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Short Communication

Estimating seasonal reference evapotranspiration using limited weather data

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A reliable estimation of reference evapotranspiration (ET_o) is highly essential for managing agricultural water in water scarce regions. ET_o can be computed directly using micro-meteorological techniques based on energy balance and water vapour mass flux transfer approaches or indirectly using the empirical methods. However, using direct methods may involve high cost and time, whereas the indirect approaches are based on site specific weather data (Prasad and Kumar 2013; Jadhav *et al* 2015; Sibale *et al* 2016). Among the numerous available empirical methods of estimating ET_o, the FAO-56 PM equation has been globally recognized as a standard method (Allen *et al* 1998; Tabari *et al* 2011). However, it involves a maximum number of parameters for estimation of ET_o. The FAO-PM equation based ET_o calculator helps to reduce the number of input parameters for ET_o estimation. Thus, the FAO-ET_o calculator can also be recognized as a standard method for accurate ET_o estimation. The present study was undertaken to estimate long-term (1995-2019) daily average ET_o using seventeen methods including FAO-ET_o calculator, compare the performance of sixteen methods with FAO-ET_o calculator and identify the appropriate alternative (s) to FAO-ET_o calculator for seasonal ET_o estimation.

The present study was undertaken at the department of Soil and Water Engineering, Punjab Agricultural University (PAU), Ludhiana to investigate appropriate substitute (s), requiring limited weather data for estimating seasonal ET_o as accurately as FAO-ET_o calculator. The daily weather data for twenty-five years (1995-2019) was obtained from the weather observatory of PAU, Ludhiana (located between 30°54’ N latitude and 75°48’ E longitude with an altitude of 247 m above mean sea level). The climatic data included daily air temperature (minimum and maximum), relative humidity (minimum and maximum), wind speed, sunshine hours, rainfall and evaporation.

Ludhiana district is bounded between latitude 30°33” to 31°01”N and longitude 75°25” to 76°27”E, having geographical area of 3767 km^2. In this region, the summer temperature exceeds 38°C and touches 47°C with dry spells. Winter experiences frost during December and January with minimum temperature below 4°C, dominated by North-Eastern winds during winter season. The average annual rainfall in the region is 680 mm, 75-80% of which is received during monsoon period (June to September). There are mainly four seasons viz. Spring (March-May), Summer (June-August), Autumn (September-November) and Winter (December-February).

The FAO-ET_o calculator was used as standard for performance evaluation of the other sixteen methods of ET_o estimation. Finally, nine most appropriate methods (Tabari (2011a), Tabari (2011b), Irmak (2003), Hargreaves-Samani (1985), Pan-Evaporation (1998), Priestly-Taylor (1972), Caprio (1974), Jensen and Haise (1963) and Penman (1948)) were screened for further evaluation based on their closeness with FAO-ET_o calculator in terms of estimated ET_o. The analysis was carried out to identify the appropriate alternative (s) to FAO-ET_o calculator, requiring limited weather data (2-3 parameters only) for seasonal ET_o estimation.

The performance analysis included computation of different statistical parameters viz. mean absolute error (MAE), root mean square error (RMSE), standard deviation (SD) and Willmott index of agreement (d).

Identifying best suitable alternative (s) to FAO-ET_o calculator for ET_o estimation

Spring season: The ET_o computed by using FAO-ET_o calculator, Jensen and Haise (1963), Hargreaves-Samani (1985) and Pan-

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Table 1: Statistical analysis

