A PROCEDURE FOR ESTIMATING EVAPOTRANSPIRATION AND COMPARISON OF VARIOUS MODELS FOR CROP WATER REQUIREMENT AT KANCHEEPURAM DISTRICT

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Abstract—

Daily and mean weekly output from seven evapotranspiration models with original constants (FAO-24 Blaney-Criddle, Hamon, Pristiey taylor , Hargreaves, Jenson-Haise, Romanenko and Turc), have been tested against reference evapotranspiration data computed by FAO Penman-Monteith model to assess the accuracy of each model in estimating gross reference evapotranspiration in Tamil Nadu. Models were compared at fourteen stations of the India Meteorological Department observatories using data from 1981 to 1992. From the seven models, five models were selected for evaluation. The criteria for selection was, the values of cross correlation (R^2), intercept 'a' and slope 'b' of regression line. The constants of each selected model were recalibrated using three different procedures. In the first approach, it is assumed that the mean annual ET_o estimated by each selected model is equal to the mean annual ET_o estimated by the (PM) model. Therefore the percentage error between annual ET_o estimated by each selected model and that of PM model was determined. ET_o Value, equal in magnitude to the rate of percentage error was applied uniformly to mean daily ET_o for any one model considered. If the error is positive, correction is negative and vice versa. Then the adjusted ET_o was equated to the expression of the respective models by using the corresponding daily meteorological variable required for the models and the constant was calculated on daily basis. Yearly average and the averages for the period were determined, model wise, for all locations. The constant values thus obtained were averaged, considering the frequently occurred values and also the values near to it, to obtain a unique value of the constant for each model. Assumption in the second approach was that the percentage error in ET_o of any one model and the PM model is zero. The procedure described in the first approach was followed in determining the constant, model wise for the region.

Keywords:Evapotranspiration, Penman-Monteith model, Estimating gross reference, Crop water requirement

I. INTRODUCTION

The most plausible means of mitigating the scarcity of water in different regions of the world is through increasing the productivity of existing water resources and produce more food with less quantity water. Increase in water productivity provides a means both to ease water scarcity and to leave more quantity water for other human and ecosystem usage. Irrigated agriculture underwent exponential growth over the past century periods - from 50 M ha globally in 1900 to 267 M ha in 2000. Similarly, the water usage by crops- dominated by the irrigation-saw a parallel rate of growth from about 40 cubic KM to 3,700 cubic KM during the same period. Asian countries use between 80 - 90 percentages of their developed water resources towards meeting the water requirements of the crops cultivated. These demands are likely to further enhance to satisfy the increasing food demands of very large and ever increasing populations.

II. CROP WATER REQUIREMENTS

Crop water use, consumptive use and evapotranspiration (ET) are the terms that are used interchangeably to describe the total water were spent by a crop. The requirement of Water depend mainly on the nature and stage of growth of the crop and environmental conditions. Different crops have different total water-use requirements under the same weather and climatic conditions. Hence the crop coefficients appropriate to the specific crops are used along with the values of reference evapo-transpiration for computing the consumptive use at different growth stages of the crop by water-balance approach. Crops will transpire water at the maximum rate when soil water is at field capacity. When soil moisture were decreases, crops have to exert energy to extract water from soil. Usually, the transpiration percent rate does not decrease significantly until the soil moisture falls below 50% of field capacity. The evapotranspiration (ET in mm) of a crop under irrigation is obtained by the following equation:

$$ET_c = K_c * Et_o$$

Where, Et_o is the reference evapo-transpiration and Kc is the crop coefficient.

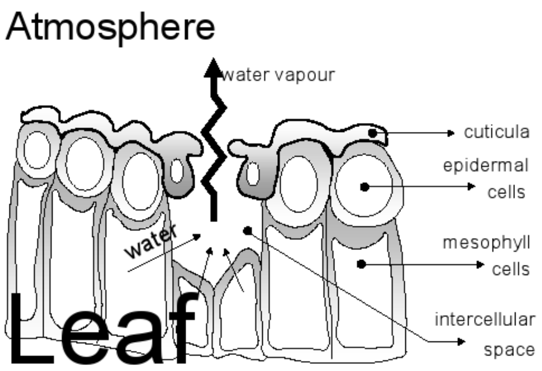


Fig 1: Schematic representation evapotranspiration of a stoma in the plant Courtesy FAO Irrigation and Drainage Paper No. 56

