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EVALUATION OF DIFFERENT MODELS TO ESTIMATE REFERENCE EVAPOTRANSPIRATION AT DIFFERENT CLIMATIC ZONES OF PAKISTAN

Arshad Ali[1], Zia Ul Haq[*2], Khurram Sheraz[3]

[1,*2,3]*Department of Agricultural Engineering, University of Engineering & Technology, University Campus Peshawar, Pakistan*

[1]arshadali@uetpeshawar.edu.pk, [*2]zia.haq@uetpeshawar.edu.pk, [3]shiraz@uetpeshawar.edu.pk

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Corresponding Author: *
Zia Ul Haq

Abstract

Evapotranspiration plays an important role in many fields like agriculture, irrigation, water resource management, and the environment. The right information of reference evapotranspiration can help in increasing water use efficiency and productivity. The reference evapotranspiration can be measured by in-field methods, but they are time consuming, costly, require greater care of the complex instrumentation, and require skilled persons. Due to these restrictions, the utilization of empirical, semi empirical, and physical equations for estimation of reference evapotranspiration are more convenient. Pakistan like other developing countries, has limited ground-based weather stations and limited weather parameters availability, which restrict the applicability of Penman-Monteith FAO56 (PM-FAO56) equation. Therefore, alternative equations for calculation of reference evapotranspiration need to be evaluated for different regions with different data sources. Also, in case of the limited or missing ground-based weather data, the National Aeronautics and Space Administration Prediction of Worldwide Energy Resource (NASA-POWER) meteorological data is considered as one of the prominent easily available data sources. In this study different models are evaluated with PM-FAO56 model for estimation of reference evapotranspiration by utilizing the NASA-POWER data for different climatic zones of Pakistan. Three stations from four climatic zones of Pakistan are selected to check the variability of models performance. One combination based, five temperature-based, five radiation-based, and five mass-transfer based models are used in comparison with PM-FAO56 model. The results of the models were evaluated by well-known statistical indices which include root mean square error (RMSE), mean absolute error (MAE), Nash-Sutcliffe efficiency (NSE), Pearson correlation coefficient (r), index of agreement (d), and percentage error of estimate (PE). The Valiantzas (combination based) model appeared to show very good performance and correlation at all stations of the study area for estimation of daily reference evapotranspiration indicated by RMSE, MAE, NSE, r, d and PE. All the temperature-based models except Blaney-Criddle model showed good performance followed by radiation-based models and mass-transfer based models.

INTRODUCTION

Evapotranspiration is the removal of water through evaporation from soil, water bodies, wet vegetation and transpiration from plants bodies and leaves through stomata [1]. It has important role in agriculture, hydrology, and particularly in irrigation scheduling [2, 3]. Crop Water requirement is determined from crop coefficient and reference evapotranspiration [4]. Reference Evapotranspiration can be determined directly by field methods like, Tension Lysimeter [5, 6], Bowen ratio [7], and large aperture scintillometer [8]. Field methods are time consuming, costly, require greater care of the complex instrumentation, skilled researcher [2, 9, 10], area specific and higher cost of maintenance. Due to these restrictions, utilization of empirical equations for reference evapotranspiration estimation are more convenient. Several empirical equations and models are available and utilized by researchers to estimate reference evapotranspiration based on available data. Based on the input data there are four categories of models for estimation of reference evapotranspiration; combination based models [11, 12], temperature based models [13–17], radiation based models [10, 18–20], and mass transfer based models [21–27].

Among all the available models the Penman-Monteith Food & Agriculture Organization (PM-FAO56) equation is widely used. It is recommended by FAO and International Commission for Irrigation and Drainage (ICID) to estimate reference evapotranspiration and evaluate other models [11]. Many researches have concluded that reference evapotranspiration estimated by PM-FAO56 equation is closely related to observed reference evapotranspiration [3, 28–31]. But main limitation of the PM-FAO56 equation is the requirement of more number of meteorological parameters, which include maximum and minimum air temperature, relative humidity, net radiation, wind speed, and soil heat flux [32–34]. In developed countries, sufficient ground-based stations and satellite-based climate data are freely available with good accuracy. On the other hand, in most of the developing countries, limited ground-based stations, and limited parameters of climatic data are available, which restrict the applicability of PM-FAO56 equation. Therefore, alternative models and different data sources are available to cope with the limitation of PM-FAO56 model.

