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Performance of Radiation-Based Reference Evapotranspiration Equations Vs FAO 56-PM Model at Sub-Humid Region of Uttarakhand

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Abstract-In the present study, the comparative performance of 20 radiation-based equations for estimating reference evapotranspiration (ET_0) was statistically analyzed with reference to well proven Food and Agriculture Organization Penman-Monteith (FAO-56 PM) model for sub-humid Pantnagar, located in the *Tarai* region of Uttarakhand. The higher value of Agreement index of ET_0 values obtained between FAO24-Radiation and FAO-56 PM ET_0 methods observed on different timescales endorses its appropriateness as well. The Castaneda-Rao method gave ratio of ET_0 method / ET_0 FAO-56 PM almost equal to 1.00 at all timescales.

Index Terms-Radiation based; reference evapotranspiration; sub-humid.

1. INTRODUCTION

In India, about 70 percent population is dependent on agriculture and allied activities. Due to inadequate and uneven distribution of rainfall during crop growth period, it becomes necessary to apply additional water to the soil in the form of irrigation for plant use.In order to improve crop water use efficiency, accurate estimation of evapotranspiration (ET), the sum of amount of water returned to atmosphere through combined process of evaporation and transpiration, is essentially required for efficient water management.

Lysimeter are normally used for measuring ET directly by considering change in soil moisture from known volume of soil covered with vegetation [1], but its use is very expensive, takes more time to install and requires more maintenance due to which ET is estimated with the help of a large number of empirical or semi-empirical formulae. A modification of ET concept is reference evapotranspiration (ET_0) that provides a standard crop (a short, clipped grass) with an unlimited water supply so that a user can calculate maximum evaporative demand from that surface for a given day. This value, adjusted for a particular crop, is the consumptive use (or demand) and its deficit represents that component of consumptive use that goes unfilled during the given time period. This deficit value is the amount of water that must be supplied through irrigation to meet the water demand of crops [2, 3].

The FAO Penman-Monteith (FAO-56 PM) method is recommended as the standard method for determining ET_0 as it is physically based and explicitly incorporates both physiological and aerodynamic parameters. The superior performance of this method in various climates has been evaluated and confirmed by various researchers [3-8]. The method requires solar radiation, wind speed, air temperature and humidity data but all these input variables may not be available for a given location due to non-availability of well-established weather stations and thus, some parameters are not recorded. Especially in developing countries like India, quality of data and difficulties in gathering all necessary weather parameters can present serious limitations. The FAO Expert Consultation on Methodologies for Crop Water Requirements recommended that empirical methods be validated for new regions using standard FAO-56 PM method [5, 6].

Keeping in view the relevance of precise ET_0 estimation, an attempt has been made in the present study to evaluate, decide and select alternative radiation-based methods to get almost at par ET_0 values (from observed climatic data) on daily, weekly and monthly basis on the basis of their performance with widely acclaimed FAO-56 PM method as an index for Pantnagar, located in the sub-humid *Tarai* region of Uttarakhand.

2. MATERIALS AND METHODS

Study area and weather dataset: The present study was conducted to perform comparative analysis of different radiation-based ET_0 methods for Pantnagar (79.49°E, 29.03°N, 243.80 m msl) on the basis of 24 years of daily meteorological dataset consisting of temperature (maximum and minimum); relative humidity (maximum and minimum) and duration of actual sunshine hours. The required meteorological dataset was obtained from Govind Ballabh Pant

University of Agriculture & Technology, Pantnagar (Uttarakhand).

FAO–56 Penman Monteith Model: The original Penman-Monteith combination equation, combined with equations of aerodynamic and surface resistance, called as "FAO Penman-Monteith equation" [3, 5] is given below:

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where ET_0 is reference evapotranspiration (mm day^{-1}); R_n is net radiation at crop surface (MJ m^{-2} day^{-1}); G is soil heat flux density (MJ m^{-2} day^{-1}); T is mean daily air temperature ($^{\circ}$C); U_2 is wind speed at 2 m height (m s^{-1}); e_s is saturation vapour pressure (kPa); e_a is actual vapour pressure (kPa); e_s-e_a is saturation vapour pressure deficit (kPa); Δ is slope of vapour pressure curve (kPa$^{\circ}$C^{-1}) and γ is psychometric constant (kPa$^{\circ}$C^{-1}).

