth. The water requirement of rice decreases from 3.46 mm/day in the late- season to 3.03mm per day during the period of harvesting. In Yala season, ET_C values were recorded as in between 2.13 to 4.5 mm/day during the period of May to July. The water requirement of rice decreases from 4.5 mm/day to 3.29 mm per day during the late season to the period of harvesting. According to the study, effective rainfall were found to be 601.4 and 298.5 mm/ decade in Maha and Yala season respectively, and total crop water requirement are 349.2 and 436.7 mm/ decade in Maha and Yala season respectively. Therefore the model for planning of irrigation water requirements of rice is very important for efficient utilization of water and to meet the possible change of climate in agricultural sector.**

Keywords — Cropwat, effective rainfall, evapotranspiration, rice water requirement

I. INTRODUCTION

Rice, the basic food of Sri Lanka, is the most important source of employment and income of the rural population [1]. Major constrains to meet the increasing food demands of the population are scarcity of irrigation water and land availability for crop production [2]. Water is important for plant growth and food production. Since, there is competition between municipal, industry users and agriculture for the finite amount of available water, estimating irrigation water requirements accurately is important for water project planning and management [3]. Therefore, field measurements are needed to find the crop water requirement of a particular crop. Owing to practical difficulties in obtaining accurate field measurements for ET_C, prediction methods are commonly used. However, these methods often need to be applied under climatic and agronomic conditions different from those under which they were originally developed. Testing the accuracy of the methods under a new set of conditions is laborious, time consuming and costly. To overcome such difficulties, guidelines were formulated by FAO to calculate ET_C of crops under different climatic and agronomic conditions [4]. Batticaloa District has many agriculture activities such as Paddy, vegetables, chilies and other crop cultivation. Paddy is the major cultivation for farmers in this district. Their basic economy and food is mainly depending on rice production. The study area's paddy cultivation is also affected by the rainfall fluctuation and the scarcity of irrigation water which lead to number of problems in paddy production and human life. It is also a major problem in primary economic activities. Therefore, improved practices on cultivation and the adoption of new technology against water scarcity are important to get optimum yield of the crop. In this view, efficient application of water based on the crop water requirement is identified as one of the adoptation techniques to solve the water scarcity problem in the study area. There is lack of information with respect to Batticaloa district on crop water requirements and the shortfall of data at a regional scale. Hence, this study made an attempt to compute the crop water requirements of rice in Batticaloa district in Sri Lanka using CROPWAT 8.0 [5].

II. MATERIALS AND METHODS

Study location

This study was conducted in Batticaloa district that belongs to eastern province of Sri Lanka. The geographical coordinates of the Batticaloa district is 7°34′ N, 81°41′ E.

Selection of model

In this study, CROPWAT model was selected for the computation of crop water requirement and irrigation scheduling for rice in Batticaloa district. CROPWAT 8.0 was used to calculate reference evapotranspiration using climatic variables such as maximum and minimum temperature, sunshine hour, rainfall, relative humidity and wind speed.

CROPWAT model input data

The basic input data for CROPWAT model are the climatic parameters which are required for calculating Reference Evapotranspiration. Researchers proposed several methods to determine evapotranspiration out of which the Penman-Monteith Method [6] has been recommended as the appropriate combination method to determine the crop water requirements using climatic data such as temperature, humidity, sunshine and wind speed. FAO Penman-Monteith method [6] was used in the present study for determining reference crop evapotranspiration (ET_O) since it has been reported to provide values that are very consistent with actual crop water use data worldwide [7].

Station data

Table 1: Batticaloa district location

Country	Sri Lanka
Station	Batticaloa
Altitude	8.53 m
Latitude	7.34 ºN
Longitude	81.41 ºE

Climate data

Following long-term meteorological data were collected from meteorological department.

- Maximum Temperature and Minimum Temperature (Celsius)
- Maximum Relative Humidity and Minimum Relative Humidity (%)
- Wind Speed (kmph)
- Sunshine Hours (Hrs)

Table 2: Climate data

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Mean RH (%)	Wind speed (km/h)	Sunshine hours (Hour)
January	27.53	23.21	81	14.3	6.4
February	28.20	23.22	80	13	7.9
March	29.70	23.90	79	10.9	8.8
April	31.11	24.90	78	9.5	8.6
May	32.40	22.50	73	9.2	8.4
June	33.60	25.40	68	9.3	8.4
July	33.20	25.00	69	9.8	8
August	32.50	24.80	71	9.7	8.3
September	32.10	24.60	73	9.7	8.3
October	30.60	24.10	79	9.5	7.5
November	29.00	23.50	82	10.4	6.7
December	27.81	23.20	83	12.9	5.6

Rainfall Data

Average monthly rainfall data were collected from meteorological department to find out the effective rainfall to calculate the crop water requirement and irrigation scheduling.

