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Short communication

Selection of PET formulae for estimation over the Palghat Gap of Kerala

K.N. KRISHNAKUMAR and G.S.L.H.V. PRASAD RAO
Dept. of Agricultural Meteorology, College of Horticulture,
Kerala Agricultural University, Vellanikkara, Thrissur-680 656, Kerala

The moisture transfer from a vegetated surface to the atmosphere is known as potential evapotranspiration (PET) when the moisture supply is unlimited in the soil. It is the primary component of the hydrologic cycle and plays an important role in the soil-water-balance. Accuracy in estimation of evapotranspiration is paramount in soil-water- accounting, irrigation scheduling, nutritional management, crop yield simulation and hydrologic studies. It is widely used for practicing scientific irrigation in terms of frequency and amount of water when soil moisture is deficient to meet the water requirement of crops. Owing to the difficulty in accurate direct measurement of evapotranspiration under field conditions, it is often estimated based on climatological data. Keeping the above in view, several workers estimated PET values using empirical equations under different agroclimatic conditions across the Country. Such studies are scarce for the State of Kerala, which falls under the humid tropics and hence this study.

The daily meteorological data from 1983 to 2001 were collected from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara (10°31' N; 76°13' E and 22.25m above M.S.L), Thrissur for computation of monthly PET using several empirical formulae, viz., Thornthwaite , Blaney-Criddle, Khosla, Papadakis, Linacre, Jenson and Haise, Modified Jenson and Haise, Hargreaves, Turc, Makkink, Stephens and Stewart, Christiansen , Penman and Modified Penman method (Michael, A.M. 1978).

The modified Penman method was found reasonable for estimating PET for several stations in India (Olinaram, 1981 and Rao *et al.*, 1983) and thus received wide acceptability. Therefore, the modified Penman method was taken as the reference for comparison. Thus, the PET values computed by various methods were compared statistically with the modified Penman method by using root mean square (RMSE), Mean bias (MBE) and mean percentage (MPE) error values as

$RMSE = [“(PETe-PETp)^2 / n]^{0.5}$, $MBE = [“(PETe-PETp)] / n$

$MPE = [“(PEPp-PETe)/PETp]100 / n$

Where,

Table 1: Seasonal PET (mm day^{-1}) at Vellanikara by various methods

Method	Southwest monsoon (Jun-Sep)	Post monsoon (Oct-Nov)	Winter (Dec-Feb)	Summer (Mar-May)	Annual
Christiansen	3.45	4.42	7.48	6.45	5.37
Jenson&Haise	5.54	6.03	6.77	7.90	6.52
Modified Jenson & Haise	5.71	6.20	6.93	8.01	6.67
Makkink	3.29	3.54	3.93	4.43	3.78
Throthwaite	4.51	4.80	5.11	7.28	5.40
Khosla	4.18	4.30	4.46	4.68	4.39
Blaney-Criddle	4.30	4.11	4.10	4.57	4.29
Stephens & Stewart	3.28	3.57	4.00	4.66	3.86
Turc	4.05	4.32	4.84	5.25	4.59
Papadakis	2.32	2.93	3.70	4.01	3.19
Hargreaves	4.00	4.07	4.55	5.46	4.51
Linacre	5.02	5.56	6.15	6.57	5.78
Penman	4.19	4.44	5.23	5.66	4.86
Modified Penman	4.50	4.69	4.77	6.13	5.00
Pan evaporation	3.19	3.63	6.35	5.76	4.69
Average	4.10	4.44	5.22	5.79	4.86
Pan coefficients with reference to Modified Penman	1.41	1.29	0.75	1.06	1.06

n = number of observations, PETp is estimated PET by modified penman and PETe is estimated PET by the corresponding empirical relations.

Linear regression analysis was performed on monthly average PET estimates with PET estimated by modified penman as dependent variable and PET estimated by various methods as the independent variable. Pan coefficients were also worked out with reference to Modified Penman method (Prasada Rao, and Krishnakumar 2003; Goyal, 2005), using the regression as follows:

$$Y = bX$$

Where, Y= Monthly PET estimated by modified Penman method, X= Pan evaporation.

