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COMPARISON OF SOME POTENTIAL EVAPOTRANSPIRATION METHODS FOR SUMAIL AREA, KURDISTAN REGION OF IRAQ

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ABSTRACT

Potential evapotranspiration (PET) was calculated in monthly basis for the Sumail area using FAO-56 Penman-Monteith and several other methods. PET calculated by Penman-Monteith method was then predicted using PET calculated by each of the other methods and pan measurement employing three mathematical equations. Among them the simple linear equation turned out to be the favorite. All the considered methods had very good predictive capability. Hargreaves method, however, was the most accurate with and without calibration.

***Key words**: FAO-56 Penman-Monteith , kurdistan Region of Iraq, potential evapotranspiration.*

1. INTRODUCTION

Evapotranspiration (ET) is an important component of the hydrological cycle and a necessary parameter for irrigation scheduling. It is defined as the loss of water to the atmosphere by the combine processes of evaporation from soil and plant surfaces and transpiration from plants (Allen *et al*., 1998). Many factors affect ET, including; weather parameters such as solar radiation, air temperature, humidity and wind speed; crop factors such as crop type, variety, density, stage of growth and management; and environmental conditions such as soil conditions, salinity, fertility, crop diseases and pests (Allen *et al.*, 1998).

According to Kite (2000) about 65% of the precipitation on the earth's surface evaporates back into the atmosphere. In the Southeastern part of the USA, about 50 to 80 percent of precipitation is returned to the atmosphere as evapotranspiration (Lu *et al*., 2005).

Potential Evapotranspiration (PET) can be generally defined as the amount of water that could evaporate and transpire from a vegetated landscape without restrictions other than the atmospheric demand (Jensen *et al.*, 1990). The concept of potential evapotranspiration (PET) provides a convenient index to estimate the maximum water loss to the atmosphere. Potential evapotranspiration (PET) is also used as an index to represent the available environmental energies and ecosystem productivity (Currie, 1991). Estimates of PET are necessary in many of the rainfall runoff and ecosystem models that are used in global change studies (Hay and McCabe, 2002). Generally potential evapotranspiration is estimated by theoretical or empirical equations or derived simply by multiplying standard pan evaporation data by a coefficient (Grismer *et al.*, 2002).

There are many methods or models available to estimate PET, but these give inconsistent values due to their different assumptions and input data requirements or because they are often developed for specific climatic regions (Grismer *et al*., 2002). Previous studies at multiple scales have suggested that different PET methods may give significantly different results (Feder *et al*., 1996). In general, most practical approaches for estimating PET are based on one or more climatic variable such as air temperature, solar radiation, wind speed and relative humidity, or on some measurements related to these variables like pan evaporation. In connection with, various methods are available for estimating PET involving equations ranging from the most complex energy balance method requiring detailed climatologic data to simpler methods requiring less data (Allen, *et al*., 1989). Among them the FAO-56 based on the Penman- Monteith (PM) method is currently used and can be considered as a standard method (Alkaeed *et al.*, 2006). However, the major drawback of this method is its requirements for data regarding air temperature, relative humidity, wind speed, and solar radiation which could not be easily available in many meteorological stations (Irmak *et al*., 2003). Additionally, it also uses a complicated unit conversions and lengthy calculation (Wu, 1997). On the other hand, there are simple methods based on either temperature alone, such as, the Thornthwaite (1948), Blaney and Criddle (1950), Kharrufa (1985), and Hargreaves and Samani (1985), or on solar radiation alone, such as, Makkink (1957), Priestly and Taylor (1972) and Hargreaves (1975). This work aims at quantifying PET in the study area using several empirical methods and quantifying the performance of these methods, and developing calibrated equation for each of the evaluated method.

The pan measurement method uses evaporation to estimate PET and is another common method especially in Asian countries (Chen *et al*., 2005). Pans provide a measurement of the integrated effect of radiation, wind speed, temperature and humidity on the evaporation from an open water surface. The pan has proved its practical value and has been widely used to estimate PET (Chen *et al*., 2005). Applying empirical coefficient to relate pan evaporation to PET for periods of 10 days or longer may be warranted (Allen *et al*., 1998). Investigations on potential evapotranspiration (PET) in the study area and its surrounding were covered by Kettaneh (1974), Ahmed and Jasim (2002), and Aqrawi (2003).