Season/year		Method								
		Caprio (1974)	Jensen and Haise (1963)	Tabari (2011b)	Tabari (2011a)	Irmak (2003)	Hargreaves-Samani (1985)	Penman (1948)	Pan-evaporation (1998)	Priestly and Taylor (1972)
Spring	MAE	1.13	0.11	1.50	1.30	0.82	0.29	1.13	0.42	0.72
	RMSE	1.16	0.15	1.69	1.56	0.99	0.29	1.22	0.51	0.89
	d	0.87	**1.00**	0.65	0.66	0.79	**0.99**	**0.90**	**0.98**	0.86
	SD	0.28	0.10	0.79	0.86	0.71	0.26	1.00	0.50	0.53
Summer	MAE	1.76	0.55	1.00	1.26	0.49	0.30	1.13	0.68	0.55
	RMSE	1.76	0.58	1.19	1.37	0.68	0.32	1.33	0.74	0.55
	d	0.61	0.89	0.59	0.58	0.73	**0.97**	0.78	**0.91**	0.83
	SD	0.05	0.17	0.64	0.54	0.55	0.10	0.83	0.57	0.52
Autumn	MAE	1.30	0.44	0.14	0.23	0.57	0.49	0.98	0.52	0.29
	RMSE	1.40	0.55	0.17	0.28	0.59	0.57	0.99	0.57	0.36
	d	0.71	**0.93**	**0.99**	**0.96**	0.88	0.85	0.06	0.86	**0.97**
	SD	0.52	0.33	0.09	0.25	0.16	0.36	0.96	0.25	0.33
Winter	MAE	0.16	0.40	0.03	0.18	0.51	0.45	0.39	0.39	0.07
	RMSE	0.19	0.41	0.04	0.18	0.52	0.46	0.42	0.40	0.09
	d	**0.96**	0.79	**1.00**	**0.95**	0.75	0.77	0.59	0.76	**0.99**
	SD	0.11	0.09	0.02	0.02	0.05	0.09	0.35	0.09	0.06
Annual	MAE	**1.09**	**0.38**	0.67	0.74	0.60	**0.38**	0.91	0.50	0.41
	RMSE	**1.27**	0.46	1.04	1.05	0.72	**0.43**	1.05	0.57	0.56
	d	0.91	**0.99**	0.88	**0.87**	0.94	0.98	0.93	0.98	0.97
	SD	0.66	0.44	0.79	0.85	0.72	**0.38**	**1.05**	0.44	0.55

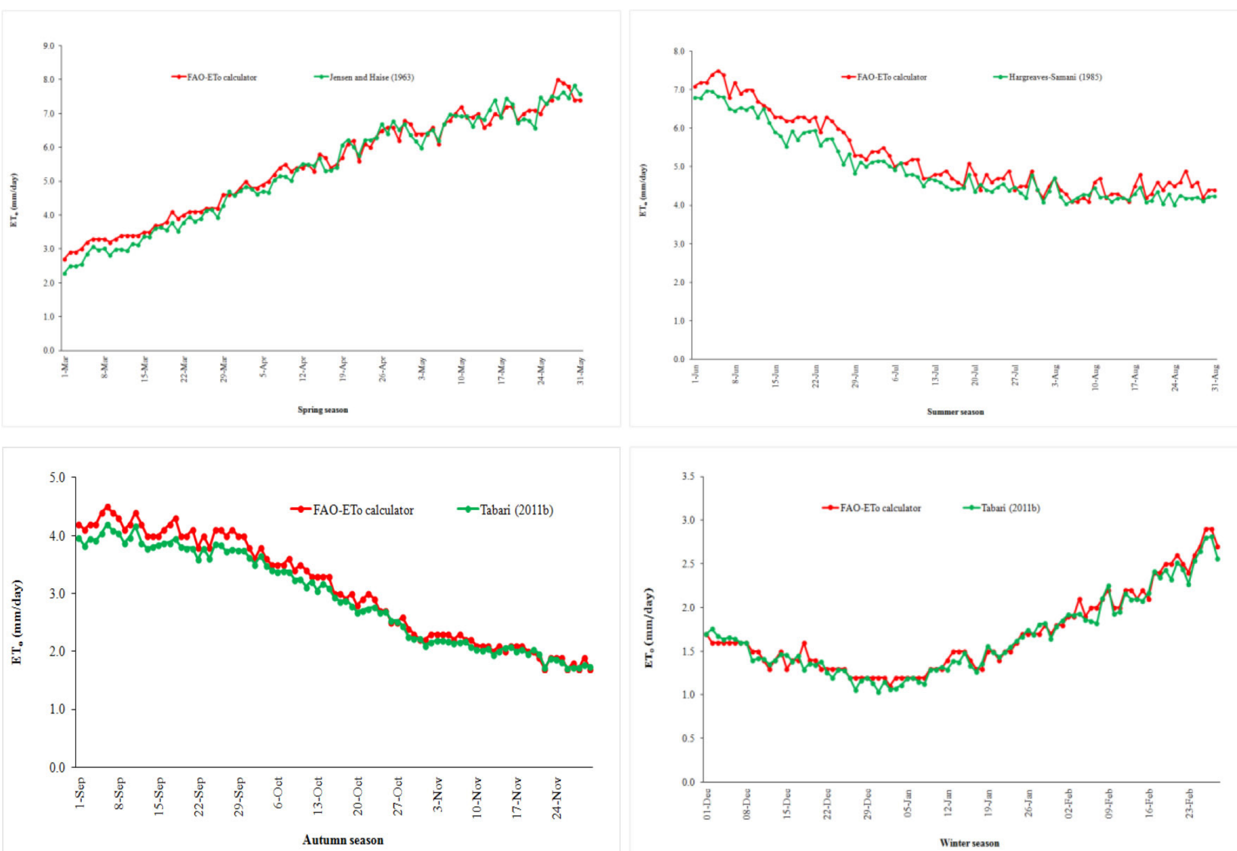

Fig. 1: Comparison of ET_o estimated by FAO-ET_o calculator with that obtained using the best alternative methods identified for spring, summer, autumn and winter seasons, respectively