The mean annual potential evapotranspiration is 5 mm per day and varied between 4.50 mm (June-September) and 6.13 mm (March-May) per day as per the modified Penman method, which was

Table 2: Comparison of various empirical methods with modified Penman method (Pooled data)

Sl. No.	Method	Parameter				
		RMSE	MBE	MPE	R^2	r
1	Papadakis	1.918	-1.814	36.888	0.534	0.731
2	Christiansen	2.880	0.360	26.830	0.313	0.559
3	Linacre	0.921	0.776	16.610	0.629	0.793
4	Thorthwaite	0.749	0.395	10.320	0.825	0.908
5	Penman	0.427	-0.142	7.516	0.737	0.859
6	Blaney-Criddle	3.467	-0.717	14.170	0.463	0.680
7	Khosla	0.841	-0.610	11.490	0.642	0.801
8	Hargreaves	0.609	-0.489	10.463	0.788	0.888
9	Turc	0.560	-0.410	9.350	0.771	0.878
10	Jension and Haise	1.581	1.513	30.198	0.872	0.934
11	Modified Jenson and Haise	1.727	1.670	33.436	0.866	0.931
12	Makkink	1.276	-1.230	24.240	0.839	0.916
13	Stephens and Stewart	1.190	-1.150	22.970	0.871	0.933
14	Pan evaporation	1.381	-0.319	29.561	0.815	0.664

considered as the reference for comparison. The Jenson and Haise method (both modified and original) overestimated (> 6.5 mm day^{-1}), while Papadakis (3.19 mm day^{-1}), Makkink (3.78 mm day^{-1}) and stephens and Stewart (3.86 mm day^{-1}) underestimated when compared to that of the modified penman method. All other methods are intermediary (Table 1). The average PET varied between 4.1 mm day^{-1} and 5.79 mm day^{-1} depending upon the season when results from all the methods were pooled together. As expected, summer recorded the maximum (5.79 mm day^{-1}) PET with a minimum (4.1 mm day^{-1}) during southwest monsoon season in the humid tropics like Kerala, where heavy and continuous monsoon is expected from June to September. Interestingly, the second maximum (5.22 mm day^{-1}) was noticed during winter unlike other parts of Kerala. It was due to strong winds that are blown over the Palghat region from the middle of November to the middle of February. It is reflected on the pan coefficient also which was the lowest (0.75) during winter and the highest (1.41) during the season of southwest monsoon

The Christiansen method gave the highest PET (7.48 mm day^{-1}), followed by the modified Jenson and Haise (6.93 mm day^{-1}), while the least (3.7 mm day^{-1}) by Papadakis, followed by Makkink (3.93 mm day^{-1}) and Stephen and Stewart (4.0 mm day^{-1}) during winter (Fig.1). In summer, the modified Jenson and Haise estimated the highest PET (8.01 mm day^{-1}) while the lowest (4.01 mm day^{-1}) was by Papadakis as in the case of winter. It revealed that the Papadakis method estimated the least PET when compared to that of the modified Penman method irrespective of seasonal

