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Verification of Empirically Estimated PET in South - Western Punjab

Som Pal Singh, C.J. Singh and S.S. Hundal
Regional Research Station, PAU, Bathinda
**Department of Agronomy and Agrometeorology, PAU, Ludhiana*

ABSTRACT

Empirical methods were used to estimate the monthly potential evapotranspiration (PET) at PAU, Regional Research Station, Bathinda. The PET values estimated by the Thornthwaite method were highest (262.8±39.3 mm) in June and by Papadakis (273.0±27.4mm) in the month of May. The lowest respective values (11.8±33.2mm and 88.4±25.8mm) were found in the month of January. The evaporation data (Ep) recorded with mess covered USDA pan evaporimeter also showed the similar trends. Using PET and Ep data, a set of regression equations was developed for both the methods under test. Each set comprised of five types of equations i.e. linear, logarithmic, polynomial, power and exponential. The logarithmic, polynomial and power functions of these two variable predicted the PET to the highest extent (R^2=0.93).

Key words: Empirical, Potential evapotranspiration, evaporation, Punjab.

Introduction

Quantification of potential evapotranspiration (PET) is needed for crop production, management of water resources and environmental assessment (Subbaiah, 2001). As an index it has been widely used to assess the effects of the water supply on growth and yield of the crops. Numerous formulae and methods for calculating PET directly from the meteorological data have been proposed over the years. Some of these are purely empirical while others are based on the physics of the evaporation phenomenon (Mavi 1986). Of all these methods, modified Penman method has received the wide acceptability (Doorenbos and Pruit, 1977). But taking into consideration the limited meteorological data available at Bathinda, simple empirical formulae with adequate accuracy needed testing. Therefore, an attempt has been made to estimate PET by using the first category formulae of Thornthwaite (1948) and papadakis (1965), which need one or two weather parameters only.

Material and Methods

Weather data (1977-2001) available from GND Thermal Plant and Regional Research Station, Bathinda (Latitude 30°17'N; Longitude 74°58'E and altitude 211 meters above mean sea level) were used to quantify the PET using empirical methods of Thornthwaite (1948) and Papadakis (1965). The evaporation data recorded at Regional Research Station, Bathinda (1990-2001) were used to establish the relationships with PET. Five types of the function between PET and *Ep viz.* linear, power, logarithmic, polynomial and exponential were used to verify the accuracy of the PET predicted. The analysis was carried out separately, both for Thornthwaite and Papadakis method. The Thornthwaite method involving ony one weather parameter as input is explained as under:

$$e = 1.7\ (10T/I)^a$$

Where, e is unadjusted PET in cm per month

(a month consisting of 30 days each and 12 hours a day).

T = Mean air temperature (°C)

I = Annual or seasonal heat index. It is the summation of 12 values of monthly heat indices i

$i = (T/5)^{1.514}$

a = An empirical exponent computed by the following expression

$a = 0.000000675\ I^3 - 0.0000771\ I^2 + 0.1792\ I + 0.49239$

PET = k x e x 10 mm $month^{-1}$

k = adjustment factor for which values are given by Michael (1978)

The values of the heat index 'I' and empirical exponent, 'a' computed from the long-term data for Bathinda are 134.8 and 3.16 respectively.

Papadakis equation requiring only two weather parameters is described as under:

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

Where, PET is the potential evapotranspiration

e_{max} is saturation vapor pressure (mb) corresponding to daily maximum temperature.

e_{min-2} is saturation vapor pressure (mb) corresponding to dew point temperature. Papadakis concluded that dew point temperature is roughly equal to daily minimum temperature minus 2 degree.

0.5625 is the Papadakis constant.

The PET values thus estimated by these two formulae were correlated with pan evaporation and comparison was made between the two sets of PET by a series of regression equations.

Results and Discussion

PET by thorntwhaite method

The results revealed that the highest PET was observed in the month of June (262.4 mm) followed by May (238.7 mm) and July (236.4 mm). Whereas, lowest values of this parameter were reported in the month of January (11.8±33.2 mm) followed by December (17.4±31.6 mm). This may be due to the fact that evaporative demand is more in the month of May-June and lowest in the month of December and January due to continuous fog and low sunshine hours. Further, the trend of PET data was compared with that of open pan evaporation and was found to be in the same order. Ep exceeded PET from October to May (Table 1) and lesser from June to September.