evaporation (1998) methods were observed to be in the range of 3.66-7.00, 3.41-6.96, 4.01-6.77 and 2.97-7.53 mm/day, respectively, having lowest and highest values in the months of March and May, respectively. The seasonal average ET_o was computed as 5.44, 5.32, 5.57 and 5.39 mm/day by the four respective methods, having lowest and highest values for Jensen and Haise (1963) and Hargreaves-Samani (1985) methods, respectively. Both MAE and RMSE were obtained to be lowest (0.11 and 0.15 mm/day, respectively) and highest (1.50 and 1.69 mm/day, respectively) for Jensen and Haise (1963) and Tabari (2011b) methods, respectively. SD was computed to be lowest (0.10 mm/day) and highest (1.00 mm/day) for Jensen and Haise (1963) and Penman (1948) methods. respectively. Whereas, the d value was obtained to be highest (1.00) and lowest (0.65) for Jensen and Haise (1963) and Tabari (2011b) methods, respectively. Thus, Jensen and Haise (1963) method was observed to be the best alternative to FAO-ET_o calculator, statistically having highest d value (1.0) and lowest MAE, RMSE and SD values (Table 1). The Hargreves-Samani (1985) method was observed to be the second best alternative to FAO-ET_o calculator for estimating ET_o.

Summer season : The ET_o computed by using FAO-ET_o calculator, Jensen and Haise (1963), Hargreaves-Samani (1985) and Pan-evaporation (1998) method were observed to be in the range of 4.40-6.51, 5.14-6.83, 4.16-6.07 and 3.39-6.81 mm/day, respectively, having lowest and highest values in the months of August and June, respectively. The average ET_o was computed by the four methods were 5.26, 5.81, 4.96 and 4.78 mm/day, respectively, having lowest and highest values for Pan-evaporation (1998) and Jensen and Haise (1963), respectively. MAE was computed to be lowest (0.30 mm/day) and highest (1.76 mm/day) for Hargreaves-Samani (1985) and Caprio (1974) methods, respectively. RMSE was obtained to be lowest (0.32 mm/day) and highest (1.76 mm/day) for Hargreaves-Samani (1985) and Caprio (1974) methods, respectively. SD was obtained to be lowest (0.05 mm/day) and highest (0.83 mm/day) for Caprio (1974) and Penman (1948) methods, respectively. The d value was computed to be highest (0.97) and lowest (0.58) for Hargreaves-Samani (1985) and Tabari (2011a) methods, respectively. Hence, Hargreaves-Samani (1985) method was observed to be the best alternative to FAO-ET_o calculator, statistically having highest d value (0.97) and lowest MAE and RMSE values (Table 1).

Autumn season: The ET_o computed by using FAO-ET_o calculator, Tabari (2011b), Tabari (2011a), Jensen and Haise (1963) and Priestly and Taylor (1972) methods were observed to be in the range of 2.04-4.13, 2.00-3.87, 2.19-3.68, 2.04-4.95 and 1.81-4.70 mm/day, respectively having, lowest and highest values in the months of November and September, respectively. The average ET_o computed by these five methods were 3.08, 2.95, 2.96, 3.52 and 3.22 mm/day, respectively, having lowest and highest values for Tabari (2011b) and Jensen and Haise (1963) methods, respectively. Both MAE and RMSE were obtained to be lowest (0.14, 0.17 mm/day, respectively) and highest (1.30, 1.40 mm/day, respectively) for Tabari (2011b) and Caprio (1974) methods, respectively. SD was computed to be lowest (0.09 mm/day) and highest (0.96 mm/day) for Tabari (2011b) and Penman (1948) methods, respectively. Whereas, the d value was obtained to be highest (0.99) and lowest (0.06) for Tabari (2011b) and Penman (1948) methods, respectively. Hence, Tabari (2011b) method was observed to be the best alternative to FAO-ET_o calculator, statistically having highest d value (0.99) and lowest MAE, RMSE and SD values (Table 1). Tabari (2011a) method was observed to be the second best alternative to FAO methods of estimating ET_o, using minimum weather data.