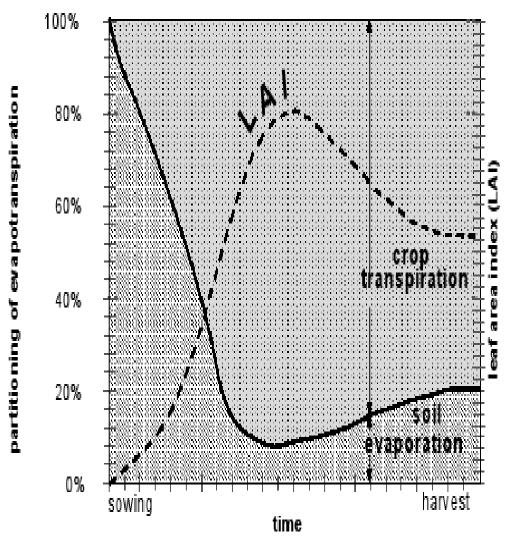


Fig.2: The partitioning of evapotranspiration into evaporation and transpiration over the growing period for an annual field crop Courtesy FAO Irrigation and Drainage Paper No. 56

III. STUDY AREA

Fig.3. Study area - Kancheepuram district

Kancheepuram district is situated on the northern East Coast of Tamil Nadu and is adjacent by Bay of Bengal and Chennai city and is bounded in the west by Vellore. South by Villuppuram district and Thiruvannamalai district, in the north by Thiruvallur district and Chennai district, in the in the east by Bay of Bengal. It lies between 11° 00' to 12° 00' North latitudes and 77° 28' to 78° 50' East longitudes. The d total geographical area of District is 4393.37 Sq.Kms and coastline of 57 Kilometers. Kancheepuram, the temple town is the District headquarters. Agriculture is the main occupation of the people with 47% of the population engaged in it. The major crop Paddy is cultivated in this District. Other crops like Groundnuts, Sugarcane, Cereals & Millets and Pulses are the other major crops. The pre-monsoon rainfall is almost uniform throughout the district. The coastal region of the district get more rains rather than the interior regions. This District is mainly depending on the21°C to 43°C and the minimum temperature ranges from 21°C to 25°C

IV. MODELS FOR ESTIMATION OF EVAPOTRANSPIRATION

To date, fourteen models are used to estimate reference crop ETo losses in allowable of consumptive usage. These models were evaluated, reviewed and compared to identify the approaches that:

1) Best represent of the physics of water losses from irrigated crops, 2) are easiest to use in terms of parameters needed, 3) consistently and accurately

capture ET losses in growing regions of Florida, and 4) are acceptable to the general scientific community.

Three general approaches to estimating reference crop ET considered were: temperature models and methods, radiation methods and combination methods. Generalized crop coefficient curve showing the evolution of the crop coefficient throughout the growing season, the basal Kc, and the effects of evaporation due to wetting events. (Taken from Wright, 1982, 1990)

Temperature Methods

The temperature methods are empirical equations that rely on air temperature model as a surrogate for the total amount of energy that is available of the reference crop for evapotranspiration. However, there is no direct of unique relationship between energy. And temperature. This limits the generality of the following temperature methods and models. The Local calibration of methods may provide some measurement of accuracy, particularly for some averaging periods on a monthly or seasonal basis.

Table 1. Model& Metrological Data

Model	Metrological Data Requirements
FAO PM (1998)	Air Temperature, Solar Radiation, Humidity, Wind speed
FAO- 24B – C(1977)	Air Temperature, Sunshine, Humidity, Wind speed
HAMON (1961)	Air Temperature
HARGREAVES (1988)	Air Temperature, Extra-terrestrial Radiation
LINARE (1977)	Air Temperature, Humidity
JENSON – HAISE (1970)	Air Temperature, Solar Radiation
ROMENANKO (1961)	Air Temperature
TURC (1961)	Air Temperature, Solar Radiation Humidity, ,