Many Satellite based datasets are available which provide climate and weather data like Interim Reanalysis Products (IRA) [35], Japanese Meteorological Agency (JRA-55) [36], National Center for Environmental Prediction (NCAP) [37], Modern Era Retrospective-Analysis for Research and Applications (MERRA) [38], Climate Forecast System Reanalysis (CFSR) [39]. In case of the limited availability of data for most of the region, the National Aeronautics and Space Administration Prediction of Worldwide Energy Resource (NASA-POWER) metrological data is considered to be one of the available data sources [40, 41]. However, a detailed study is required to evaluate the utility of the NASA-POWER data for estimation of reference evapotranspiration by different models and for different climates. In this study the performance of sixteen models (one combination based, and five from each temperature-based, radiation-based, and mass-transfer based) are evaluated in different climates of Pakistan.

2. STUDY AREA, MATERIALS, AND METHODS

Pakistan is geographically situated from 23°35’ to 37°05’ North and from 60°50’ to 77°50’ East. The latitudinal location, rough topography, vegetation cover, and proximity to sea level are some factors which brings the variation in the climate of Pakistan. Based on the rainfall distribution, Pakistan has been classified into four regions i.e., arid, semi-arid, sub-humid, and humid [42].

Data used in this study were retrieved from NASA-POWER Data Access Viewer (https://power.larc.nasa.gov/data-access-viewer/) for twelve stations distributed across the different climates of Pakistan. The details of the stations along with their climate type are given in Table 1 and shown in Figure 1. Daily observations of air maximum temperature (°C), minimum temperature (°C), mean relative humidity (%), and wind speed (m/sec) at 2-meter height from January 01, 2016, to August 31, 2023, were downloaded.