PET by Papadakis method

The values estimated by the Papadakis method were more than those calculated by Thornthwaite for almost all the months except for the month of July and August. The highest value of PET by this method was observed in the month of May (273±27.4 mm) followed by June (270.1±26.6 mm) and April (237±17.1 mm). The lowest PET values by papadakis was in the month of January (88.4±25.8 mm) followed by February (98.9±22.8 mm) and December (102.7±7.0 mm). The evaporation data was also found exactly in the same order (Table 1). The PET estimated by this method seemed to be more uniform and close to the Ep values for almost all months except for the month of May where Ep values exceeded the PET. The PET and Ep values were closer to each other during April to July and the variation was more pronounced during the other months.

Table 1. Monthly PET (±SD) estimated by the Thornthwaite and Papadakis methods and pan evaporation (Ep) at Bathinda

Month	PET		Ep
	Thornthwaite	Papadakis	Pan Evaporimeter
January	11.8±33.2	88.4±25.8	52.7±27.3
February	20.3±30.7	98.9±22.8	67.2±23.1
March	56.9±20.1	139.1±11.2	114.7±9.4
April	129.6±0.8	237.0±17.1	235.0±25.3
May	238.7±32.3	273.0±27.4	288.3±40.7
June	262.8±39.3	270.1±26.6	249.0±29.4
July	236.4±36.0	206.6±8.3	204.6±16.6
August	204.9±22.5	173.0±1.4	136.4±3.1
September	173.1±13.4	198.9±33.2	120.0±7.8
October	105.2±6.3	191.8±3.9	145.7±0.4
November	48.3±22.6	155.6±6.4	93.0±5.6
December	17.4±31.6	102.7±21.7	58.9±25.5

Seasonal influence on the performance of the models

During the summer, post monsoon and winter season the PET computed by the Thornthwaite was lower than that computed by the Papadakis method whereas during the southwest monsoon season the PET was reported to be more in case of Thornthwaite method (Table 2). The PET by Thornthwaite method during the winter season (January to February) is minimum (32.07 mm) and is almost 1/5th of the PET estimated by papadakis.

Table 2. Effect of season on the performance of empirical model

Season	PET (Thornthwaite)		PET (Papadakis)	
	Total (mm)	Mean	Total (mm)	Mean
Summer (March-May)	425.26	141.75	649.14	216.38
SW Monsoon (June-September)	877.20	219.31	848.71	212.18
Post monsoon (October-December)	170.87	56.96	450.11	150.04
Winter (January-February)	32.07	16.05	187.37	93.68

Table 3. Relationship between PET and Ep

Set-I Thornthwaite method			
Y	=	1.0113 x -23.765	(R^2=0.70)
Y	=	146.91 In (x)-587.82	(R^2=0.76)
Y	=	$-0.0046x^2$ +2.5309-122.3	(R^2=0.76)
Y	=	$0.0121x^{1.8145}$	(R^2=0.83)
Y	=	$14.348e^{0.117x}$	(R^2=0.68)
Set-II Papadakis method			
Y	=	0.7688x +64.521	(R^2=0.91)
Y	=	109.11 ln(x) -351.76	(R^2=0.93)
Y	=	$0.0018x^2$ +1.3756x +25.175	(R^2=0.93)
Y	=	$6.717x^{0.66}$	(R^2=0.93)
Y	=	$85.899e^{0.0045x}$	(R^2=0.84)

Where Y is the PET predicted and x is Ep

Therefore, it is clear from this trend that the performance of the models is poor during the winter and post monsoon seasons. However, during the south-west monsoon and summer season, estimates of these models are quite satisfactory (Table 2). Kumar *et al.* (1987) found a seasonal influence on PET estimated by them for many Indian stations. They indicated that Thornthwaite method tends to give higher estimates than Penman method during the monsoon seasons.

Relationship between PET and Ep

Linear, power, polynomial, exponential and logarithmic relationships were fitted between PET (Thornthwaite and papadakis) and Ep. The regression with the highest correlation co-efficient was identified for the estimation of PET for both the cases. Perusing the equations given below (Table 3) it is clear that the Thornthwaite method underestimated the PET in comparison to Papadakis and explained 68 to 83% variability only. Jadhav *et al.* (1999) related the PET estimated by Doorenbos and Pruitt with evaporation at Solapur and found correlation upto 93%.

In case of the Papadakis method the logarithmic, power, and polynomial functions predicted the PET to the extent of 93% for each function and is followed by linear one where the variability in PET is explained upto 91%. However, the exponential function in this case explained the variability of the PET upto 84% only. Kingra *et al.* (2002) estimated PET for Ludhiana by different approaches and observed papadakis method predicted PET to the h ighest extent of 84%.

Conclusion

From the verification of the analysis it is concluded that potential evapotranspiration predicted by Papadakis method is more reliable and usable than that predicted by Thornthwaite in the Southwestern Punjab.

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