Table 3: Rainfall data

Month	Rainfall (mm)
January	279.1
February	178.3
March	84.8
April	72.4
May	31.2
June	18.5
July	37
August	61.7
September	61.7
October	178.1
November	285.2
December	429.8

Crop data

The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Crop coefficient values (Kc) were taken from available published data. Based on the published information following crop data were collected.

Table 4: Crop data (Rice)

	Stages				
	Initial	Development	Mid	Late	Total
Kc value	0.5	-	1.05	0.7	-
Stages (days)	20	30	40	30	120
Rooting depth (m)	0.10	-	0.60	0.60	-
Critical depletion (fraction)	0.20	-	0.20	0.20	-
Yield response	1.00	1.09	1.32	0.50	1.10

Soil data

The Soil module is essential data input, requiring the general soil data like Total Available Water (TAW), maximum infiltration rate, maximum rooting depth, initial soil moisture depletion. In case of calculation of rice water requirement, additional soil data are required such as drainable porosity, critical depletion for puddle cracking, water availability at planting, maximum water depth. Based on the published data, Batticaloa district has wide range of Reddish Brown Earths, Non-calcic Brown soil and Low-humic gley soils in the paddy land. However, major soil type in paddy lands are clay in texture [8], [9].

Table 5: Soil data (Clay)

Soil name	Clay
Total available soil moisture (FC- WP)	150 mm/m
Maximum rain infiltration rate	62 mm/day
Maximum rooting depth	60 cm
Initial soil moisture depletion (as % TAM)	0 %
Initial available moisture	150 mm/meter

Source: [10], [11] and [12].

III. RESULTS AND DISCUSSION

1. Effective Rainfall

Table 6 show the average monthly rainfall and effective rainfall in mm. Effective rainfall was calculated by USDA method in CROPWAT 8.0. Batticaloa district receives around 1060.1 mm effective rainfall per year. Highest value of effective rainfall is observed in December (168mm) and lowest value of effective rainfall is observed in June (18mm). Rainfall reduces irrigation water requirement on the ground. Therefore, there are chances for water saving. For agricultural production, effective precipitation refers to the portion of rainfall that can be effectively stored in the root zone after the losses such as runoff (RO) and deep percolation (DP) [13]. Therefore, paddy cultivation needs irrigation water in mid of the year (April to August) but rain water is sufficient in November to February for paddy cultivation in Batticaloa District. During the dry period higher percentage of available rainfall is effectively stored in the root zone because, the absorbance capacity of soil is high due to dry nature of the soil. During rainy season, especially during December and January soil reached its saturation capacity very often, therefore there is a chance for runoff losses. Therefore, percentage of effective rainfall in relation to the receiving rainfall is less during this period compared to the dry season months.

Table 6: *Effective Rainfall*

	Rainfall	**Effective rainfall**
	mm	mm
January	279.1	152.9
February	178.3	127.4
March	84.8	73.3
April	72.4	64
May	31.2	29.6
June	18.5	18
July	37	34.8
August	61.7	55.6
September	61.7	55.6
October	178.1	127.3
November	285.2	153.5
December	429.8	168
Total	1717.8	1060.1

2. Reference Evapotranspiration

Table 7 shows the average monthly reference evapotranspiration (ET_O). ET_O value recorded as a range in between 3.07 to 4.57mm/day during December to April. Maximum amount of temperature and sunshine hours lead to higher values of ET_O in mid of year [14]. Therefore, reference evapotranspiration directly affects the crop water requirement or crop evapotranspiration in mid of the year, leads to high irrigation water requirement during April to August.

