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Short communication

Evaluation of three methods for estimating reference evapotranspiration (ET_o) at Dapoli, Maharashtra

DAVIS SIBALE, M.S MANE*, S.T PATIL and P.M. INGLE

Department of Irrigation and Drainage Engineering

College of Agricultural Engineering and Technology (C.A.E.T), Dapoli-415712(MS)

E-mail: *davissibale@yahoo.com, mahanandmane@rediffmail.com*

The estimation of reference evapotranspiration (ET_o) is the most important step towards designing, planning and managing different irrigation networks, water distribution systems, water application, water balance and water management practices (Landeras *et al*, 2008 and Sentelhas *et al.* 2010). Many methods e.g pan evaporation method, Hargreaves-Samani, Jensen Haise, Turc, Thornwaite, Blanney-Criddle, Priestley-Taylor, Makkink and FAO 56 PM method have been proposed for estimating ET_o based on weather data, and range from locally developed, empirical relationships to physically based energy and mass transfer models. To allow for greater understanding, sharing, and inter-comparison of evapotranspiration information worldwide, under varying climatic and agronomic conditions, FAO-56 Penman Monteith method is regarded as a standardized method of estimating evapotranspiration. FAO-56 Penman Monteith method demands much weather data that may be unavailable in various places hence there is need to come up with alternative methods.

For this study, 28 years (1985-2013) climatic data were collected from the Department of Agronomy, College of Agriculture, Dr.BSKKV, Dapoli. The climatic data included maximum and minimum air temperatures, sunshine hours, wind speed, maximum and minimum relative humidity, and rainfall.

Methods for estimating reference evapotranspiration (ET_o)

The daily reference evapotranspiration values were estimated using the following methods:

1. FAO-56 Penman Monteith Method (Allen *et al.,* 1998)
2. Hargreaves-Samani Method (Hargreaves-Samani, 1985)
3. Jensen-Haise equation (James, 1988)
4. Pan Evaporation Method (Doorenboss and Pruitt, 1984)

Statistical indicators e.g. root mean square error (RMSE), mean bias error (MBE), index of agreement (d), correlation coefficient (r), coefficient of determination (R^2), standard error (S.E), and confidence index (c) were used to evaluate the models.

Reference Evapotranspiration (ET_o)

The daily reference evapotranspiration values for each model were calculated and converted into monthly reference evapotranspiration. The trend in mean monthly ET_o is presented in Table 1.

The highest monthly ET_o values were recorded in summer season (March to May) and the lowest monthly ET_o values were recorded in winter season (October to February). For all methods of estimating reference evapotranspiration, the highest monthly ET_o values were recorded in May (162.3 mm, 159.0 mm, 150.3 mm and 115.6 mm for Hargreaves Samani, FAO 56 PM, pan evaporation and Jensen Haise models, respectively). The lowest monthly ET_o values were recorded in December (87.1 mm, 64.1 mm, 56.7 mm and 35.9 mm for Hargreaves Samani, FAO 56 PM, pan evaporation and Jensen Haise models, respectively).

The pan evaporation method under-estimated monthly ET_o by 8 % when compared to monthly ET_o estimated from FAO 56 PM. It showed closer values than other models. Jensen Haise model also under-estimated monthly ET_o by 37 % with largest deviation of monthly ET_o when compared to ET_o values from FAO 56 PM. Hargreaves-Samani model over-estimated monthly ET_o by 15 % when compared to monthly ET_o estimated from FAO 56 PM.

Comparisons were made between monthly reference evapotranspiration values obtained from each empirical method and monthly ET_o values from FAO 56 PM model. The benchmark method for comparisons was FAO 56 PM model because it is globally accepted and can be used under a variety of climatic regimes and reference conditions.

With regard to statistical analysis, the best model is the one with the highest index of agreement (d), correlation coefficient (r), coefficient of determination (R^2), and confidence index but also having low root mean square error

Table 1: Monthly and seasonal reference evapotranspiration (mm) by different methods

Month	FAO 56 PM	Pan Evaporation	Jensen -Haise	Hargreaves Samani
January	68.0	58.8	40.9	89.1
February	80.0	75.1	50.7	105.5
March	128.1	124.9	100.2	146.0
April	148.4	136.1	109.6	159.6
May	159.7	150.3	115.6	162.3
June	115.3	110.4	70.4	123.7
July	97.4	86.5	53.7	107.7
August	86.4	77.4	42.3	95.7
September	96.6	88.7	53.2	112.5
October	88.7	77.6	48.6	110.1
November	75.0	68.7	40.9	102.4
December	64.1	56.7	35.9	87.1
Monsoon (June-September)	395.8	363.2	219.7	439.7
Winter (October-February)	376.0	337.1	217.3	434.3
Summer(March - May)	436.3	411.4	325.6	467.9

Table 2: Summary statistics of monthly ET_o estimates computed using various models under test

MODEL	RMSE	MBE	d	r	R^2	S.E	C	Performance rating
Pan Evaporation	0.69	-0.51	0.99	0.88	0.79	0.38	0.87	Excellent
Hargreaves-Samani	0.94	0.84	0.99	0.86	0.75	0.41	0.85	Very good
Jensen-Haise	1.2	-0.84	0.97	0.71	0.50	0.56	0.69	Good

(RMSE), mean bias error (MBE), standard error (s.e), and t-stat. In reference to Table 2 below, pan evaporation method showed good correlation with FAO 56 PM model as compared to other methods.

All the statistical parameters given in Table 2 revealed that ET_o estimated by pan evaporation is very close to that of FAO 56 Penman Monteith Model.

Analyses of 28 years climatic data of Dapoli indicated that pan evaporation method compared reasonably well with FAO 56 PM model. Hargreaves-Samani model is the second best and Jensen Haise model is ranked third. Similar results are obtained by Rao and Rajput (1993). This revealed that pan evaporation method can successfully be used in the absence of adequate climatic data that is required for the use of FAO 56 Penman Monteith model in the region.

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