Soil Conservation Service (SCS) Modified Blaney-Criddle Method

The Blaney-Criddle equation was developed to estimate Evapotranspiration ETo losses in the western United States by the SCS (SCS, 1967). This is the method adopted by SFWMD to estimate evapotranspiration necessary to supplemental irrigation determination. The Blaney-Criddle method is simple, using accurate measurement data on temperature only. It should be noted and plotted that this method it is not very accurate. It provide a rough evaluation or order of the magnitude only. Jensen et Al. (1990) found the method and Thornthwaite, criticized to be among the poor temperature models. Below extreme climatic conditions the Blaney-Criddle method was mainly an inaccurate. In windy, dry, sunny areas, the reference ETo was under estimation. In calm, humid, clouded area, the reference ETo was over estimating. Permitting to the Blaney-Criddle Method, the Mathematical expression and formula for the consumptive usage of a crop for the growing period wise was given by

$$U = k * f \text{ ....Eqn} \qquad (3).$$

where:

U = consumptive Monthly water use of the crop, inches,

k = Empirical consumptive-use crop coefficient,

f = Monthly consumptive-use factor.

The consumptive practice factor was a product of mean monthly temperature and monthly ratio (%) of day light hours.

SFWMD Model

The SFWMD Model was based on the improved Blaney-Criddle Equation (SFWMD, 1997). The unique Blaney-Criddle method was estimated evapotranspiration by correlating average monthly temperature and percentage of daylight, to a crop's ETo. SFWMD.s calculation of crop ETo was identical to that calculated with the Modified of Blaney-Criddle method. The various between the two methods were the crop coefficients used by the models. The above formula, which describes the method used to determine a crop's monthly potential ETo, does not provide a separate estimate for the reference ETo. To decide the reference ETo, it was necessary to have an adjusted crop stage growth coefficient for the reference grass crop. SFWMD does not have such a coefficient. For the purpose of this study, the constants for pasture were applied.

Radiation Methods

The ET process was controlled by obtainable energy and the capability of evaporated water to be transferred from the surface. The transfer process was a function of the wind speed and the sum of water vapor in the air neighboring to the surface. Priestley and Taylor (1972) recognized that for a well-water surface that the extends over a large surface area, the Eto process was well described by net radiation, air temperature and pressure. However, the Jensen et al**.** (1990) found the radiation methods significantly underestimated ET for rates greater than 4 mm/day.

AGMOD Blaney-Criddle Model

The SWFWMD Agricultural Water Practice Model v2.0 (AGMOD) uses a Blaney-Criddle model to evaluation crop ET (Cohen, 1989). The AGMOD Blaney-Criddle model, also mentioned to as the modified-BlaneyCriddle method, was based on the Modified Blaney-Criddle method. The value-added Blaney-Criddle equation valued evapotranspiration by correlating average monthly temperature and percentage of daylight to a crop's ETo. Shih (1977) displayed that the Adapted Blaney-Criddle method gave more correct results in the Florida using solar radiation and modified crop coefficients. The SWFWMD method substitutes p, the monthly percent of daylight hours, with the monthly percent (%) of annual inward solar radiation. The change from percent daytime hours to percent inward solar radiation controls for Florida's humid climate and summertime convective systems. These systems reduction the energy accessible for evapotranspiration. The SWFWMD crop coefficients are around 85% of the original Blaney-Criddle coefficients. The reduced crop coefficients are in custody with Doorenbos and Pruitts (1977) references for wind and humidity alterations. The crop's once-a-month possible ETo was given by,

$$U_m = \frac{Kc[0.0173*t_m*-0.314]*t_m*R_m}{100} \quad \text{......Eqn (4).}$$

where: Um = Crop's monthly latent ETo, inches,

Kc = Adjusted crop growth stage coefficient,

t_m = Mean month temperature, ^oF, and

Rm = Monthly percentage of annual inward of the solare radiation.

The Hargreaves method (Hargreaves and Samani, 1985) of calculating daily grass reference ET was additional empirical methodology that has been used in cases where the availability of weather data was limited. The technique was recognized by Davis, California from a lysimeter study on Alta fescue grass. The unique Hargreaves formula estimates reference ET from solar radiation and temperature

F (u) = Wind related function,

e_a = Saturation vapor pressure(ea) at mean air temperature,

e_d = Mean actual vapor pressure(ed) of the air, m bar, and

c = Adjustment factor to account for day and night weather conditions.