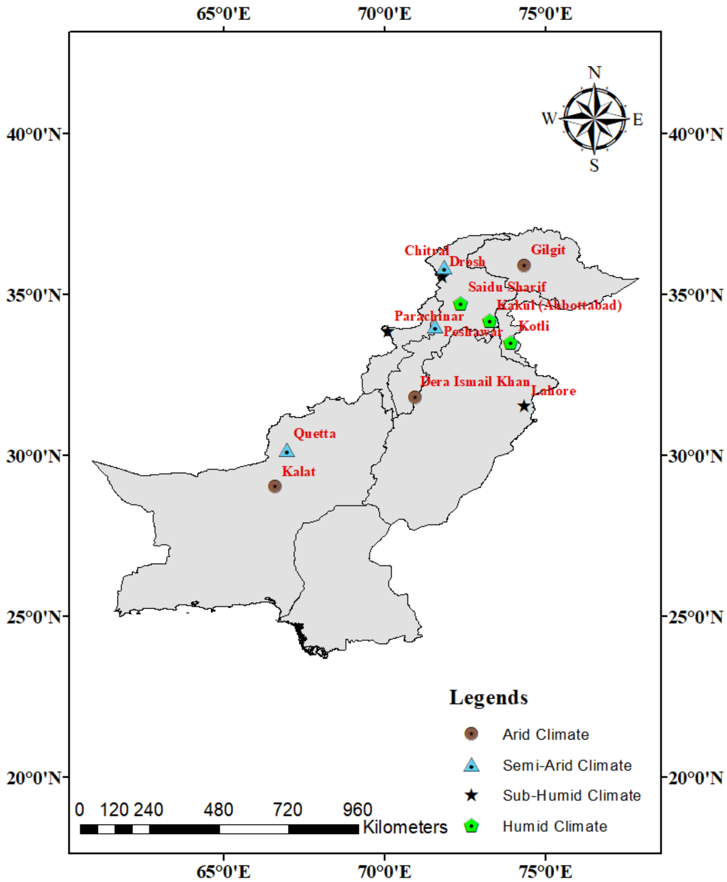

Figure 1: Location Map of Meteorological Weather Stations

Table 1: Details of Meteorological Weather Stations along with Climate Type

S. No	Climate Type	Sub-Climate Type*	Station	Lat. (N)	Long. (E)	Elevation (m)
1	Arid Climates	A	Dera Ismail Khan	31°49’	70°56’	171.20
2			Gilgit	35°55’	74°20’	1460.0
3		B	Kalat	29°02’	66°35’	2015
4	Semi-Arid Climates	A	Peshawar	34°01’	71°34’	327
5		B	Chitral	35°51’	71°50’	1497.80
6			Quetta	30°11’	66°57’	1626
7	Sub-Humid Climates	A	Lahore	31°33’	74°20’	214.00
8		B	Drosh	35°34’	71°47’	1463.90
9			Parachinar	33°52’	70°05’	1725.0
10	Humid Climates	A	Kotli	33°31’	73°54’	614.00
11		B	Kakul (Abbottabad)	34°11’	73°15’	1308.0
12			Saidu Sharif	34°44’	72°21’	961.00

*Sub-Climate Type; A: Long Summers and Short Winters, B: Short Summers and Long Winters
Source: https://www.pmd.gov.pk/observatories/index.html, [42]

The Food and Agricultural Organization (FAO) and International Commission for Irrigation and Drainage (ICID) recommends the Penman-Monteith (PM-FAO56) method to estimate the daily reference evapotranspiration from meteorological data as shown in Equation (1) given in Table 2. To explore alternative methods to PM-FAO56, which require a smaller number of input parameters, one combination-based model, five models each from temperature-based, radiation-based, and mass-transfer based are selected in this study. The list of the models used in this study to estimate reference evapotranspiration are given in Table 2. The abbreviation and symbols of variables used in Table 2 are given in Table 3. The selected models are most widely used to estimate the reference evapotranspiration at different scales both locally and globally due to their simplicity and requirements of a smaller number of input parameters.

Table 2: Models Used in this Study for Estimation of Reference Evapotranspiration

Model Type	Model	Equation	Equation No.	Reference
Combination Based Models	Penman-Monteith FAO56 (PM-FAO56)	$ET_o = \dfrac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{(T_{mean}+273)} u_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)}$	1	[11]
	Valiantzas (Val.)	$ET_o = 0.051(1-\alpha)R_s\sqrt{\lvert T_{mean}+9.5\rvert} - 2.4\left(\frac{R_s}{R_a}\right)^2 + 0.048(T_{mean}+20)\left(1-\frac{RH_{mean}}{100}\right)(0.5+0.536u_2) + 0.00012z$ Where $\alpha = 0.25$	2	[12]
Temperature Based Models	Blaney and Criddle (BC)	$ET_o = 25.4\dfrac{(1.8T_{mean}+32)}{180}p$ P is mean annual percentage of daytime hours = 0.274	3	[15]
	Hargreaves and Samani (HS)	$ET_o = 0.0023(T_{mean}+17.8)(T_{max}-T_{min})^{0.5}R_a/\lambda$	4	[14]
	Droogers & Allen (DA)	$ET_o = [0.003R_a(T_{mean}+20)(T_{max}-T_{min})^{0.4}]/\lambda$	5	[32]
	Ravazzani (Rav.)	$ET_o = \left[(0.817+0.00022z)(0.0023R_a)(T_{mean}+17.8)(T_{max}-T_{min})^{0.5}\right]/\lambda$	6	[16]
	Baier & Robertson (BR)	$ET_o = [0.109\,R_a + 0.157\,T_{max} + 0.158\,(T_{max}-T_{min}) - 5.39]$	7	[17]

