Journal of Agrometeorology 4 (2) : 143 -149 (Dec 2002)

Estimation of PET by various methods and its relationship with mesh covered pan evaporation at Ludhiana

P. K. KINGRA, PRABHJYOT KAUR AND S. S. HUNDAL
Department of Agricultural Meteorology, Punjab Agricultural University Ludhiana - 141 004

ABSTRACT

Mesh covered pan evaporation at Ludhiana was correlated with potential evapotranspiration (PET) computed by using empirical methods of Thornthwaite (1948), Papadakis (1965), Jenson and Haise (1963) and Modified Jenson and Haise (1975). Weather data for 30 years period from 1970 to 1999 for Ludhiana was used to work out PET by various methods. Linear regression equations were fitted between monthly PET by each method and the measured pan evaporation. Pan evaporation correlated well with monthly PET having R^2 value of 0.84 for Papadakis method, 0.79 each for Jenson & Haise and for Modified Jenson & Haise method, and 0.65 for Thornthwaite method.

Key words : Potential evapotranspiration, Pan evaporation, Empirical methods

The practice of intensive agriculture under irrigated conditioins in Punjab state has resulted in depletion of a considerable part of its water resources for irrigation purposes. Further exploitation of water resources seems to be limited. The judicious utilization of irrigation water is the only way to increase the potentialities of available resources to fulfil the increasing demand for water in intensive cultivation. Evapotranspiration (ET) is an important parameter related to crop production, due to its largely successful application in the economic utilization and application of irrigation water as per actual requirement of the crop (Rosenberg *et al.* 1983). Irrigation practices adopted by the farmers are generally arbitrary and not necessarily based on crop's actual water needs. Evapotranspiration is the main index of crop-water requirements which needs to be estimated on a scientific basis so that the required amount of water can be applied to the crop at the proper time, taking into account the effective rainfall and irrigation efficiency.

The evaluation of potential evapotranspiration (PET) by an empirical method has great appeal because ET is estimated without disturbing the plant and soil. Although ET can also be estimated through lysimetric studies but its immobility and high cost restrict its utility. The empirical formulae hold good at the locations where they are developed. Such methods can serve as tools to estimate the rate of evapotranspiration. The paper discusses the comparison of four empirical methods for estimating PET and their relationship with mesh covered open pan evaporation (EP).

MATERIALS AND METHODS

Weather data for 30 years period i.e. from

Table 1: Monthly values (mean ± s.d.) of mesh covered pan evaporation (EP) and potential evapotranspiration (PET) computed by four empirical methods for the 1970-1999 period at Ludhiana

Month	EP	PET (mm)			
		Papadakis	J & H	Modified	Thornthwaite
January	48.4 ± 8.7	75.5 ± 7.6	51.6 ± 6.7	64.4 ± 14.4	12.7 ± 2.1
February	66.1 ± 12.5	90.1 ± 13.6	69.9 ± 9.6	81.1 ± 10.7	20.2 ± 3.8
March	115.5 ± 20.2	123.7 ± 19.1	120.1 ± 16.9	131.4 ± 17.4	54.6 ± 10.0
April	212.7 ± 37.0	209.4 ± 29.3	189.4 ± 18.1	196.5 ± 18.1	142.2 ± 21.1
May	309.5 ± 62.0	251.9 ± 36.8	245.6 ± 26.4	248.4 ± 25.7	258.3 ± 42.2
June	274.0 ± 38.5	215.8 ± 28.1	242.3 ± 26.2	244.7 ± 24.9	296.3 ± 27.4
July	159.3 ± 41.2	136.6 ± 23.7	194.4 ± 30.6	196.6 ± 30.6	253.9 ± 23.0
August	128.4 ± 21.6	125.8 ± 19.4	179.0 ± 22.9	181.8 ± 23.0	224.4 ± 18.8
September	130.9 ± 19.0	154.6 ± 19.9	170.2 ± 22.4	174.0 ± 22.5	178.3 ± 16.7
October	121.0 ± 20.4	173.0 ± 17.7	136.1 ± 15.8	155.7 ± 16.6	106.5 ± 9.9
November	79.1 ± 14.3	133.0 ± 11.3	84.4 ± 7.8	92.6 ± 8.7	44.7 ± 5.4
December	54.4 ± 18.0	89.6 ± 14.0	54.7 ± 9.4	64.0 ± 10.9	17.3 ± 2.7

1970 to 1999 was collected for Ludhiana to compute PET using various methods. The monthly computations were made according to the following empirical formulae.

Papadakis method

$$PET = 0.5625 * (e_{max} - e_{min-2}) * 10$$

(Papadakis, 1965)

where,

PET : Monthly potential evapotrans-piration in mm

e_{max} : Saturation vapour pressure at mean maximum temperature (mb)

e_{min-2} : Saturation vapour pressure (mb) at mean minimum temperature minus 2°C. Papadakis reasoned that 2°C is the usual difference between minimum temperature and dew point temperature.