ASCE-Penman Monteith 2000

The ASCE Evapotranspiration in Irrigation and Hydrology Commission (ASCE-ET) endorses, for the intended purpose of establishing uniform evapotranspiration (ET) estimates and transferable crop coefficients, the dual standardized reference evapotranspiration surfaces: (1) A short crop (similar to grass) and (2) B elevated crops (similar to the alfalfa), and one standardized reference evapotranspiration equation based on the Penman-Monteith equation (Allen et al, 2000; Itenfisu ETo al 2000; Walters et al., 2000, Wright et al., 2000). Dual reference surfaces that are similar to known crops were recommended by the committee due to the widespread use of grass and alfalfa across the United States and due to their individual advantages for specific applications and times of the year. As a part of the standardize procedure, the Penman-Monteith equation and associated equations for calculating aerodynamic and bulk surface resistance were combined and reduced to a single equation having two coefficients. The constants vary as a function of the reference surface and time step (hourly or daily). This summary of the ASCE PM-2000 approached only uses the grass crop reference that was relevant to the Florida irrigation environment.

$$ET_0 = \frac{0.408\Delta(R_n - G)R_s + \gamma\frac{C_u}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + C_d U_2)} \quad \text{Eqn (9).}$$

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 $^{-1}$, (Generally very small and assumed to be zero),

T = Mean daily air temperature at 1.5 to 2.5 meter height, °C,

u_2 = Wind speed at 2 meter height, m s .1,

e_s = Saturation vapor pressure at 1.5 to 2.5-meter height, KPa,

e_a = Actual vapor pressure at 1.5 to 2.5-meter height, KPa,

e_s-e_a = Saturation vapor pressure deficit, KPa,

Δ= Slope vapor pressure curve KPa°C.1,

γ= Psychometric constant, KPa°C.1,

C_n = A numerator constant for location type and calculation time step, and

C_d = A denominator constant for reference type and calculation time step.

Generalized the crop coefficient curve display the evaluation of the crop coefficient during the growing season, the basal Kc, and the effects of evaporation due to wetting events, Wright 1982, 1990

The Priestley-Taylor method

The process of ETo was controlled by available energy and the ability of evaporated water to be moved from the surface. The transfer process was a function of the wind speed and the amount of water vapor in the air closest to the surface. **Priestley and Taylor (1972)** demonstrated that for a well-water surface that extends over a large surface area, the ETo process was well described by air temperature, net radiation, and pressure. However, **Jensen et al. (1990)** was found the radiation methods considerably under estimated ETo for rates greater than 4 mm/day.

V. RESULTS AND DISCUSSION

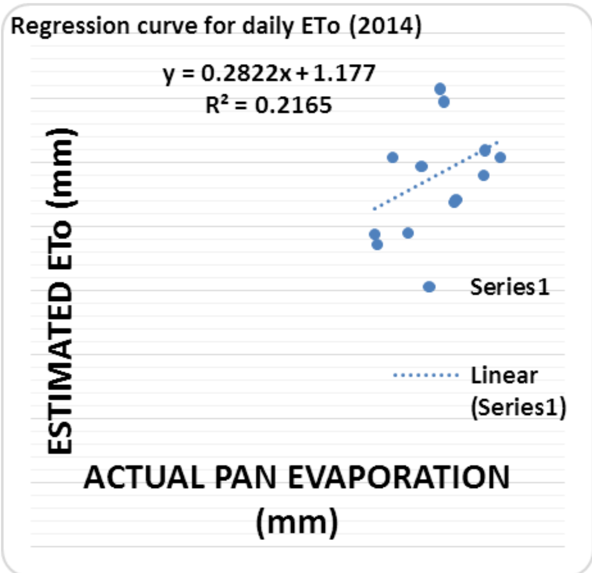
Mean annual ETo computed by any one model from a location were related to corresponding mean annual ETo computed by Penman-Monteith model by Linear regression. For any one selected model mean annual ETo was computed .This is related to the corresponding mean annual ETo of Penman-Monteith model of Kancheepuram District by linear regression. Daily meteorological parameters mean air temperature; maximum air temperature, minimum air temperature, wind speed, sunshine hour and duration and relative humidity for Kancheepuram District India were considered for the current study. The program will calculate daily reference evapotranspiration (ET_o) for the karunguzi station Kancheepuram District and monthly reference evapotranspiration, depends on the user requirement.

The mean Monthly ET_o was computed by the models described in reference evapotranspiration. The percent error between any one model and standard PM model was computed and a plot was made. Percent error of pristiey taylor model with reference to PM model for a locations is discussed below, method wise. The result will assist agricultural and environmental planners in assessing the water need for Tamilnadu agricultural Industry.