Radiation Based Models	FAO-24 Radiation (FAO.24)	$ET_o=\left(1.066 - 0.0013RH_{mean} + 0.045u_2 - 0.0002RH_{mean}u_2 - 0.000031RH_{mean}^2 - 0.0011u_2^2\right).\left(\frac{\Delta}{\Delta+\gamma}\right)$	8	[43]
	Makkink (Mak.)	$ET_o= 0.61\left(\frac{R_s}{\lambda}\right)\left(\frac{\Delta}{\Delta+\gamma}\right) - 0.12$	9	[18]
	Priestly & Tayler (PT)	$ET_o= 1.26\left(\frac{R_n-G}{\lambda}\right)\left(\frac{\Delta}{\Delta+\gamma}\right)$	10	[19]
	Copais Equation (Cop.)	$ET_o= 0.057+0.277C_2+0.643C_1+0.0124C_1$ $C_1= 0.6416-0.00784RH_{mean}+0.372R_s-0.00264R_s.RH_{mean}$ $C_2= -0.0033+0.00812T_{mean}+0.101R_s+0.00584R_s.T_{mean}$	11	[44]
	Jensen & Haise (JH)	$ET_o= (0.025\ T_{mean}+0.08)(R_s/\lambda)$	12	[20]
Mass-Transfer Based Models	Dalton (Dal.)	$ET_o= (3.648+0.7223u_2)(e_s-e_a)$	13	[21]
	Mahringer (Mah.)	$ET_o= 0.286\ (u_2)^{0.5})\ (e_s-e_a)$	14	[25]
	Romanenko (Rom.)	$ET_o= 0.00006(100-RH_{mean})(T_{mean}+25)^2$	15	[24]
	Trabert (Trab.)	$ET_o= 0.3075u_2^{0.5}(e_s-e_a)$	16	[26]
	Szasz	$ET_o=0.0053(T_{mean}+21)^2(1-RH_{mean}/100)^{\frac{2}{3}}.(0.0519u_2+0.905)$	17	[27]

Further definitions of variables used in Table 2 are given as follows [11]:

$$\Delta = \frac{2504\exp\left(\frac{17.27T_{mean}}{T_{mean}+237.3}\right)}{(T_{mean}+237.3)^2} \tag{18}$$

$$R_n = R_{ns} - R_{nl} \tag{19}$$

$$R_{ns} = (1 - \alpha)R_s \tag{20}$$

$$R_{nl} = \sigma\left[\frac{T^4_{max.K}+T^4_{min.K}}{2}\right](0.34-0.14\sqrt{e_a})(1.35\frac{R_s}{R_{so}}-0.35) \tag{21}$$

$$R_s = k_{Rs}\sqrt{(T_{max}-T_{min})}\,R_a \tag{22}$$

$$R_{so} = (0.75+2\times10^{-5}z)R_a \tag{23}$$

$$R_a = \frac{24(60)}{\pi}.G_{sc}.d_r(\omega_s(\sin\varphi.\sin\delta)+\cos\varphi.\cos\delta.\sin\omega_s) \tag{24}$$

$$d_r = 1+0.033\cos\left(\frac{2\pi.J}{365}\right) \tag{25}$$

$$\omega_s=\frac{\pi}{2}-\arctan\left[\frac{-\tan\varphi.\tan\delta}{1-(\tan\varphi)^2(\tan\delta)^2}\right] \tag{26}$$

$$\delta=0.4093\sin\left(\frac{2\pi J}{365}-1.39\right) \tag{27}$$

$$e_{T.min}=0.6108\exp\left(\frac{17.27T_{min}}{T_{min}+237.3}\right) \tag{28}$$

$$e_s=\frac{e_{T.max}+e_{T.min}}{2} \tag{29}$$

$$e_a=\frac{e_s.RH_{mean}}{100} \tag{30}$$

$$u_2=\frac{4.87}{\ln(67.8u_h-5.42)} \tag{31}$$

Table 3: Abbreviation of variables used in Table 2 [11]

Notation	Name of Variable	Unit
$\mathbf{ET_o}$	reference evapotranspiration	mm/day
$\mathbf{\Delta}$	slope of saturation vapor pressure curve at mean air temperature	kPa/°C
$\boldsymbol{\gamma}$	psychometric constant = 0.054	kPa/°C
$\boldsymbol{\lambda}$	latent heat of vaporization = 2.45	MJ/Kg
$\mathbf{R_n}$	net radiation	MJ/m^2-day
$\mathbf{R_{ns}}$	net solar or net shortwave radiation	MJ/m^2-day
$\mathbf{R_{nl}}$	net longwave radiation	MJ/m^2-day
α	albedo or canopy reflection coefficient = 0.23	
$\mathbf{R_{so}}$	clear sky radiation	MJ/m^2-day
$\mathbf{k_{Rs}}$	adjustment coefficient (0.16…0.19)	°C$^{-0.5}$
G	soil heat flux density ≈ 0	MJ/m^2-day
$\mathbf{u_2}$	daily mean wind speed at 2m height	m/sec