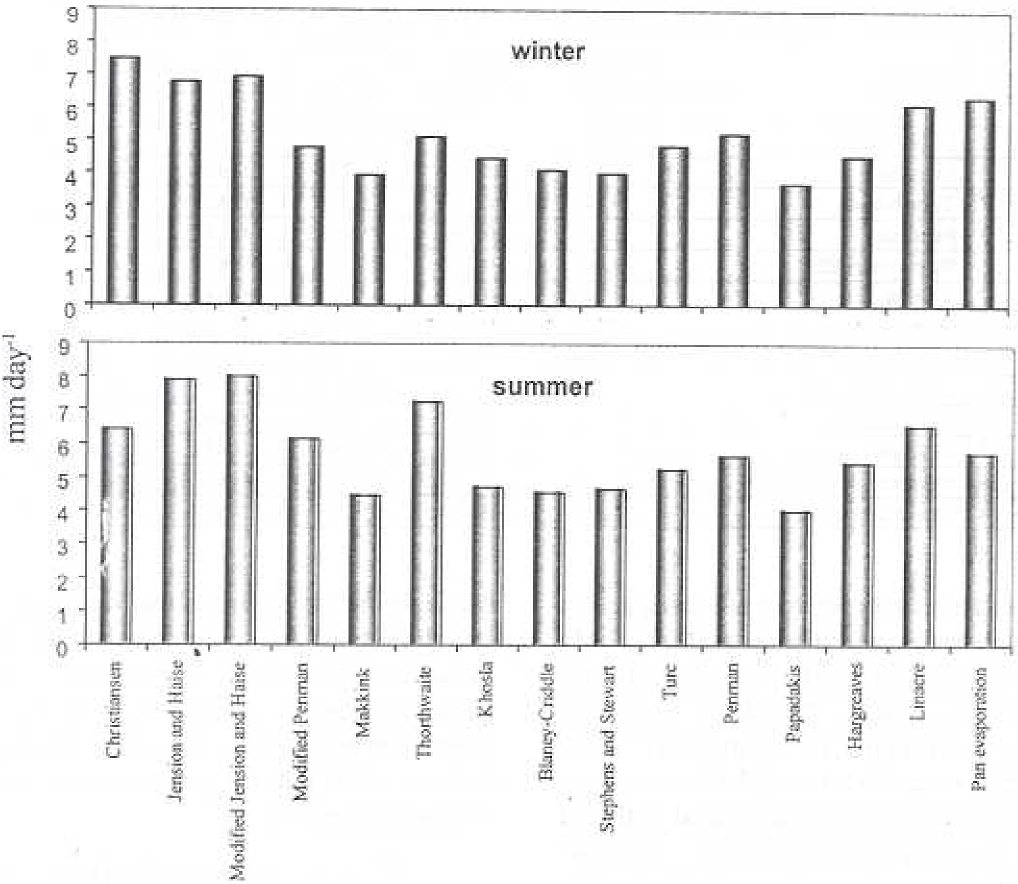

Fig.1: Seasonal PET (mm day^{-1}) during winter and summer by various methods and pan evaporation at Vellanikkara

differences. Similar was the case with the modified Jenson and Haise method as it overestimated the PET except in winter during which the Christiansen method estimated the maximum PET. Hence, the methods of Christiansen, Jenson and Haise (both original and modified), Papadakis and Makkink need re-validation for field application, Rao *et al.*, 1983 also reported that Christiansen method overestimated over Rajasthan, which falls in the arid climates.

In terms of MBE values, the Penman method is the best method and pan evaporation is the second best (Table 2). The highest efficiency as indicated by the minimum RMSE values is shown by Penman method (0.427), followed by Turc method (0.560) as the second best. The

MPE value is minimum for Penman method (7.52%) and was the maximum for Papadakis method (36.89%).

The study of seasonal influence on PET estimates indicated that errors during southwest monsoon (4.76%) and post monsoon (4.11%) season were the lowest with Thorthwaite method, whereas Turc and modified Jenson and Haise gave lowest MPE values during winter (3.50%) and summer (4.91%), respectively. Thus, though the Penman method showed lowest errors on annual basis, it is clear that the different methods have better accuracy levels on seasonal basis. This suggests that the variables of the corresponding equations can estimate the PET effectively in the respective seasons.

The PET estimated by the Penman method gave highest R^2 values during southwest monsoon (0.963), winter (0.905) and summer season (0.782) whereas, Ture method gave highest R^2 values during post monsoon (0.838).

The above analysis indicated that the Penman method is the best fit with the modified Penman method on annual basis while differed seasonally as expected. The mean annual potential evapotranspiration is 5 mm per day and varied between 4.50 mm (June-September) and 6.13 mm (March-May) as per the modified Penman method. The pan coefficients varied between 0.75 and 1.41 depending up on the season. The wind factor should be given more weightage during winter (December to February) over the central part of Kerala as strong winds blow across the Palghat region from the middle of November to the middle of February as all the methods underestimated the PET except Christiansen, Jenson & Haise and Modified Jenson & Haise.

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