A.PRISTIEY TAYLOR METHOD

Table: 2 Shows actual pan evaporation and estimated pan evaporation for Pristiey Taylor method the year 2014

YEAR	MONTH	ACTUAL PAN-EVAPORATION	ESTIMATED ETo
2014	JAN	5.43	3.04
	FEB	5.86	2.97
	MAR	6.2	3.47
	APRIL	6.14	3.57
	MAY	6.82	3.09
	JUNE	7.05	3.04
	JULY	6.79	2.9
	AUG	6.38	2.71
	SEP	6.35	2.69
	OCT	5.66	2.45
	NOV	5.19	2.36
	DEC	5.16	2.44



Graph:1 Shows regression between actual pan evaporation and estimated pan evaporation for the Pristiey Taylor method year 2014

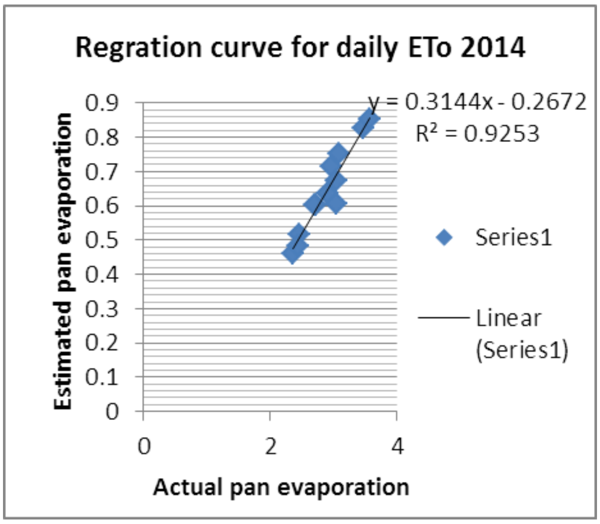
Table: 3 Shows RMSE, MAE, and Ax value of Pristiey taylor method for the year 2000-2014

PRISTIEY TAYLOR			
YEAR	RMSE	MAE	Ax
2000	0.241597	0.205125	0.722594
2001	0.273507	0.238097	0.683273
2002	0.141593	0.106253	0.867253
2003	0.301252	0.266441	0.653095
2004	0.452654	0.416994	0.519185
2005	0.444564	0.409071	0.525689
2006	0.369944	0.334409	0.585333
2007	0.358883	0.323175	0.594613
2008	0.346587	0.310892	0.604919
2009	0.385845	0.350637	0.572719
2010	0.337735	0.301783	0.614007
2011	0.231658	0.197679	0.723777
2012	0.222506	0.186888	0.743928
2013	0.477493	0.228	0.73288
2014	0.515655	0.2659	0.726369

B.PENMAN MOTHITH METHOD

Table: 4 Shows actual pan evaporation and estimated pan evaporation for the Penman Mothith method year 2014

YEAR	MONTH	ACTUALPAN EVAPORATION	ESTIMATED ETo
2014	JAN	3.04	0.607
	FEB	2.97	0.714
	MARCH	3.47	0.825
	APRIL	3.57	0.851
	MAY	3.09	0.751
	JUNE	3.04	0.672
	JULY	2.9	0.634
	AUG	2.71	0.602
	SEP	2.69	0.602
	OCT	2.45	0.515
	NOV	2.36	0.459
	DEC	2.44	0.481



Graph: 2 Shows regression between actual pan evaporation and estimated pan evaporation for the Penman Mothith method year 2014 year 2014

Table: 5 : Shows RMSE , MAE , and Ax value of Penman Monteith method the year 2000-2014

PEN MOTHITH			
YEAR	RMSE	MAE	Ax
2000	0.238931	0.238931	0.548673
2001	0.26925	0.26925	0.528019
2002	0.140142	0.140142	0.704352
2003	0.293117	0.293117	0.511597
2004	0.449369	0.449369	0.376278
2005	0.440488	0.440488	0.386896
2006	0.366215	0.366215	0.435699
2007	0.356918	0.356918	0.432608
2008	0.343087	0.343087	0.449529
2009	0.37972	0.37972	0.439799
2010	0.334408	0.334408	0.455329
2011	0.227387	0.227387	0.569137
2012	0.440488	0.440488	0.386896
2013	0.418808	0.1754	0.623073
2014	0.43314	0.18761	0.594807

Figure shows the month wise 2000-2012 the line decrease gradually 300mm to 200mm .it is an impact of environmental and really it consider the effects of climate change on a global scale.