The computation of daily ET_0 using Eq. (1) requires meteorological parameters consisting of air temperature (maximum and minimum), mean daily actual vapour pressure (e_a) derived from either dew point temperature or relative humidity (maximum and minimum), daily average of 24-hour wind speed measured at two meter height (u_2), and net radiation (R_n) measured or computed from solar and long-wave radiation or from actual duration of sunshine hours (n). Since soil heat flux (G) has a relatively small value, therefore, it was ignored for computing ET_0 on daily basis [3].

The FAO-56 PM method is recommended as a standard one to compute ET_0 as this method gives proximate close values with actual values measured in a wide range of location and climatic conditions and it was, therefore, chosen as index method in the present study to compute reference evapotranspiration.

Radiation-based ET_0methods: The commonly used 20 radiation-based ET_0 equations considered in this study (Table 1) were evaluated with the help of Microsoft™Excel® as computing tool.

Assumptions and Statistical Analysis: The analysis of results to draw fruitful inferences from them in terms of statistical indices was being done as it has been pointed out by [9, 10] that commonly used correlation measures e.g. correlation coefficient, coefficient of determination and tests of statistical significance in general are often inappropriate or misleading. Different statistical indices considered to evaluate performance of different methods includes Agreement index (D), Root Mean Square Error (RMSE), Mean Bias Error (MBE), MAXimum Absolute Error (MAXE), Percentage Error (%), Coefficient of determination (R^2) and Standard Error of Estimate (SEE). The "Agreement Index" (D) is being proposed [10-12] as a descriptive measure. On the basis of literature reviewed on different statistical indices, higher values of D and R^2 (near to "1.0"), values near to "0.0" for RMSE, MBE, MAXE, PE and SEE were considered "good" for deciding the performance of considered methods. The quantification of under- and over-estimation of ET_0 method as compared to that obtained with FAO-56 PM model was being done in terms of their ratio and its value near to "1.00" was considered "good".

3. RESULTS AND DISCUSSIONS

Cross comparison of radiation-based ET_0 equations

The performance of 20 radiation-based ET_0 equations was evaluated by comparing their daily, weekly and monthly ET_0 estimates with those obtained with FAO-56 PM model. For weekly and monthly comparisons, daily ET_0 values averaged over one week and month period were plotted against values obtained by FAO-56 PM method. The long-term daily, weekly and monthly average ratios of ET_0 method/ET_0 FAO-56 PM were computed in order to quantify over- and under-estimation of developed equations relative to FAO-56 PM ET_0 values.

The statistical analysis of radiation-based ET_0 equations for study area (Table 2) indicate that FAO24-Radiation method was best as it gave optimal value of D as 0.952 (daily basis), 0.961 (weekly basis) and 0.962 (monthly basis). The lowest values of MBE on daily, weekly and monthly basis were obtained with Irmak R_s method as 3.640, 3.597 and 4.077 respectively. The lowest values of SEE on daily basis (0.026) was obtained with Abtew method, whereas, lowest values of SEE on weekly and monthly basis were obtained with Turc method as 0.026 and 0.111 respectively. The best value of ratio of ET_0 method to that of FAO-56 PM (almost equal to "1.00") was obtained with Castaneda-Rao method as 0.995, 0.997 and 0.996 on daily, weekly and monthly basis respectively.

Considering calculated values of RMSE on daily, weekly and monthly basis, 10 best methods on daily basis were obtained as Stephens (0.844) followed by FAO24-Radiation (0.864), Priestley-Taylor (0.878), Hansen (0.908), Castaneda-Rao (0.933), modified Priestley-Taylor (0.936), Irmak R_s (0.966), de Bruin (1.020), Irmak R_n (1.021) and Stephens-Stewart (1.057). On weekly basis, the FAO24-Radiation method was found best with lowest RMSE value (0.704 mm day^{-1}), whereas, Stephens method was observed best on monthly basis as it gave lowest RMSE value as 2.798 mm day^{-1} among all other considered methods.

Similarly, in terms of D values for study area, it is clear that FAO24-Radiation method was found best with values of D as 0.952, 0.961 and 0.962 on daily, weekly and monthly basis respectively. The Stephens and Priestley-Taylor methods gave almost same D values followed by modified Priestley-Taylor method on weekly and monthly basis at the study area.

4. CONCLUSIONS

Considering the limitations associated with reliability and availability of good quality weather data especially in developing countries, the widely acclaimed and well-proven FAO-56 PM model cannot be used to estimate reference evapotranspiration due to which identification of simpler ET_0 equations is required. In this study, the performance of 20 radiation-based ET_0 equations as compared to FAO-56 PM model was evaluated.

