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Research Article

COMPARISON OF REFERENCE EVAPOTRANSPIRATION IN SEMI-ARID REGION

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Abstract- The reference evapotranspiration calculation is important to find out the evaporative demand of the atmosphere. It is not dependent on crop types, development and management practices. Various methods are available to estimate reference evapotranspiration (ET_0) from standard meteorological observations. The Penman-Monteith method is considered to be the most physical and reliable method and is often used as a standard to verify other empirical methods [1]. In this study, the values of Reference Evapotranspiration ET_o by FAO Penman-Montieth equation, CROPWAT 8.0 software, and Pan evaporimeter data for the period of June 2015 to May 2016 Agricultural Engineering College and Research Institute, Kumulur, Trichy was compared. The calculation of ET_0 with FAO Penmann Monteith method was done in Excel and the values of ET_0 varied from 4.5mm/day to 6.21 mm/day. The ET_o value was 3.93mm/day to 6.16 mm/day when calculated through CROPWAT 8.0 software. The ET_o value for using the Pan Evaporimeter data varied from 2.2mm/day to 6.7 mm/day. ET_o values calculated from the three methods were compared and shown in graphical format.

Keywords- Reference Evapotranspiration, FAO Penman Montieth Method, Crop Wat, Pan Evaporation Method.

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Introduction

The evapotranspiration rate from a reference surface, is called the reference crop evapotranspiration (ETo) [1].

Study of evapotranspiration is very much important for irrigation scheduling of crops, water resources planning etc. The reference evapotranspiration multiply with crop coefficient value give the actual crop evapotranspiration rate and this can be used for irrigation scheduling [5].

Meteorological data are required to estimate reference evapotranspiration (ET_0). There are many methods are available to calculate reference evapotranspiration. The Penman-Monteith method is considered to be the most physical and reliable method and is often used as a standard to verify other empirical methods [3].

The FAO Penman-Monteith method is the standard method for computation of the reference evapotranspiration. The FAO Penman-Monteith method requires weather parameters like radiation, air temperature, air humidity and wind speed data. The United Nations food agriculture organization (FAO) adopted the Penman-Monteith method as global standard to estimate reference crop (ETo) from meteorological data [5]

Reference evapotranspiration (ET0) estimates have been computed on a global scale using a high-resolution monthly climate dataset with Penman-Monteith and Hargreaves method and the results showed very reasonable agreement between the two methods [4]. Four reference evapotranspiration (ETo) equations are compared using weather data from 37 agricultural weather stations across the state of California. The Hargreaves equation compared well to the FAO Penman–Monteith method [7]. Adopting the FAO Penman–Monteith (FAO-PM) equation as the standard for ETo estimation, an attempt was made to predict daily ETousing the public weather forecast messages available in China[2].Reference evapotranspiration (ET0) equations like Hargreaves, Thornthwaite, Turc, Priestley–Taylor, and Jensen–Haise were evaluated using data from different humid locations. From the results obtained it was found that the Turc equation is most suitable for estimating reference evapotranspiration at humid locations when weather data are insufficient to apply the FAO-56 PM equation [8].

The objective of this study is to compare the values of Reference Evapotranspiration ETo by FAO Penman-Montieth equation, CROPWAT 8.0 software, and Pan evaporimeter data for the period of June 2015 to May 2016 Agricultural Engineering College and Research Institute, Kumulur, Trichy.

Materials and Methods

The meteorological data for the period June 2015 to May 2016 were collected from the Department of Applied Sciences and Engineering, Agricultural Engineering College and Research Institute, Kumulur, Trichy. The study area Kumulur is located 10.9^{0}N latitude and 79.82^{0}E longitude with altitude of 62 m from MSL. For Kumulur Station, the reference evapotranspiration was estimated using the following three methods:

FAO Penman-Monteith Method

The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data. The humidity values were found out using psychrometric chart using the wet bulb and dry bulb temperature data. The FAO Penman-Monteith equation is follow as:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{---------- [1]}$$

where, ET_o is reference evapotranspiration (mm day^{-1}), R_n is net radiation at the crop surface (MJ m^{-2} day^{-1}),G is soil heat flux density (MJ m^{-2} day^{-1}), T is mean daily air temperature at 2 m height (°C), $u_2$is wind speed at 2 m height (m s^{-1}), e_s is saturation vapour pressure (kPa),e_a is actual vapour pressure (kPa), e_s-e_a is saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve (kPa $°C^{-1}$) and γ is psychrometric constant (kPa $°C^{-1}$). In which all the parameters were calculated from the proposed formulae using spreadsheet.