C. RAINFALL

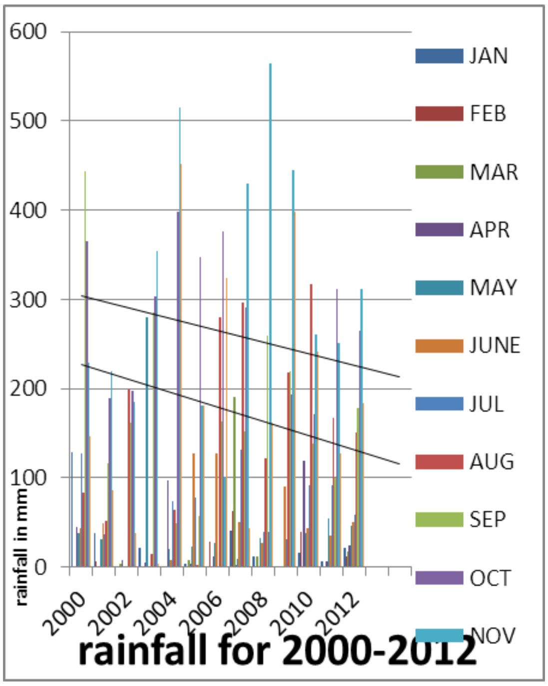


Fig: 4 Shows Overall Comparison for Rainfall (Observed) for 2000-2012

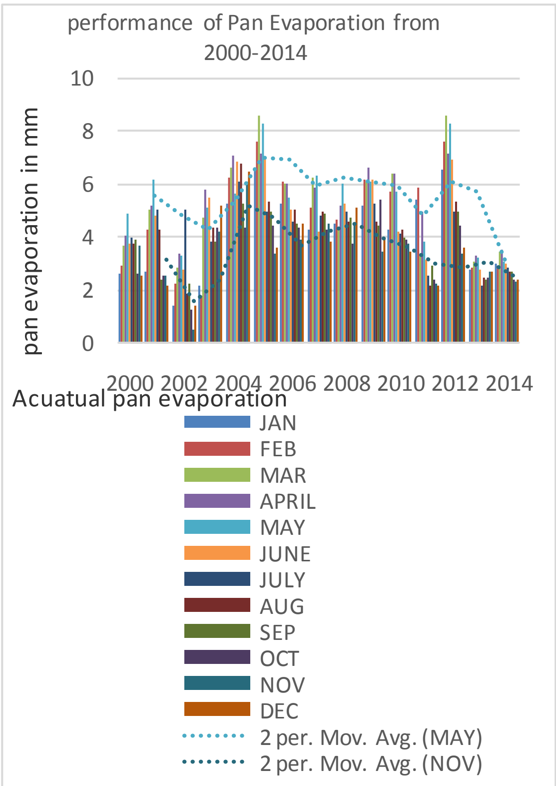


Fig:5 Actual pan Evaporation Performance from year 2000-2014

This figure 1.7 shows about the Pan Evaporation performance from the year 2000-2014. It represents that pan evaporation does not perform equally. It differs every five to seven year. The slope suddenly decreases. Mainly we have the difference in 2012 to 2014. The slope gradually increases from 2002 to 2005. It performs moving average level from the month of May and November. Because May has high evaporation and November has low evaporation. These two curves are parallel.