e_a	saturation vapor pressure	kPa
e_s	actual vapor pressure	kPa
$e_{T.max}$	saturation vapor pressure function at T_{max}	kPa
$e_{T.min}$	saturation vapor pressure function at T_{min}	kPa
T_{mean}	mean daily air temperature	°C
R_s	solar radiation	MJ/m^2-day
R_a	extraterrestrial radiation	MJ/m^2-day
G_{sc}	solar constant = 0.0820	MJ/m^2-min
d_r	inverse relative distance Earth-Sun	
ω_s	sunset hour angle	radian
φ	Latitude	radian
δ	solar declination	radian
J	number of the day in the year between 1 (1 January) and 365 or 366 (31 December	
RH_{mean}	mean daily relative humidity	%
Z	elevation of site above mean sea level	M

The performance of the models for estimation of reference evapotranspiration was evaluated by well-known statistical indices including root mean square error (RMSE), mean absolute error (MAE), Nash-Sutcliffe efficiency (NSE), Pearson correlation coefficient (r), index of agreement (d), and Percentage Error of estimate (PE). A detailed description of statistical indices is given in Table 4.

Table 4: Statistical Indices for Evaluation of Model Performance

S.#	Name	Formula	Range	References
1	RMSE (mm/d	$\left(\frac{1}{m}\sum_{i=1}^{m}(Y_i - X_i)^2\right)^{1/2}$	Lower values (close to 0) indicate more accuracy	[45]
2	MAE (mm/da	$\left(\frac{1}{m}\sum_{i=1}^{m}\lvert Y_i - X_i\rvert\right)$	Lower values (close to 0) indicate more accuracy	[46]
3	NSE	$1-\left[\frac{\sum_{i=1}^{m}(X_i - Y_i)^2}{\sum_{i=1}^{m}(X_i - \overline{X}_i)^2}\right]$	-∞ to 1 NSE = 1 (optimum value) -∞ < NSE ≤ 0 (unacceptable performance)	[47]
4	Pearson Correlation Coefficient (r	$\frac{\sum_{i=1}^{m}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{m}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{m}(Y_i - \overline{Y})^2}}$	-1 to 1 1 = Perfect +ve Cor. -1 = Perfect –ve Cor.	[48]
5	Index of Agreement (d	$1-\frac{\sum_{i=1}^{m}\lvert X_i - Y_i\rvert^2}{\sum_{i=1}^{m}(\lvert X_i - \overline{X}\rvert + \lvert Y - \overline{Y}\rvert)^2}$	0–1 (higher values indicate better fit)	[45]
6	PE	$\left\lvert\frac{\overline{Y}-\overline{X}}{\overline{X}}\right\rvert \times 100\%$	Smaller PE values indicate better performance	[49]

X = Estimated ET_o by PM-FAO56 Model, Y = Estimated ET_o by other Models, $\overline{X}$, and $\overline{Y}$ are the mean of X and Y respectively, and m is the total number of observations.

3. RESULTS AND DISCUSSION

The performance of sixteen alternative models (one combination-based, five each from temperature-based, radiation-based, and mass-transfer based) are compared with Penman-Monteith-FAO56 model in this study. The comparison was performed at three stations from each arid, semi-arid, sub-humid, and humid climates in Pakistan. The variation in performance by each model at different stations is shown in Figure 2. The Valiantzas (combination-based model) appeared to show very good performance (less variation) at all stations in the region for estimation of daily reference evapotranspiration indicated by RMSE, MAE, NSE, r, d, and PE. All the temperature-based models except Blaney-Criddle model showed good performance followed by radiation-based models and mass transfer-based models.

