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Short Comminucation

Comparison and evaluation of selected evapotranspiration models for Ludhiana district of Punjab

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Evapotranspiration is the key component of hydrologic cycle.Its precise estimation is of vital importance for studying hydrologic water balance, crop yield simulation and design of irrigation systems (Kumar *et al*., 2011; Parasuraman *et al*., 2007).Various methods are employed to measure the evapotranspiration, but owing to difficulty in getting precise evapotranspiration measurement directly, it is generally estimated from meteorological data with the help of different models.Several studies have been conducted to compare and evaluate the performance of different ET models (Kingra and Mahey 2009; Kingra *et al.,* 2002, Jadhav *et al.,* 2015;Sibale *et al.,* 2015; Prasad and Kumar, 2013). In the present study the performance of different evapotranspiration models were evaluated and compared with pan evaporation for their use in Ludhiana district of Punjab using 21 years (1995-2015) of data obtained from School of Agrometeorology and Climate Change, PAU, Ludhiana.

Seven reference evapotranspiration models viz. FAO-56 Penman-Monteith model (Allen *et al*., 1998); Thornthwaite model (Thornthwaite, 1948); Blaney-Criddle model (Blaney and Criddle, 1950), Hargreaves model (Hargreaves, 1975),Hargreaves-Samani model (Allen *et al*., 1998), Stephens-Stewart model (Stephens and Stewart, 1963), Jensen-Haise model (Jensen and Haise, 1963) and Pan Evaporimeter (Allen *et al*., 1998) were used to estimate the evapotranspiration.

$$\text{Evapotranspiration} = \text{pan evaporation} \times \text{pan factor}$$

The pan factor of 0.8 was used to calculated evapotranspiration from pan evaporation.The mean monthly ET over a period of 21 years from all the models was compared with the evaporation from open pan evaporimeter because in pan evaporimeter actual evaporation is taken into account. The relationship between ET and pan evaporation was studied using different statistical parameters, namely, mean bias error (MBE), mean absolute percentage error (MAPE), root mean square error (RMSE), correlation coefficient and Willmott index of agreement and Student's t-test in SAS software (version 9.4)

The monthly ET estimated by Jensen-Haise was almost same in January (44.5 mm) and December (44.9 mm), while the maximum ET estimated was 244.3 mm in May. The similar trend in estimated ET for different months was found for Stephens-Stewart model, with maximum in May (152.6 mm) and minimum in December (29.5 mm). The ET was over estimated byHargreaves model as compared to Pan E for the cooler months of January, February, August, September and December,while it was under estimated for other months. The Thornthwaite model, though under estimated ET for the cooler months, the ET estimation was fairly good for the warmer months of April, May and June. The minimum (11.8 mm) and maximum ET (238.5 mm) was estimated for the month of January and June, respectively. The ET estimation with Blaney Criddle model was good as compared to all the ET estimation models except Penman Monteith and Jensen-Haise model. Based on the above results, it can be concluded that ET estimated by Penman Monteith model was in close agreement with the Pan E as compared to all other models. This can be attributed to the fact that Penman-Monteith model takes into consideration both radiation as well as aerodynamic components in estimation of evapotranspiration (Allen *et al.,* 1998).

Model evaluation

Mean bias error was found to be lowest for Jensen-Haise (0.029) followed by Penman-Monteith(0.074), while the highest for Hargreaves-Samani model. Both MAPE (0.10%) and RMSE (39.8 mm) were found lowest for Penman-Monteith. However, the Correlation coefficient (0.94), Wilmott d-index (0.91) and R^2(0.94) were highest for Penman-Monteith. Students-t test revealed that mean ET predicted

Table 1: Monthly Potential evapotranspiration (mm) estimated by different models during 1995-2015

	Pan E	Penman Monteith	Jensen-Haise	Stephens-Stewart	Hargreaves	Hargreaves-Samani	Thornthwaite	Blaney Criddle
Jan	40.7	43.5	44.5	29.6	47.7	28.2	11.8	80.5
Feb	61.1	62.3	69.1	45.0	67.0	41.1	25.2	109.6
Mar	111.6	111.2	126.3	80.7	110.6	72.8	59.2	167.5
April	212.0	163.7	189.4	119.2	151.9	107.1	137.0	211.0
May	292.6	205.6	244.3	152.6	186.8	125.2	224.3	239.4
June	252.1	186.0	228.9	142.8	173.7	101.1	238.5	212.0
July	159.5	149.1	198.4	124.1	152.5	70.1	209.5	159.0
Aug	129.9	135.2	176.2	110.4	137.3	62.8	188.9	159.3
Sep	123.4	123.0	162.6	102.0	127.6	67.1	166.6	185.9
Oct	103.4	94.2	126.0	79.5	102.7	64.5	110.0	166.5
Nov	68.1	59.0	74.2	47.5	66.1	44.4	50.6	125.0
Dec	41.6	40.2	44.9	29.5	45.7	28.0	17.9	90.3

Table 2: Statistical evaluation of different ET models in comparison to Pan evaporation model

Parameter	Penman Monteith	Jensen Haise	Stephens-Stewart	Hargreaves	Hargreaves-Samani	Thornthwaite	Blaney Criddle
MBE (mm)	0.07	0.03	0.18	0.08	0.26	0.05	0.10
MAPE (%)	0.10	0.18	0.23	0.23	0.25	0.50	0.91
RMSE (mm)	39.8	35.2	64.2	46.9	84.6	48.3	51.3
R^2	0.94	0.91	0.91	0.90	0.93	0.84	0.86
d-index	0.91	0.90	0.78	0.85	0.79	0.84	0.81
t-calculated	1.15	0.36	3.56*	1.34	7.35*	0.53	1.80

*The predicted values are significantly different from Pan Evaporation at ±=0.05

by Stephens-Stewart and Hargreaves-Samani model were significantly different (p=0.05) from Pan Evaporation, while all other models predicted ET at par with Pan Evaporation. The results are in conformity to several other researchers who reported Penman Monteith as the best model for predicting ET (Allen *et al.,* 1998).Based on the statistical evaluation of different models, it can be concluded that Penman-Monteith is the most accurate model for predicting ET. However, under conditions of limited data availability, other empirical models like Jensen-Haise, Hargreaves, Thornthwaite and Blaney-Criddle can be used.

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