The Castaneda-Rao method gave best estimate of FAO-56 PM model at all considered timescales. The ET_0 equations proposed by McGuinness-Bordne, Berengena-Gavilan, Caprio, FAO24-Radiation, Irmak R_s, Irmak R_n and Hansen over-estimated FAO-56 PM model values, whereas, de Bruin, modified Priestley-Taylor, Stephens, Makkink, Stephens-Stewart, Jensen-Haise, Xu-Singh, Jones-Ritchie, Turc, Christiansen and Abtew methods under-estimated it in the sub-humid environmentprevailing at Pantnagar on daily, weekly and monthly basis.

On the basis of values of D and RMSE on daily, weekly and monthly basis, the performance of FAO24-Radiation ET_0 method was found best, however, Abtew method was observed as worst.

REFERENCES

[1] Watson, I. and Burnett, A.D., 1995, Hydrology: An Environmental Approach. Boca Raton, FL: CRC Press.

[2] Dingman, S.L., 1994, Physical Hydrology. Prentice-Hall, Upper Saddle River, NJ

[3] Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998, Crop evapotranspiration - Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage paper No. 56, Food and Agriculture Organization of United Nations, Rome.

[4] Jensen, M.E., Burman, R.D. and Allen, R.G., 1990, Evapotranspiration and Irrigation water requirements, ASCE Manual and Report on Engineering Practices No. 70. ASCE, New York

[5] Smith, M., Allen, R.G., Monteith, J.L., Pereira, A., Pereira, L. and Segeren, A., 1991, Report of the expert consultation on procedures for revision of FAO guidelines for prediction of crop water requirements. Rep., UN-FAO, Rome.

[6] Allen, R.G., Smith, M., Perrier, A. and Pereira, L.S., 1994, An update for the definition of reference evapotranspiration, *Intl. Commission Irrig. and Drain. Bulletin*, 43(2): 1-34.

[7] Allen, R.G., Walter, I.A., Elliot, R., Mecham, B., Jensen, M.E., Itenfisu, D., Howell, T.A., Snyder, R., Brown, P., Echings, S., Spofford, T., Hattendorf, M., Cuenca, R.H., Wright, J.L. and Martin, D., 2000, Issues, requirements and challenges in selecting and specifying a standardized ET equation, In: Proc. 4th Nat IrrigSymp, AmerSocAgricEngrs, Phoenix.

[8] Walter, I.A., Allen, R.G., Elliott, R., Jensen, M.E., Itenfisu, D., Mecham, B., Howell, T.A., Snyder, R., Brown, P., Eching, S., Spofford, T., Hattendorf, M., Cuenca, R.H., Wright, J.L. and Martin, D., 2000, ASCE's standardized reference evapotranspiration equation, In: Proc 4th Nat IrrigSymp, AmerSocAgricEngrs, Phoenix.

[9] Fox, D.G., 1981, Judging air quality model performance: A summary of AMS Workshop on dispersion model performance, *Bull. Amer. Meteorol. Soc.*, 62: 599-609.

[10] Willmott, C.J., 1982, Some comments on the evaluation of model performance, *Bull. Amer. Meteo. Soc.*, 63(11): 1309-1312.

[11] Willmott, C.J., 1981, On the validation of models, *Phys. Geog.*, 2: 184-194.

[12] Willmott, C.J. and Wicks, D.E., 1980, An empirical method for the spatial interpolation of monthly precipitation within California, *Phys. Geog.*, 1: 59-73.

[13] Abtew, W., 1996, Evapotranspiration measurements and modeling for three wetland systems in South Florida, *J. Amer. Water Resour. Assoc.*, 32:465–473.

[14] Berengena, J. and Gavilán, P., 2005, Reference evapotranspiration estimation in a highly advective semiarid environment, *J. Irrig Drain Engg.*, 131:147–163.

[15] Caprio, J.M., 1974, The solar thermal unit concept in problems related to plant development and potential evapotranspiration, In: Lieth H, editor. Phenology and seasonality methoding, Ecological studies, Vol. 8, 353–364.

[16] Castaneda. L. and Rao, P., 2005, Comparison of methods for estimating reference evapotranspiration in Southern California, *J. Environ. Hydrol.*, 13:1–10.