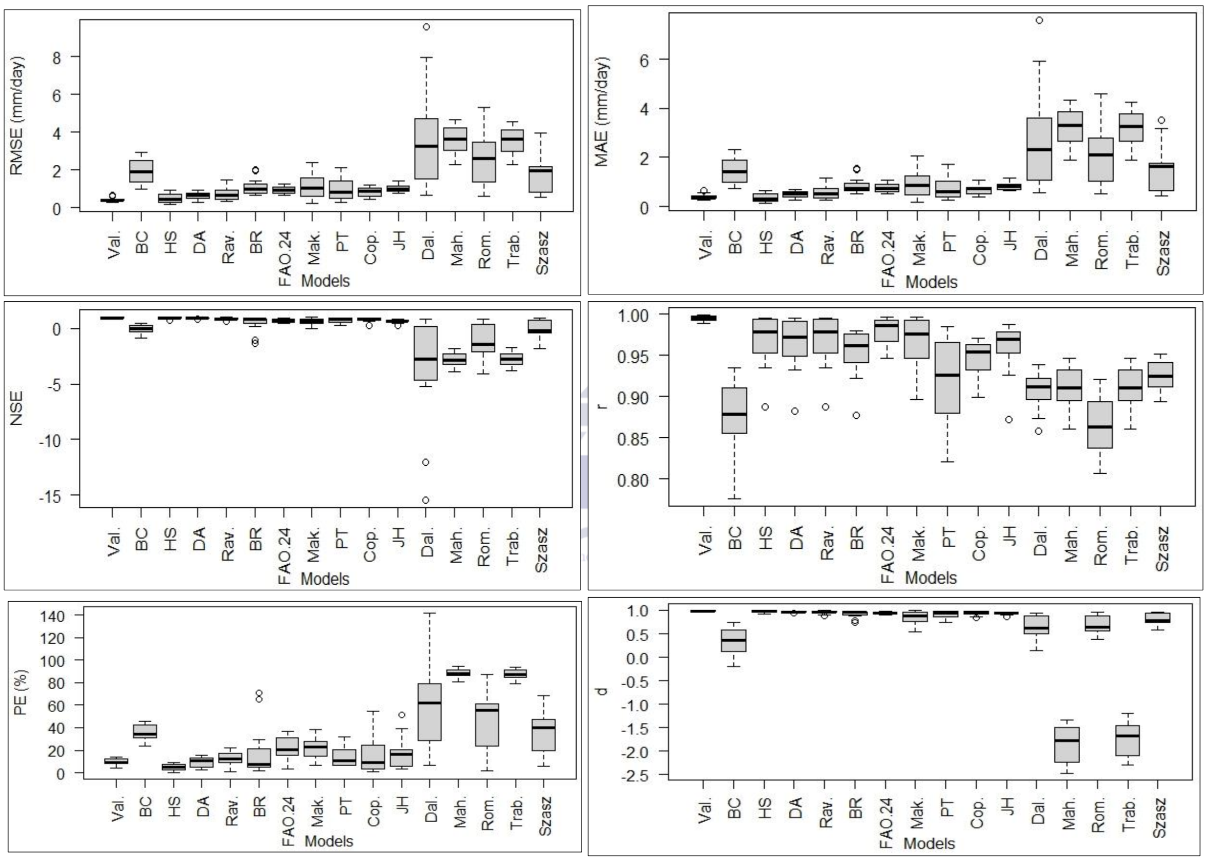

Figure 2: Performance of reference evapotranspiration models with the Penman-Monteith FAO-56 Model based on Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Nash-Sutcliffe Efficiency (NSE), Pearson Correlation Coefficient (r), Index of Agreement (d) and Percentage Error of estimate (PE).

Among the temperature-based models; Hargreaves and Samani, Droogers & Allen, and Ravazzzani models showed lower values of RMSE, MAE, and PE bounded between 0.19 to 1.47, 0.15 to 1.18, and 0.35% to 22.00% respectively, and significant values of NSE, r, and d, are observed which ranged between 0.58 to 0.98, 0.88 to 0.99, and 0.87 to 0.99 respectively. Among the radiation-based models FAO-24 Radiation, Copais, and Jensen & Haise models showed the best performance than Makkink and Priestly Taylor models at all climatic stations. Whereas, among the mass-transfer based models, Mahringer and Trabert model showed less variation in statistical indices at all stations than Dalton, Romanenko, and Szasz models.