Winter season : The ET_o computed by using FAO-ET_o calculator, Tabari (2011b), Priestly and Taylor (1972), Caprio (1974) and Tabari (2011a) were observed to be in the range of 1.41-2.28, 1.39-2.22, 1.27-2.27, 1.43-2.54 and 1.60-2.45 mm/day, respectively, having lowest and highest values in the months of December and February, respectively. The average ET_o computed by these methods were 1.71, 1.67, 1.64, 1.86 and 1.64 mm/day, respectively, having lowest and highest values for Priestly and Taylor (1972) or Tabari (2011a) and Caprio (1974) methods, respectively. Both MAE and RMSE were computed to be lowest (0.03, 0.04 mm/day, respectively) and highest (0.03, 0.04 mm/day, respectively) for Tabari (2011b) and Irmak (2003) methods, respectively. SD was obtained to be lowest (0.02 mm/day) and highest (0.35 mm/day) for Tabari (2011a and b) and Penman (1948) methods, respectively. Whereas, the d value was computed to be highest (1.00) and lowest (0.59) for Tabari (2011b) and Penman (1948) methods, respectively. Thus, Tabari (2011b) method was observed to be the best alternative to FAO-ETo calculator, statistically having highest d value (1.0) and lowest MAE, RMSE and SD values (Table 1). The Priestly-Taylor (1972) method was observed to be the second best alternative of estimating ET_o using minimum weather data. Overall, in seasonal context, Jensen and Haise (1963) and Hargreaves-Samani (1985) methods were observed to be the best alternatives to FAO-ET_o calculator for ET_o estimation using limited weather data during Spring and Summer seasons, respectively (Fig. 1). Whereas, Tabari (2011b) method was observed to be the best alternative to FAO methods for ET_o estimation using limited weather data during both Autumn and Winter seasons, respectively (Fig. 1). In yearly context, Hargreves-Samani (1985) method was observed to be the best alternative to FAO-ET_o calculator. Jensen and Haise (1963) method was observed to be the second best alternative of estimating ET_o.

The statistical comparison indicated the Jensen and Haise (1963) method as the best alternative to FAO-ET_o calculator (d=1.0) for ET_o estimation using limited weather data during the Spring season. For the Summer season, Hargreaves-Samani (1985) method was identified as the best alternative to FAO-ET_o calculator (d=0.97). Whereas, during both Autumn and Winter seasons, Tabari (2011b) method can be the best substitute to FAO-ET_o calculator, requiring only 2-3 weather parameters for ET_o estimation, having d values of 0.99 and 1.0, respectively.

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REFERENCES

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998). Crop evapotranspiration. guidelines for computing crop water requirements. *FAO Irrig. Drain.,*56: 300.

Caprio, J.M. (1974). The Solar Thermal Unit Concept in Problems Related to Plant Development and Potential Evapotranspiration*. Ecol. Stud.,* 8:353-364*.*

Hargreaves, G.H. and Samani, Z.A. (1985). Reference crop evapotranspiration from temperature. *Appl. Eng. Agric*., 1 (2): 96–99.

Irmak, S., Irmak, A., Allen, R.G. and Jones, J.W. (2003). Solar and Net Radiation-Based Equations to Estimate Reference Evapotranspiration in Humid Climates*. J. Irrig. Drain. Eng.,* 129(5): 336-347.

Jensen, M.E. and Haise, H.R. (1963). Estimating Evapotranspiration from Solar Radiation. *J. Irrig. Drain. Div.,*89: 15-41.

Jadhav, P.B., Kadam, S.A. and Gorantiwar, S.D. (2015). Comparison of methods for estimating reference evapotranspiration (ET_o) for Rahuri region. *J. Agrometeorol.,*17(2): 204-207.

Penman, H.L. (1948). Natural Evaporation from Open Water Bare Soil and Grass. *Proc. Math. Phys. Eng. Sci.,*193(1032): 120-145.

Prasad, S. and Kumar, V. (2013). Evaluation of FAO-56 Penman-Monteith and alternative methods for estimating reference evapotranspiration using limited climatic data at Pusa. *J. Agrometeorol.,*15: 22-29.

Priestley, C.H.B. and Taylor, R.J. (1972). On the assessment of the surface heat flux and evaporation using large-scale parameters. *Mon. Weather Rev.,* 100: 81-89.

Tabari, H., Grismer, M.E. and Trajkovic, S. (2011a and b). Comparative analysis of 31 reference evapotranspiration methods under humid conditions*. Irrig. Sci.* 31(2): 107-117.