[17] Christiansen, J.E. (1968), Pan evaporation and evapotranspiration from climatic data, *J. Irrig Drain Div.*. 94:243–265.

[18] de Bruin, H.A.R. and Stricker, J.N.M. (2000), Evaporation of grass under non-restricted soil

moisture conditions, *Hydrol. Sci J.*, 45:391–406.

[19] Doorenbos, J. and Pruitt, W.O. (1977), Guidelines for Predicting Crop Water Requirements, Irrigation and Drainage paper No. 24, 2nd ed., FAO, Rome, Italy.

[20] Hansen, S. (1984), Estimation of potential and actual evapotranspiration, *Nord Hydrol.*, 15:205–212.

[21] 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. Engg.*, 129 (5): 336–347.

[22] Jensen, M.E. and Haise, H.R. (1963), Estimating evapotranspiration from solar radiation, *J. Irrig. Drain. Engg.*, 89: 15-41.

[23] Jones, J.W. and Ritchie, J.T. (1990), Crop growth methods: Management of farm irrigation systems, In: Hoffman GJ, Howel TA, Solomon KH (eds), ASAE Monograph No. 9, 63–89.

[24] Makkink, G.F. (1957), Testing the Penman formula by means of lysimeters, *J. Insti. Water Eng.*, 11:277–288.

[25] McGuinness, J.L. and Bordne, E.F. (1972), A comparison of lysimeter-derived potential evapotranspiration with computed values, Technical Bulletin 1452, Agricultural Research Service, USDA, Washington, DC, 71 pp.

[26] Priestley, C.H.B. and Taylor, R.J. (1972), On the assessment of surface heat flux and evaporation using large scale parameters, *Monthly Weather Rev.*, 100:81–92.

[27] Stephens, J.C. (1965), Discussion of "estimating evaporation from insolation", *J. Hydraul. Div.*, 91:171–182.

[28] Jensen, M.E. (1966), Empirical methods of estimating or predicting evapotranspiration using radiation, In: Evapotranspiration and its role in water resources management, ASAE, 49–53, 64.

[29] Turc, L. (1961), Estimation of irrigation water requirements, potential evapotranspiration: A simple climatic formula evolved up to date, *Ann. Agron.*, 12:13–49.

[30] Xu, C.Y. and Singh, V.P. (2000), Evaluation and generalization of radiation-based methods for calculating evaporation, *Hydrol. Process*, 14:339–349.

Table 1 Details of radiation-based ET_0 methods considered in the study

Model / method	Equation	References
Abtew (Abt)	$ET_0 = 0.408 \times 0.01786 \times R_s T_{max}$	[13]
Berengena-Gavilan (BG)	$ET_0 = 0.408 \times 1.65 \left(\frac{\Delta}{\Delta+\gamma}\right)(R_n - G)$	[14]
Caprio (Cap)	$ET_0 = (0.01092708\ T_{av} + 0.0060706) R_s$	[15]
Castaneda-Rao (CR)	$ET_0 = 0.408 \times 0.70 \left(\frac{\Delta}{\Delta+\gamma}\right) R_s - 0.12$	[16]
Christiansen (Chr)	$ET_0 = 0.408 \times 0.0385 \times R_s$	[17]
de Bruin (dBr)	$ET_0 = 0.408 \times 0.65 \left(\frac{\Delta}{\Delta+\gamma}\right) R_s$	[18]
FAO24-Radiation (FRad)	$ET_0 = 0.408 \times a \left(\frac{\Delta}{\Delta+\gamma}\right) R_s - 0.30$	[19]
Hansen (Han)	$ET_0 = 0.408 \times 0.70 \left(\frac{\Delta}{\Delta+\gamma}\right) R_s$	[20]
Irmak R_n (IrR_n)	$ET_0 = 0.289 \times R_n + 0.023 \times T_{av} + 0.489$	[21]
Irmak R_s(IrR_s)	$ET_0 = 0.149 \times R_s + 0.079 \times T_{av} - 0.611$	[21]
Jensen-Haise (JH)	$ET_0 = 0.408 \times C_T (T_{av} - T_x) R_s$	[22]
Jones-Ritchie (JR)	$ET_0 = 0.00387 \times (0.6T_{max} + 0.4T_{min} + 29) R_s \times \alpha$	[23]
Makkink (Mak)	$ET_0 = 0.408 \times 0.61 \left(\frac{\Delta}{\Delta+\gamma}\right) R_s - 0.12$	[24]
McGuinness-Bordne (MB)	$ET_0 = \left\{(0.0082 \times T_{av} - 0.19)\left(\frac{R_s}{1500}\right)\right\} \times 2.54$	[25]
Modified Priestley-Taylor (MPT)	$ET_0 = 0.408 \times 1.18 \left(\frac{\Delta}{\Delta+\gamma}\right)(R_n - G)$	[13]
Priestley-Taylor (PT)	$ET_0 = 0.408 \times 1.26 \left(\frac{\Delta}{\Delta+\gamma}\right)(R_n - G)$	[26]
Stephens (Ste)	$ET_0 = 0.408 \times (0.0158\ T_{av} + 0.09) \times R_s$	[27, 28]
Stephens-Stewart (SS)	$ET_0 = 0.408 \times (0.0148\ T_{av} + 0.07) \times R_s$	[28]
Turc (Tur)	$ET_0 = (0.3107 \times R_s + 0.65) \times \left(\frac{T_1}{T_{av} + 15}\right)$	[29]
Xu-Singh (XS)	$ET_0 = 0.408 \times 0.98 \left(\frac{\Delta}{\Delta+\gamma}\right)(R_n - G) - 0.94$	[30]