The overall correlations of different models with each other's and with PM-FAO56 model is shown in Figure 3. The Valiantzas model shows the highest correlation (0.99) followed by FAO-24 Radiation (0.97), Hargreaves & Samani (0.96), Droogers & Allen (0.96), Makkink (0.95), and Jensen & Haise (0.95) with PM-FAO56 model. The correlations of Valiantzas model with FAO-24 Radiation, Hargreaves & Samani, Droogers & Allen, Makkink, Ravazzani, and Jensen & Haise were 0.98, 0.97, 0.96, 0.96, 0.95, and 0.95 respectively. The correlations of Hargreaves & Samani model with Droogers & Allen, Jensen & Haise, Makkink, Baier & Robertson, and FAO-24 Radiation models were 1.0, 0.99, 0.98, 0.97, and 0.97 respectively. The correlation of temperature-based models was more significant with each other followed by radiation-based models.

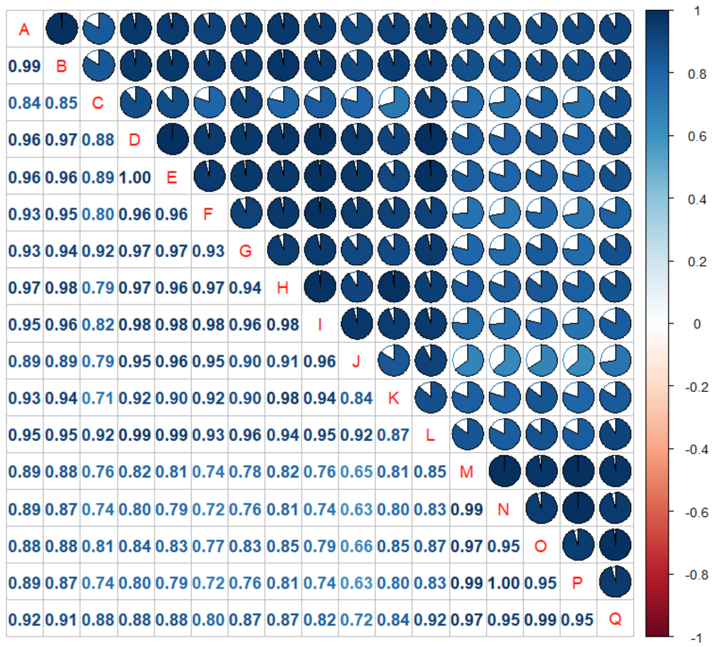

Figure 3: Overall correlation of models with each other

(A: Penmn-Monteith56, B: Valiantzas, C: Blaney & Criddle, D: Hargreaves & Samani, E: Droogers & Allen, F: Ravazzani, G: Baier & Robertson, H: FAO-24 Radiation, I: Makkink, J: Priestly & Taylor, K: Copais, L: Jensen & Haise, M: Dalton, N: Mahringer, O: Romanenko, P: Trabert, Q: Szasz)

The correlations of all the alternative models with PM-FAO56 model in four different climates for estimation of reference evapotranspiration are given in Table 5. Higher correlation values i.e., $\geq$ 0.95 are highlighted. The Valiantzas (combination-based) model showed a superior correlation ranging between 0.99 and 1.00 at all the climatic stations. The results were highly correlated in humid climates, followed by semi-arid, arid and sub-humid climates. All the temperature-based models except the Blaney-Criddle model showed high correlation in sub-humid and humid climates followed by semi-arid and arid climates. Among the radiation-based models, the FAO-24 Radiation model gives superior correlation in all the twelve stations from four different climates which range between 0.95 and 1.00. The correlations of Makkink, Copais, and Jensen & Haise models were higher in humid climates followed by sub-humid, semi-arid, and arid climates. The Priestly & Taylor Radiation-based model showed poor correlation in comparison to other radiation-based models. Overall, the correlations of all the mass transfer-based models were less than 0.95 in all the stations of different climates. Comparatively, the results of Mahringer and Trabert models were better than the Szasz, Romanenko, and Dalton models at the arid climates followed by semi-arid, sub-humid, and humid climates.