Table 7: Reference Evapotranspiration

Month	**Rad**	**ETo**
	MJ/m²/day	**mm/day**
January	17.4	3.3
February	20.7	3.9
March	23	4.45
April	22.7	4.57
May	21.8	4.26
June	21.3	4.26
July	20.8	4.24
August	21.9	4.42
September	22.1	4.46
October	20.2	4.06
November	18	3.52
December	15.9	3.07
Average	20.5	4.04

3. Effective rainfall and References Evapotranspiration

Figure 1 shows the relationship between effective rainfall and reference evapotranspiration in Batticaloa district. It shows that the negative relationship between effective rainfall and references evapotranspiration. Because atmospheric temperature and sunshine hours are low in rainy season. So it will lead to reduce the evaporation and transpiration. Therefore, increasing rainfall will reduce the reference evapotranspiration in paddy land.

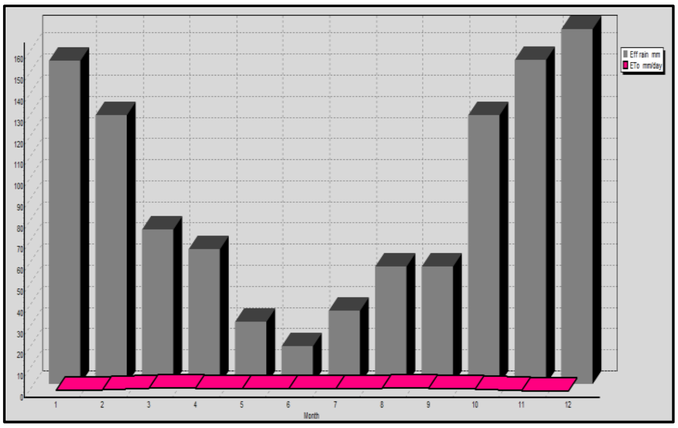

Fig 1: Effective rainfall and References Evapotranspiration

4. Crop water requirement in Maha season

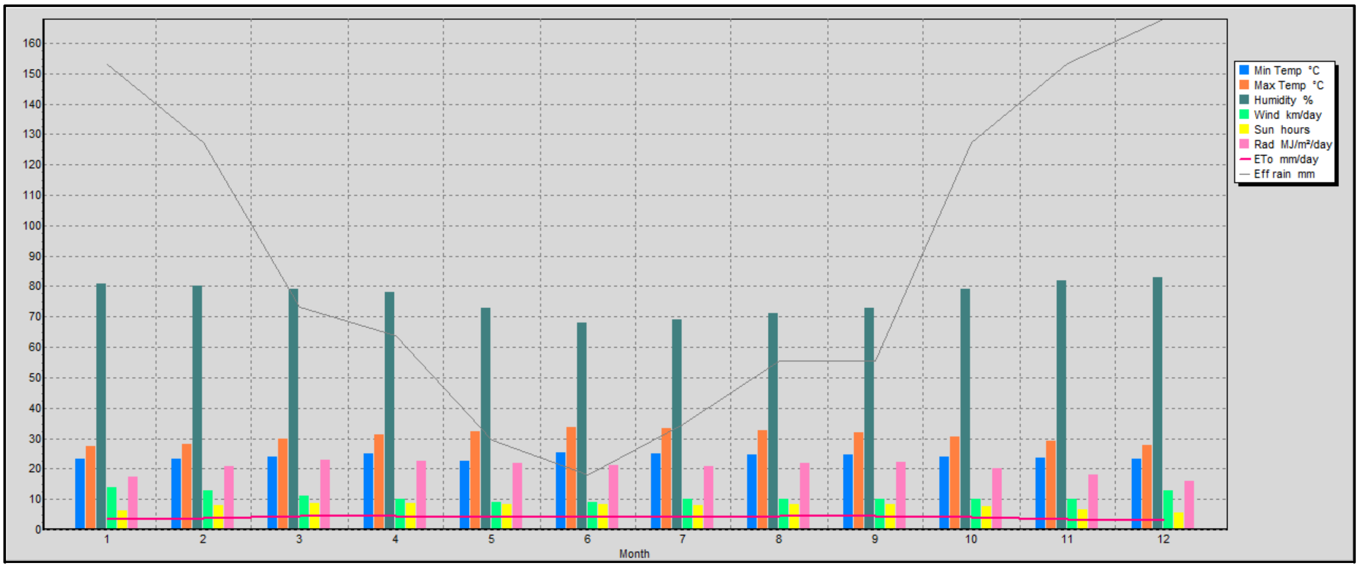

Fig 2: Climate data, reference evapotranspiration and effective rainfall

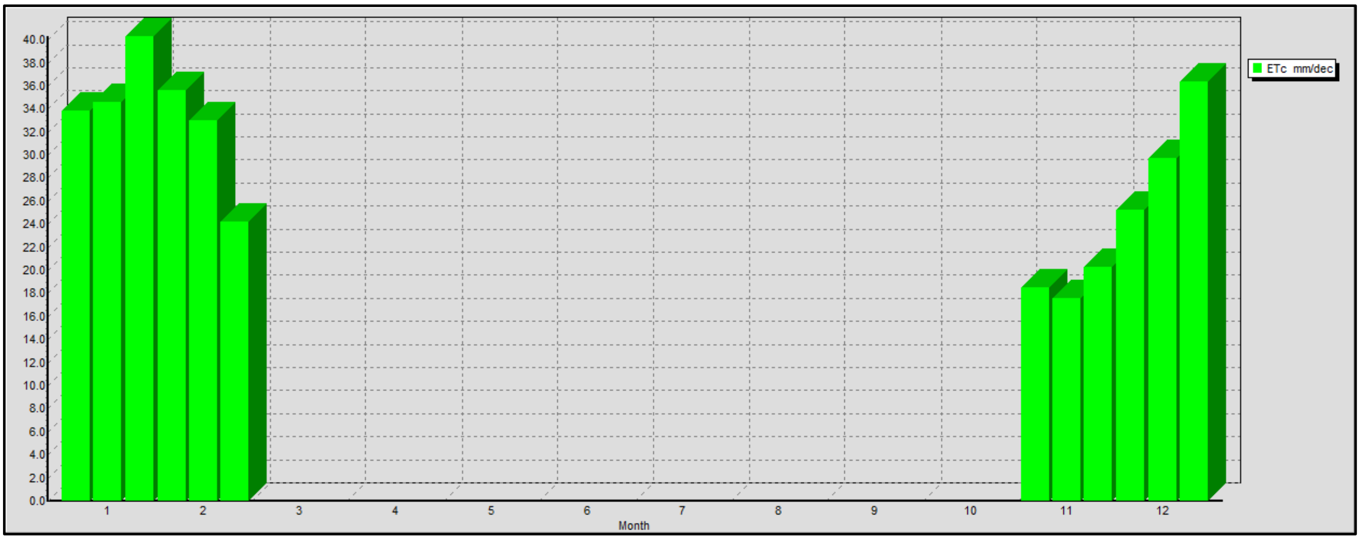

Fig 3: Crop evapotranspiration

Figure 2 shows the relationship between Climatic condition, effective rainfall and reference evapotranspiration in Batticaloa district. According to the graph, amount of rainfall is low in mid of the year with increased temperature. Rainfall amount is high in October to January with decreased temperature. This trend lead to increases the evapotranspiration rate in mid of year. Therefore crop water requirement is higher in mid of year (November to February). ET_C value recorded as a range between 1.76 to 3.66 mm/day during November to January. In the initial stage, water requirements for the rice is only about 1.85 mm per day. Crop water requirement increase from initial stage to mid stage from 1.85 to 3.3mm per day respectively. Then, it further increases from 3.3 mm to 3.46 mm per day during the mid-season stage where the rice consumes much water for growing and reaches its maximum height. Finally, the water requirement of rice decreases from 3.46 to 3.03mm per day in the late- season, which is the period of ripening. This is also the time for draining water for the harvesting of paddy. [13] also mentioned that in the initial stage, the rice needs only about 60 mm per decade to compensate for the water requirements of crops. It can be explained that the rice crop began to consume much water during the growing period. The water requirement of rice decreases linearly from 56.2 mm to 46.7 mm at the end of the decade during the growth phase where the rice demand maximum water for growing. Then, it increases from 39 mm to 48 mm at the beginning of the mid-season stage where the rice consumes much water for growing and reaches its maximum height.