ET_0 = reference crop evapotranspiration (mm day^{-1}), G = soil heat flux density (MJ m^{-2} day^{-1}), R_n= net radiation (MJ m^{-2} day^{-1}), R_s= solar radiation (MJ m^{-2} day^{-1}), T_{av} = average daily air temperature (°C), T_{max} = maximum air temperature (°C), T_{min} = minimum air temperature (°C), u_2 = mean daily wind speed at 2 m height (m s^{-1}), Δ = slope of saturation vapor pressure–temperature curve (kPa °C^{-1}), γ = psychometric constant (kPa °C^{-1}), λ = latent heat of vaporization (MJ kg^{-1}), and a, C_T, T_1, T_x, α = experimental coefficients.

Table 2 Statistical performance of radiation-based methods versus FAO-56 PM model for estimating ET_0 values

Methods	D	RMSE	MBE	MAXE	PE	R²	SEE	Ratio
Daily basis								
Abt	0.407	4.113	-3.647	-0.755	96.621	0.722	0.026	0.038
BG	0.880	1.445	1.045	3.897	27.968	0.809	0.953	1.321
Cap	0.899	1.399	1.006	3.852	26.839	0.866	0.881	1.268
CR	0.918	0.933	-0.269	1.293	7.324	0.831	0.575	0.995
Chr	0.418	3.965	-3.501	-0.709	92.742	0.728	0.049	0.082
dBr	0.898	1.020	-0.408	1.122	10.641	0.831	0.534	0.964
FRad	0.952	0.864	0.508	2.763	13.538	0.891	0.681	1.165
Han	0.922	0.908	-0.149	1.413	4.731	0.831	0.575	1.038
IrR_n	0.889	1.021	0.045	1.309	4.535	0.805	0.537	1.135
IrR_s	0.903	0.966	0.034	1.362	3.640	0.837	0.497	1.119
JH	0.860	1.484	-1.219	1.540	32.341	0.819	0.804	0.618
JR	0.604	2.401	-2.057	-0.343	54.456	0.878	0.267	0.477
Mak	0.854	1.219	-0.735	0.782	19.326	0.831	0.501	0.862
MB	0.750	2.327	1.859	5.562	49.628	0.662	1.382	1.601
MPT	0.924	0.936	-0.328	1.182	8.721	0.809	0.681	0.945
PT	0.937	0.878	-0.094	1.620	4.514	0.808	0.727	1.009
Ste	0.941	0.844	-0.392	0.896	10.259	0.865	0.583	0.916
SS	0.904	1.057	-0.707	0.506	18.625	0.866	0.534	0.828
Tur	0.421	3.936	-3.480	-0.762	92.195	0.862	0.039	0.086
XS	0.707	2.084	-1.851	-0.596	48.954	0.808	0.566	0.453
Weekly basis								
Abt	0.393	4.050	-3.639	-1.046	96.418	0.823	0.037	0.042
BG	0.881	1.331	1.040	2.530	27.826	0.841	0.794	1.311
Cap	0.905	1.243	1.006	2.451	26.822	0.909	0.650	1.273
CR	0.923	0.817	-0.269	0.738	7.347	0.905	0.368	0.997
Chr	0.404	3.903	-3.493	-0.976	92.550	0.822	0.049	0.085
dBr	0.898	0.923	-0.408	0.650	10.660	0.905	0.342	0.964
FRad	0.961	0.704	0.510	1.578	13.591	0.934	0.474	1.174
Han	0.928	0.789	-0.150	0.858	4.757	0.905	0.369	1.038
IrR_n	0.894	0.923	0.042	0.875	4.549	0.838	0.446	1.116
IrR_s	0.908	0.866	0.032	1.054	3.597	0.882	0.381	1.109
JH	0.858	1.395	-1.219	0.349	32.350	0.865	0.638	0.628
JR	0.588	2.356	-2.057	-0.493	54.459	0.937	0.168	0.478
Mak	0.846	1.142	-0.734	0.366	19.318	0.906	0.320	0.864
MB	0.752	2.227	1.849	4.576	49.262	0.739	1.216	1.548
MPT	0.929	0.828	-0.329	0.530	8.761	0.842	0.565	0.939
PT	0.944	0.755	-0.096	0.849	4.567	0.842	0.604	1.002
Ste	0.947	0.726	-0.392	0.417	10.255	0.915	0.411	0.919
SS	0.903	0.975	-0.706	0.131	18.600	0.914	0.379	0.831
Tur	0.409	3.876	-3.480	-1.047	92.193	0.924	0.026	0.085
XS	0.692	2.039	-1.847	-1.006	48.857	0.838	0.471	0.461
Monthly basis								
Abt	0.429	16.187	-14.519	-5.181	90.245	0.871	0.507	0.093
BG	0.885	5.402	4.152	9.821	26.444	0.874	3.147	1.286
Cap	0.903	5.207	4.364	8.496	27.131	0.929	2.574	1.276
CR	0.936	3.091	-0.990	2.240	6.558	0.928	1.464	1.003
Chr	0.440	15.588	-13.931	-4.835	86.580	0.872	0.545	0.135
dBr	0.915	3.513	-1.538	1.906	9.581	0.926	1.392	0.971
FRad	0.962	2.835	2.272	5.543	14.085	0.951	1.769	1.182