4. CONCLUSIONS

The applicability of alternative models for estimation of reference evapotranspiration were investigated in this study. The models were evaluated by utilizing the daily meteorological NASA POWER data for different climatic zones of Pakistan. The results were compared with reference evapotranspiration estimated from Penman Monteith-FAO56 model. The comparative results showed that the Valiantzas (combination-based) model performed very well at all climatic regions. Overall, the performance of temperature-based models was better than radiation-based models and mass-transfer based models at all stations. Among the temperature-based models: the Hargreaves & Samani, Droogers & Allen, and Ravazzani models gave better results than Blaney & Criddle and Bair & Robertson models. Similarly, except Priestly & Taylor model, the rest of radiation-based models performed very well in which the result of FAO-24 Radiation was superior. All mass-transfer based models performed very poorly at majority of the climatic stations. On average, the best models concluded from this study which could be used as an alternative to PM-FAO56 models are ranked in order of merit as follow: Valiantzas, FAO-24 Radiation, Hargreaves & Samani, Jensen & Haise, Ravazzani, Droogers & Allen, Makkink, Bairs & Robertson, and Copais.

From the study it is concluded that simple reference evapotranspiration models e.g., Valiantzas, FAO-24 Radiation, Hargreaves & Samani, and Jensen & Haise could be used under condition of limited climatic data in the region. However, the differences in the results of the alternative models in different climates need the development of calibrating parameters for better results. Further, the results obtained in this study can be calibrated by comparison with the measured lysimeter reference evapotranspiration for the local condition. The origin and the environmental conditions of the model development should be considered while selecting the alternate equation for estimation of reference evapotranspiration. Similarly, to avoid error in estimation of reference evapotranspiration, crop water requirements, and water balance the alternative models needs to be calibrated at regional level, different climates, and at different season of the year to account for changes in climatic variables.

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Table 5: Correlation of alternative models with Penman-Monteith FAO56 at different climates

Climate Type	Station	Alternative Models															
		Combination Based Model	Temperature Based Models					Radiation Models					Mass Transfer Based Models				
		Valiantzas	Blaney & Criddle	Hargreaves and Samani	Droogers & Allen	Ravazzani	Baier & Robertson	FAO-24 Radiation	Makkink	Priestly & Tayler	Copais	Jensen & Haise	Dalton	Mahringer	Romanenko	Trabert	Szasz
Arid Climates	Dera Ismail Khan	1.00	0.88	0.95	0.94	0.95	0.94	0.96	0.93	0.86	0.93	0.95	0.94	0.95	0.89	0.95	0.94
	Kalat	0.99	0.78	0.89	0.88	0.89	0.88	0.95	0.90	0.82	0.90	0.87	0.92	0.94	0.82	0.94	0.90
	Gilgit	0.99	0.93	0.99	0.99	0.99	0.98	0.99	0.99	0.98	0.96	0.97	0.91	0.91	0.91	0.91	0.94
Semi-Arid Climates	Peshawar	1.00	0.90	0.98	0.97	0.98	0.96	0.98	0.97	0.92	0.95	0.97	0.90	0.90	0.85	0.90	0.92
	Chitral	0.99	0.92	1.00	1.00	1.00	0.98	1.00	1.00	0.99	0.97	0.97	0.92	0.92	0.92	0.92	0.95
	Quetta	1.00	0.86	0.94	0.93	0.94	0.92	0.97	0.94	0.88	0.93	0.93	0.93	0.95	0.86	0.95	0.92
Sub-Humid Climates	Drosh	0.99	0.92	1.00	0.99	1.00	0.98	1.00	1.00	0.98	0.96	0.98	0.91	0.91	0.90	0.91	0.94
	Lahore	0.99	0.85	0.96	0.95	0.96	0.94	0.97	0.95	0.88	0.93	0.95	0.92	0.93	0.86	0.93	0.92
	Parachinar	1.00	0.90	0.97	0.96	0.97	0.95	0.98	0.96	0.93	0.97	0.96	0.92	0.91	0.88	0.91	0.93
Humid Climates	Kotli	1.00	0.85	0.98	0.97	0.98	0.96	0.99	0.98	0.92	0.97	0.98	0.90	0.89	0.86	0.89	0.93
	Kakul (Abbottabad)	1.00	0.86	0.99	0.98	0.99	0.97	0.99	0.98	0.93	0.95	0.98	0.86	0.86	0.81	0.86	0.89
	Saidu Sharif	1.00	0.88	0.99	0.99	0.99	0.97	0.99	0.99	0.95	0.95	0.99	0.87	0.87	0.82	0.87	0.90

5. REFERENCES

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