Table 8: Crop water requirement in Maha season

Month	Decade	Stage	Kc	ETc	ETc	Eff rain
			coeff	mm/day	mm/dec	mm/dec
Nov	1	Init	0.5	1.85	18.5	48.6
Nov	2	Init	0.5	1.76	17.6	51.7
Nov	3	Deve	0.6	2.03	20.3	53.1
Dec	1	Deve	0.78	2.53	25.3	55.3
Dec	2	Deve	0.97	2.97	29.7	57.3
Dec	3	Mid	1.05	3.3	36.3	55.2
Jan	1	Mid	1.05	3.38	33.8	52.9
Jan	2	Mid	1.05	3.46	34.6	51.4
Jan	3	Late	1.05	3.66	40.3	48.4
Feb	1	Late	0.96	3.56	35.6	46.2
Feb	2	Late	0.85	3.3	33	43.8
Feb	3	Late	0.74	3.03	24.2	37.4
Total					**349.2**	**601.4**

5. Crop water requirement in Yala season

Table 9 shows the crop water requirement during planting to harvesting period (May to August). ET_C value recorded as the range in between 2.13 to 4.5 mm/day during the period of May to July. In the initial stage, the rice needs only about 2.18 mm per day as the water requirements. Crop water requirement increase from 2.18 to 4.2 mm per day during initial stage to mid stage respectively. Then, it further increases from 4.2 mm to 4.45 mm per day during the entire period of the mid-season stage where the rice consumes much water for growing and reaches its maximum height. Finally, the water requirement of rice decreases from 4.5 to 3.29 mm per day in the late-season, the period of ripening. This is also the time for draining water for the harvest. Similar data recorded by [13].

According to the table 9, total crop water requirement is 436.7 mm/ decade but effective rainfall is 133 mm/ decade throughout the growing period. Therefore, irrigation should be needed to fulfill the rice water requirement (298.5 mm/ decade).

6. Comparison of crop water requirement in Maha and Yala season

According to the table 8 effective rainfall is 601.4 and 298.5 mm/ decade in Maha and Yala season respectively and total crop water requirement are 349.2 and 436.7 mm/ dec in Maha and Yala season respectively. This data shows that, in Yala season (dry season), the crop water requirement is higher than Maha season (rainy season). The FAO [5] also reported that, crops grown in the dry season needs more water than those grown during the rainy season.

Table 9: Crop water requirement in Yala season

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.5	2.18	21.8	13	8.8
May	2	Init	0.5	2.13	21.3	8.8	12.5
May	3	Deve	0.61	2.6	28.6	7.9	20.7
Jun	1	Deve	0.8	3.42	34.2	6.4	27.8
Jun	2	Mid	0.98	4.2	42	4.7	37.3
Jun	3	Mid	1.05	4.47	44.7	7	37.7
Jul	1	Mid	1.05	4.46	44.6	9.6	34.9
Jul	2	Mid	1.05	4.45	44.5	11.5	33
Jul	3	Late	1.05	4.5	49.5	13.8	35.7
Aug	1	Late	0.96	4.2	42	16.9	25.1
Aug	2	Late	0.85	3.74	37.4	19.5	17.9
Aug	3	Late	0.74	3.29	26.3	13.9	7.1
					436.7	**133**	**298.5**

IV. CONCLUSIONS

This paper summarizes the conclusions carried out by results and analysis of determination of crop water requirement and irrigation scheduling in Batticaloa district in Sri Lanka using CROPWAT 8.0. The FAO Penman-Monteith method used to evaluate the reference evapotranspiration and irrigation scheduling for rice cultivation in Batticaloa district. Climate data, soil data and crop data are used to determine the crop water requirement and irrigation scheduling. This will be a tool for effective irrigation planning and management. This study hence shows a more important of the CROPWAT irrigation management model could be used effectively and efficiently to estimate the agricultural water requirements for rice. The results show that the lowest ET_O and ET_C were obtained in rainy season (December) due to the presence of clouds and receiving rainfall while the highest ET_O and ET_C were obtained in dry season (June) as a result of hot dry weather due to the dryness of the air and the maximum sunshine hours. As far as the variation of ET_O with climatic parameters are concerned, solar radiation has highest effect on ET_O since it provides the energy needed for evapotranspiration. It was found that, crop water requirement is higher than effective rainfall in Yala season and crop water requirement is lower than the effective rainfall in Maha season. Therefore, irrigation is vital during the Yala season to fulfill the rice water requirement. This study concluded that the model for planning of irrigation water requirements of rice is very important for efficient utilization of water and to meet the possible change of climate in agricultural sector. Therefore, one of the best strategies to achieve this is the application and utilization of the rapid growing technologies in Information and Communication Technology. Therefore, introduction and use of this CROPWAT software is very useful in water management of paddy as well as other crops cultivated in the dry zone of Sri Lanka. It is also suggested to study further on the water requirement of different varieties of the paddy as well as vegetable crops at different zones or districts.

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