Jenson and Haise method (J & H)

$$PET = (0.014\, T_A - 0.37) * (R_S * 0.000675 * 25.4)$$

(Jenson & Haise, 1963)

where,

PET : Daily potential evapotrans-piration in mm

T_A : Mean temperature in °F
R_S : Solar radiation in ly day^{-1}

Modified Jenson & Haise method :

PET = 0.012 * (T-15.4) * R_S * 0.0171
(Clyma and Chaudhary, 1975)

where,

PET: Daily potential evapotrans-piration in mm
T : Mean air temperature in °F
R_S : Solar radiation in ly day^{-1}

Thornthwaite method

$e = 1.6 * (10\, T / I)^a$
(Thornthwaite, 1948)

where,

e : Unadjusted PET in cm/month
T : Mean air temperature in °C

I : Annual heat index = $\sum_{1}^{12} i$

i : monthly heat indices $i = (T/5)^{1.514}$

'a' is an empirical exponent computed by the following expression

$a = 0.000000675 * I^3 - 0.0000771 * I^2 + 0.01792 * I + 0.49239$

Unadjusted PET is further modified by applying adjustment factor 'k' for which table values are given by Michael (1978)

PET = k * e * 10

where,

PET : Monthly potential evapotran-spiration in mm
k : Adjustment factor
e : Unadjusted monthly potential evapo-transpiration cm month

The relationship between computed PET and mesh covered pan evaporation (EP) was studied by regression analysis between PET computed with each method (y) and mesh covered pan evaporation (x). The evaporation pan refers to USDA open pan which was covered with a wire mesh.

RESULTS AND DISCUSSION

Variations in PET and EP

The lowest values of PET as well as EP were obtained during the months of December and January and the highest values were obtained during the months of May and June (Table 1). Papadakis method estimated PET values very close to EP. PET by the Thornthwaite's method exceeded EP for the months of June to September and was lower for rest of the months throughout the year. PET estimations for the months of December, January and February were much lower than EP in Thornthwaite's method whereas the trend was reverse for Papadakis method, which overestimated PET for winter months and underestimated for summer months. Both Jenson & Haise method and Modified Jenson & Haise method also underestimated PET for the months of April to June and overestimated for other months of the year. Modified Jenson & Haise method estimated comparatively higher values of PET than Jenson & Haise method, the differences being higher for winter months and lower for summer months.

Relationship between PET and EP

The linear regression relationships of the form y = ax + b and y = ax developed between PET computed with various methods and pan