Han	0.941	2.990	-0.500	2.755	4.319	0.926	1.485	1.041
IrR_n	0.917	3.466	0.291	3.297	5.149	0.867	1.941	1.107
IrR_s	0.924	3.322	0.265	3.769	4.077	0.892	1.736	1.108
JH	0.855	5.740	-5.207	-1.486	32.322	0.895	2.341	0.636
JR	0.586	9.967	-8.792	-2.618	54.257	0.963	0.563	0.479
Mak	0.866	4.417	-2.858	0.861	17.714	0.928	1.306	0.876
MB	0.755	9.441	7.978	18.955	49.836	0.799	5.052	1.528
MPT	0.944	3.081	-1.311	1.654	8.144	0.878	2.302	0.936
PT	0.956	2.805	-0.382	2.928	4.487	0.878	2.440	0.996
Ste	0.954	2.798	-1.550	1.146	9.512	0.930	1.678	0.926
SS	0.912	3.833	-2.810	-0.049	17.327	0.929	1.577	0.842
Tur	0.405	16.486	-14.917	-5.520	92.150	0.934	0.111	0.085
XS	0.708	8.234	-7.473	-4.397	46.353	0.869	2.075	0.484

Abt = Abtew, BG = Berengena-Gavilan, Cap = Caprio, CR = Castaneda-Rao, Chr = Christiansen, dBr = de Bruin, FRad = FAO24-Radiation, Han = Hansen, IR_s= Irmak R_s, IR_n= Irmak R_n, JH = Jensen-Haise, JR = Jones-Ritchie, Mak = Makkink, MB = McGuinness-Bordne, MPT = Modified Priestley-Taylor,
PT = Priestley-Taylor, Ste = Stephens, SS = Stephens-Stewart, Tur = Turc, XS = Xu-Singh, D = Agreement index, RMSE = Root Mean Square Error (mm day^{-1}), MBE = Mean Bias Error (mm day^{-1}), MAXE = Maximum Absolute Error (mm day^{-1}), PE = Percentage Error of Estimate (%), R^2 = Coefficient of determination,
SEE = Standard Error of Estimate (mm day^{-1}), and Ratio = Ratio of ET_0 method/ET_0 FAO-56 PM.