Pan Evaporation Method

ETo were estimated from pan evaporation data observed during the study period. The water loss from the pan was observed on daily basis. ETo was estimated from the Pan evaporation data multiplied by pan coefficient value. However, special precautions and management must be applied [9]. The pan evaporation is related to the reference evapotranspiration by an empirically derived pan coefficient:

$$ET_o = K_p E_{pan} \quad \text{---------- [2]}$$

where ET_o is reference evapotranspiration [mm/day], $K_p$ispan coefficient, E_{pan}ispan evaporation [mm/day].The values of pan evaporation were collected from meteorological observatory records and ET_o was calculated.

CropWat8.0

CropWat8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. In this study, using CROPWAT program, reference evapotranspiration was calculated. The input data required and the output obtained in the CROPWAT program is given in [Table-1].

Table-1 *Input and Output for CROPWAT program*

Data	Input	Output
Climatic	Monthly means of minimum and maximum temperature, relative humidity, sunshine duration, wind speed Rainfall data (Monthly)	Reference Evapotranspiration Crop water requirement, Irrigation requirement

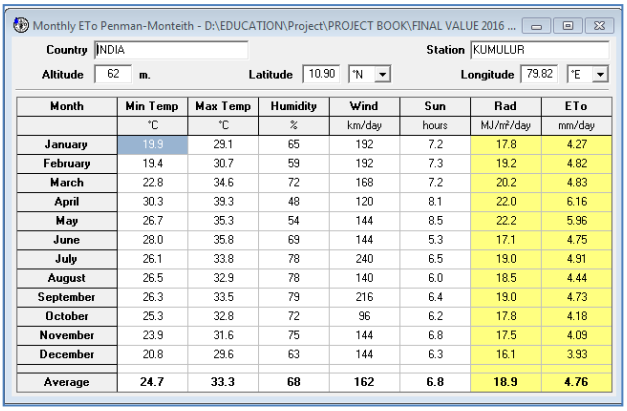
The following [Table-2] are the notes for conversion of the climatic data provided by meteorological observatory (MO) of Kumulur Station to the units required for CROPWAT 8.0: The Climate module should be selected by clicking on the "Climate/ETo" icon in the module bar located on the left of the main CROPWAT window. The default data type (Monthly / Decade / Daily values) will be opened in the data Window. By using drop down menu it is possible to change another data type from the "New" button on the toolbar. In alternative, use the "New" button in the "File" drop down menu.

The module is primary for data input, requiring information on the meteorological station (country, name, altitude, latitude and longitude) together with climatic data. CROPWAT 8.0 can calculate reference ET_o using only temperature, but humidity, wind speed and sunshine should be entered if available.

Table-2 *Conversion of the Climatic Data*

Data	Note
Temperature data	
MO	Mean Daily Maximum and Minimum Temperature, (° C)
CROPWAT	Maximum and Minimum Temperature, (° C)
Conversion	No conversion was needed
Humidity data	
MO	Wet bulb and dry bulb temperature values (° C) were used and RH (%) values were found out using psychrometric chart
CROPWAT	Average daily Relative Humidity (in percentage)
Conversion	No conversion was needed
Sunshine data	
MO	hours of bright sunshine
CROPWAT	Sunshine hours (heliograph) or sunshine percentage
Conversion	No conversion needed
Wind speed data	
MO	Average Daily Windspeed in km/hour
CROPWAT	Average Daily Windspeed in km/day or m/sec
Conversion	WS km/day = 24 x WS km/hour

After checking the data for possible errors, Climate/ET_o data can be saved selecting the "Save" button on the Toolbar or the "File" > "Save" menu item. It is important to give an appropriate name to the data set which can easily be recognized later. The CropWat calculation window is shown in [Fig-1].



Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	19.9	29.1	65	192	7.2	17.8	4.27
February	19.4	30.7	59	192	7.3	19.2	4.82
March	22.8	34.6	72	168	7.2	20.2	4.83
April	30.3	39.3	48	120	8.1	22.0	6.16
May	26.7	35.3	54	144	8.5	22.2	5.96
June	28.0	35.8	69	144	5.3	17.1	4.75
July	26.1	33.8	78	240	6.5	19.0	4.91
August	26.5	32.9	78	140	6.0	18.5	4.44
September	26.3	33.5	79	216	6.4	19.0	4.73
October	25.3	32.8	72	96	6.2	17.8	4.18
November	23.9	31.6	75	144	6.8	17.5	4.09
December	20.8	29.6	63	144	6.3	16.1	3.93
Average	24.7	33.3	68	162	6.8	18.9	4.76

Fig-1 CropWat 8.0 window

Results and Discussion

The reference evapotranspiration calculated from the three methods were presented in the following tables. The calculation of ET_0 with FAO Penman Monteith method was done in Excel and the results are shown in [Table-3]. The values of ET_0varied from 4.5 mm/day - 6.21 mm/day. The ET_o values was calculated as 2.7 mm/day for January month and 6.7 mm/day for May month while using the Pan Evaporimeter data. ET_o values calculated from the three methods are given in [Table-5]. The graphical variation of the ET_o values are shown in [Fig-2]. From the [Fig-2] it was found that the estimated ET_o values from the CropWat 8 computer program was similar to the FAO Penman Monteith Method.