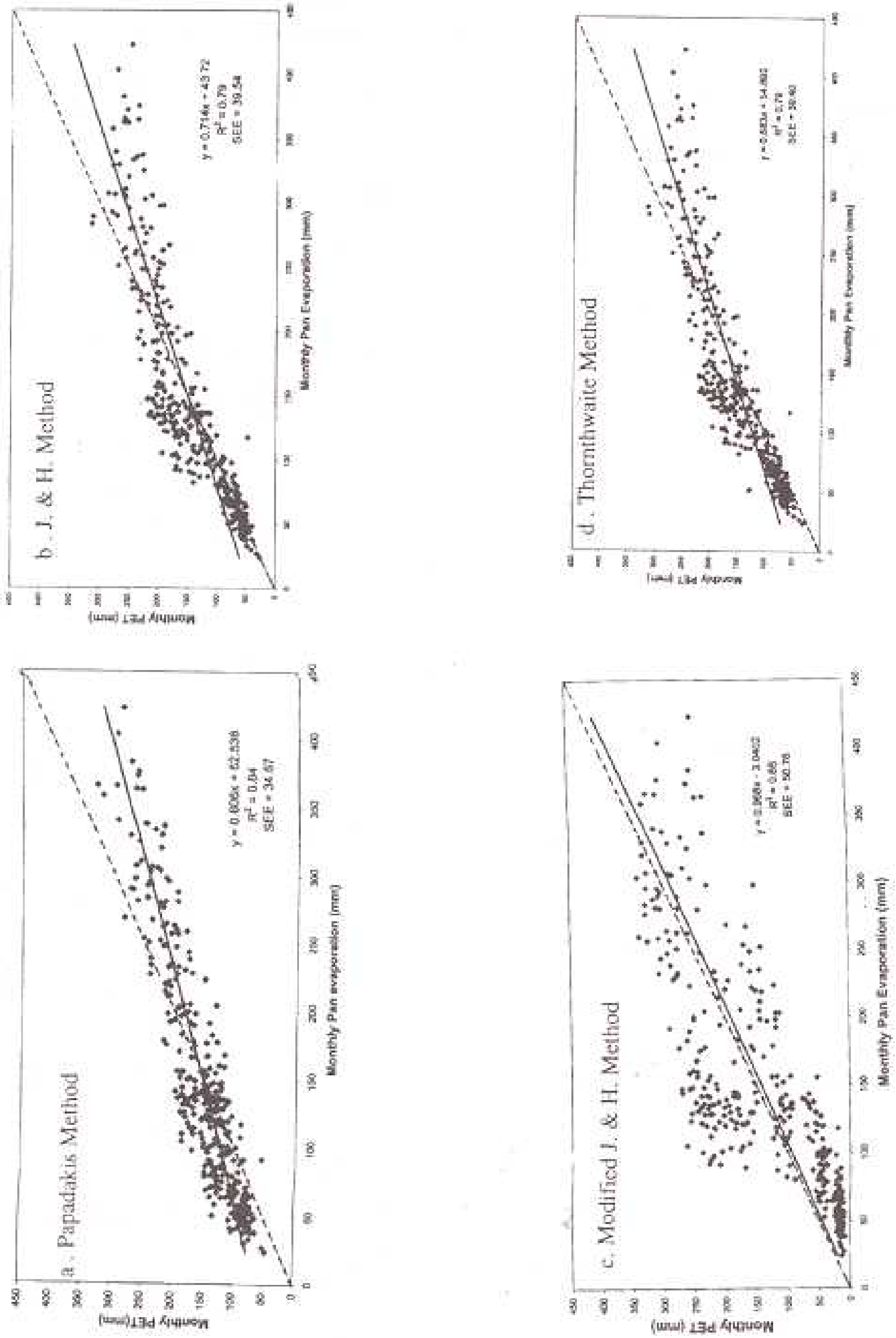

Fig. 1 : Relationship between PET and Pan evaporation (Solid line - regression line; Broken line - 1:1 line

evaporation (EP) were as follows

Sr No	Regression equation	R^2	Method
1	$y = 0.6056x + 62.536$ $y = 0.9286x$	0.84 0.51	Papadakis
2	$y = 0.7135x + 43.72$ $y = 0.9393x$	0.79 0.68	Jenson & Haise
3	$y = 0.6834x + 54.692$ $y = 0.9659x$	0.79 0.61	Modified Jenson & Haise
4	$y = 0.968x - 3.0402$ $y = 0.9286x$	0.65 0.65	Thornthwaite

where,

x : monthly pan evaporation (mm)

y : computed monthly PET (mm)

In this study, the regression function of the form $y = ax + b$ between PET computed with Papadakis method and pan evaporation (Fig.1) gave highest R^2 value (0.84) followed by Jenson & Haise method (Fig.2) and Modified Jenson & Haise method (Fig.3) ($R^2 = 0.79$ each), whereas the lowest R^2 value was observed for the Thornthwaite method ($R^2 = 0.65$) (Fig.4). Jadhav *et al.* (1999) also studied similar type of relationship between mesh covered pan evaporation and PET computed with Doorenbos and Pruit method. When our data was analysed by regression through origin ($y = ax$), R^2 values of 0.51, 0.68, 0.61 and 0.65 were obtained with Papadakis, Jenson and Haise, Modified Jenson and Haise and Thornthwaite methods, respectively, which were lower as compared to the R^2 values obtained with regression analysis of the form $y = ax + b$. This difference indicates that PET computation by various methods was biased and this bias was positive when pan evaporation was low while the bias was negative when pan evaporation was on higher side of the scale as depicted in Fig. 1(a -d). These relationships can serve as a tool to estimate the rate of PET from pan evaporation and hence irrigation scheduling of various crops.

REFERENCES

Thornthwaite, C.W. 1948. An approach towards a rational classification of climate. *Geog. Review,* 38 : 55-94

Jenson, M.E. and H.R.Haise. 1963. Estimating evapotranspiration from solar radiation. *J. Irrig. and Drain. Div. Amer. Soc. Civ. Engr. Proc.,* 89 : 15-41

Papadakis, J. 1965. Potential Evapotranspiration. Buenos Aires : 54

Clyma, W. and M.R.Chaudhary. 1975. Calibration and application of the Jenson Haise evapotranspiration equation. Colorado State University Water Management. Tech. Rep. : 40

Michael, A.M. 1978. Irrigation : Theory & Practice. Vikas Publishers, New Delhi.

Rosenberg, N. J., B.L. Blad and S.B. Verma. 1983. Microclimate : The Biological Environment. 2nd Edition, Wiley Interscience, P. 171-178

Jadhav, J.D., Mokashi D.D., Shewale M.R. and Patil. J.D.1999. Relationship between PET and mesh covered pan evaporation at Solapur. *J. Agrometeorol.* 1(1) : 93.