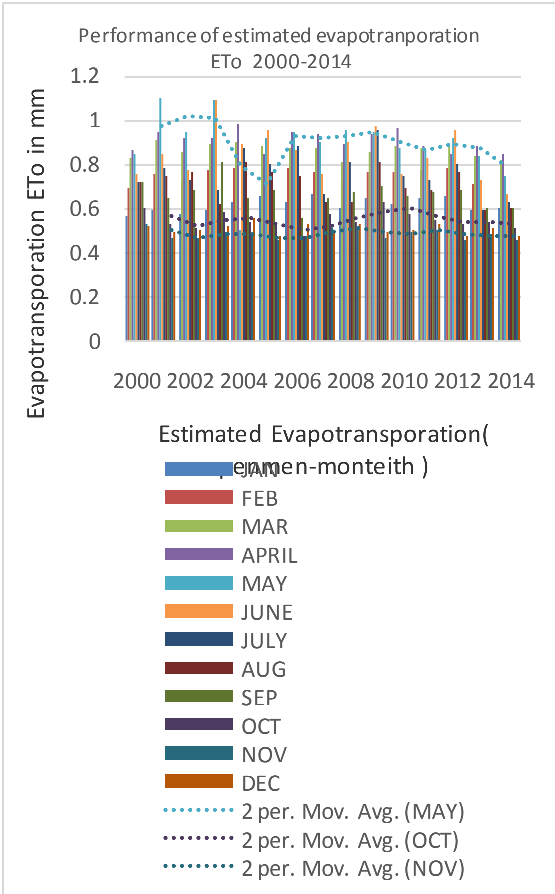


Fig:6 Estimated Evapotranspiration eto performance from year 2000-2014 for Penman Monteith method

This figure 2 shows about the performance evaporation ETo(penman monteith method) from the method the year 2000-2014 gradually increase from 2000-2014. This linear line shows gradually increasing the evapotranspiration due to the inadequate rainfall postponed increasing concrete jungle and establish of real-estate Business and industrial development

The figure shows about the performance pan evaporation and estimation ETo (penman monteith method) in this figure see the average evapotranspiration in month wise is more or less parallel curve from the month of January to December it shows that theirs is a increase of evapotranspiration (water loss) in month of April and May As a peak point and gradually gets started to decrease in the month of December this curve shows September to November and December to February these two season are best season for paddy cultivation may June and July have high evapotranspiration in this period (season) choose alternative crops like less needed duty and delta of crop maize, groundnut, baijira, gingili

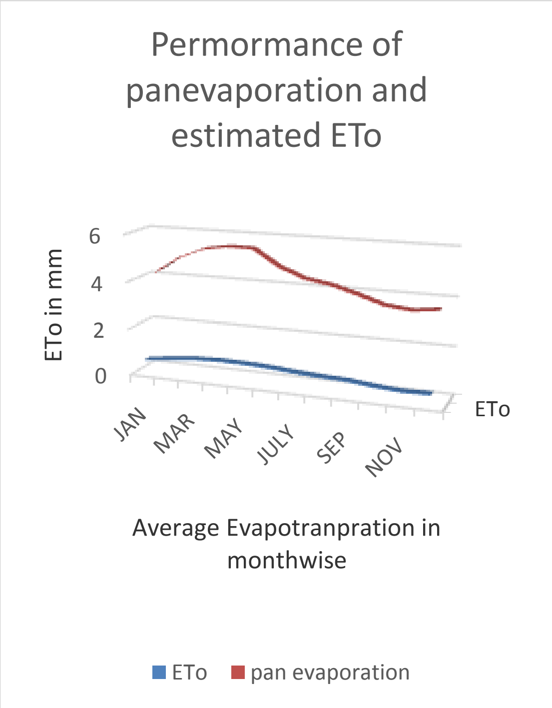


Fig:7 Performance of poration and pan estimated evapotranspiration ETo month wise for (penman monteith method)

VI. CONCLUSION

The Penman Monteith model is modified with a recalibrated constant. If the available meteorological variable is only maximum and minimum temperature, Penman Monteith model is more suitable for Kancheepuram District in daily ET_o estimation. The RMSE value is less than one for a locations. A_x value, is greater than 0.6 for a locations. The MAE values for locations were found less than 0.59. From the table 5.61 to 5.64 and Fig.1.7 to 1.9 it is evident that the Penman monteith model performs better.

Considering the model performance statistics and the graphs for the output of ET_o the temperature based model Priestley-Taylor the performance was not found satisfactory with reference to the performance of PM model. Therefore, a model are not suitable for ET_o estimation over Kancheepuram District.

reference evapotranspiration equation based on the Penman-Monteith equation Modelling. In estimation of ETo, for Crop Water Requirement for Kancheepuram District, various type models were compared. When compared to other models, Penman Monteith method uses the combined climatological effect of temperature variations and aerodynamic variations. The equation used to estimate reference crop evapotranspiration (ETo) and equation are sufficiently large to stress the importance on water management. Hence the penman monteith modeling method is used to estimate the crop water requirement for the study area at Kancheepuram district.

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