Table-3 *ET_O Values using FAO Penman Monteith Method*

Month	Δ [kPa °C^{-1}]	R_n [MJ m^{-2} day^{-1}]	G [MJ m^{-2} day^{-1}]	γ [kPa °C^{-1}]	T [°C]	U_2 [m s^{-1}]	Es [kPa]	E_a [kPa]	ET_0 [mm day^{-1}]
JAN	0.20	8.447E+00	0.134	0.07	26.13	2.960	3.51	2.28	4.22
FEB	0.22	1.040E+01	0.262	0.07	28	2.960	3.93	2.83	4.41
MAR	0.23	1.103E+01	0.094	0.07	28.67	2.590	4.13	2.93	4.63
APR	0.31	1.221E+01	0.858	0.07	34.8	1.850	5.71	2.97	5.80
MAY	0.24	1.189E+01	-0.752	0.07	29.43	2.220	4.60	2.39	6.21
JUN	0.27	8.419E+00	0.351	0.07	31.94	2.220	4.84	3.68	3.61
JUL	0.27	9.813E+00	0.035	0.07	32.19	3.700	4.95	3.27	5.47
AUG	0.26	9.447E+00	-0.109	0.07	31.41	2.220	4.74	2.98	4.72
SEP	0.25	9.441E+00	-0.069	0.07	30.92	3.330	4.59	3.08	5.00
OCT	0.23	9.285E+00	-0.262	0.07	29.05	1.480	4.11	2.92	3.77
NOV	0.21	5.746E+00	-0.298	0.07	26.92	2.220	3.60	2.81	2.66
DEC	0.19	8.004E+00	-0.245	0.07	25.17	2.220	3.39	2.98	2.67

Table-4 *ET_O Values using Pan Evaporation method*

Month	Evaporation	K_{pan}	ET_0(mm/day)
JAN	4.5	0.6	2.7
FEB	4.7	0.6	2.8
MAR	7.8	0.7	5.4
APR	8.2	0.7	5.7
MAY	8.4	0.8	6.7
JUNE	7.7	0.8	6.2
JULY	7.2	0.8	5.7
AUG	6.7	0.8	5.4
SEPT	5.8	0.7	4.0
OCT	4.7	0.7	3.3
NOV	4.1	0.6	2.6
DEC	3.7	0.6	2.2

Table-5 *Comparison the $ET_0$from FAO, Pan Evaporation and CropWat 8.0*

Month	Reference Evapotranspiration (ET_0)		
	FAO Penman Monteith Method	Pan evaporation method	CropWat 8.0
JAN	4.22	2.70	4.27
FEB	4.41	2.82	4.82
MAR	4.63	5.46	4.83
APR	5.80	5.76	6.16
MAY	6.21	6.73	5.96
JUNE	3.61	6.22	4.75
JULY	5.47	5.78	4.91
AUG	4.72	5.42	4.44
SEPT	5.00	4.07	4.73
OCT	3.77	3.35	4.18
NOV	2.66	2.60	4.09
DEC	2.67	2.20	3.93

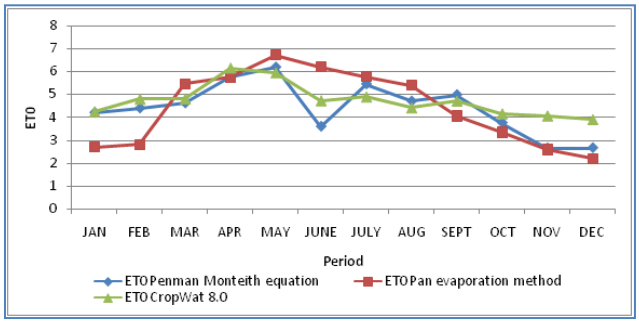


Fig-2 Comparison of ET_0 Value obtained by FAO, Pan Evaporation and CropWat 8.0

Conclusion

From the monthly meteorological weather data recorded from June 2016 to May 2017the comparison results. Reference crop Evapotranspiration (ET_o) calculated from the FAO Penman – Monteith the best method to estimate ET_o because of its inclusion of parameters in calculation. It is found that the ET_o estimated from the CropWat 8 computer program found to be similar to the FAO Penman Monteith Method. Values of reference evapotranspiration are used with crop coefficients for irrigation and water resources planning and management.

Application of research: Estimation of crop ET is very much essential for irrigation scheduling of crop. Hence suitable method should be chosen based on the agro climatic region for estimation of evapotranspiration.

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Author Contributions: All author equally contributed

Abbreviations:

- ET - Evapotranspiration
- K_c - crop coefficient
- K_p- pan evaporation
- FAO – Food and Agricultural Organization

Conflict of Interest: None declared

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