2. MATERIALS

The study area is located to the west of Dohuk City, Iraqi Kurdistan Region between latitude $36^{0}\,80^{/}$ - $36^{0}\,90^{/}$ N, and longitude $42^{0}\,69^{/}$ - $42^{0}\,93^{/}$ E (Figure 1). The climate of the area is similar to the Mediterranean climatic conditions. It is characterized by rainy cold winter and dry hot summer. The daily and monthly meteorological data were obtained from the Agro-meteorological Station of the College of Agriculture, Dohuk University in Sumail area (latitude $36^{0}\,51^{/}\,37^{//}$ N, longitude $42^{0}\,56^{/}\,30^{//}$ E) for the period from January, 1997 to December, 2006. The data included mean air temperature, mean maximum and minimum temperature, mean sunshine duration, mean wind speed and humidity, as well as the monthly water evaporation in a pan class A.

According to the recorded data of the meteorological station of the College of Agriculture, the average annual precipitation for the aforementioned period was 438.3 mm yr^{-1}, more than 55% of which occurred during January to March. The mean minimum and maximum monthly air temperature ranged from 20.5 ^{o}C to 39.6 ^{o}C in summer and 3.3 ^{o}C to 13.8 ^{o}C in winter, respectively. The monthly mean temperature in summer was 30.1 ^{o}C and in winter was 8.6 ^{o}C with an annual average of 18.3 ^{o}C, while daily mean minimum and maximum temperature in summer were 20.9 ^{o}C and 40 ^{o}C and in winter were 2.7 ^{o}C and 12.6 ^{o}C.,respectively. Monthly mean minimum and maximum relative humidity were 28% and 64%, respectively with an annual average of 45%. The observed maximum, minimum and average monthly wind speeds in the considered period were 2.2 ms^{-1}, 1.4 ms^{-1} and 1.8, ms^{-1} respectively.

3. METHDODS

The selected seven PET methods and Pan Measurement in this comparative study are commonly used and need fewer input requirements than the PM method. They include four temperature based methods, which were Thornthwaite (1948), Blaney and Criddle (1950), Kharrufa (1985), and Hargreaves and Samani (1985), and three radiation based methods, which were Makkink (1957), Priestley and Taylor (1972), Hargreaves (1975), and Pan measurement (Table 1).

The following is a description of the equation used by each method;

1. FAO-56 Penman and Monteith method.

According to Allen *et al*. (1998), the FAO-56 Penman-Monteith Method for PET estimation (mm d^{-1}) can be expressed as:

$$PET = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,(900/T + 273)\,U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)} \qquad (1)$$

Where PET is potential evapotranspiration (mm d^{-1}),R_n is net radiation at the crop surface [MJ m^{-2} d^{-1}] G is soil heat flux density (MJ m^{-2} d^{-1}),T is mean daily air temperature at 2m height (^{o}C), U_2 is wind speed at 2m height (m s^{-1}) e_s is saturation vapor pressure (kPa), e_a is actual vapor pressure (kPa), Δ is slope vapor pressure curve (kPa $^{o}C^{-1}$) γ is psychometric constant (kPa $^{o}C^{-1}$), and (e_s - e_a) is saturation vapor pressure deficit (kPa). It is the difference between the saturation (e_s) and actual vapor pressure (e_a) for the period of a day. The saturation vapor pressure (e_s) per day is computed as the mean between the saturation vapor pressure at the daily maximum and minimum air temperatures:

Table (1): Monthly Variable and Parameters Required by Each PET Method:

Variables Methods	Temperature	Radiation	Humidity	Wind Speed	Number of daylight Hours	Saturated vapor pressure
FAO-56 PM	Mean Daily	Net Radiation	Mean Daily	Mean Daily	___	Mean Daily
Thornthwaite	Mean Monthly	____	____	____	Daytime length	____
Blaney&Criddle	Mean Daily	____	____	____	Daytime length	____
Kharrufa	Mean Daily	____	____	____	____	____
Hargreaves& Samani	Daily maximum & minimum	Extraterrestrial Radiation	____	____	____	____
Makkink	Mean Daily	Solar Radiation	____	____	____	____
Priestly&Taylor	Mean Daily	Net Radiation	____	____	____	____
Hargreaves	Mean Daily	Solar Radiation	____	____	____	____
	Mean Daily	____	Mean Daily	Mean Daily	____	____

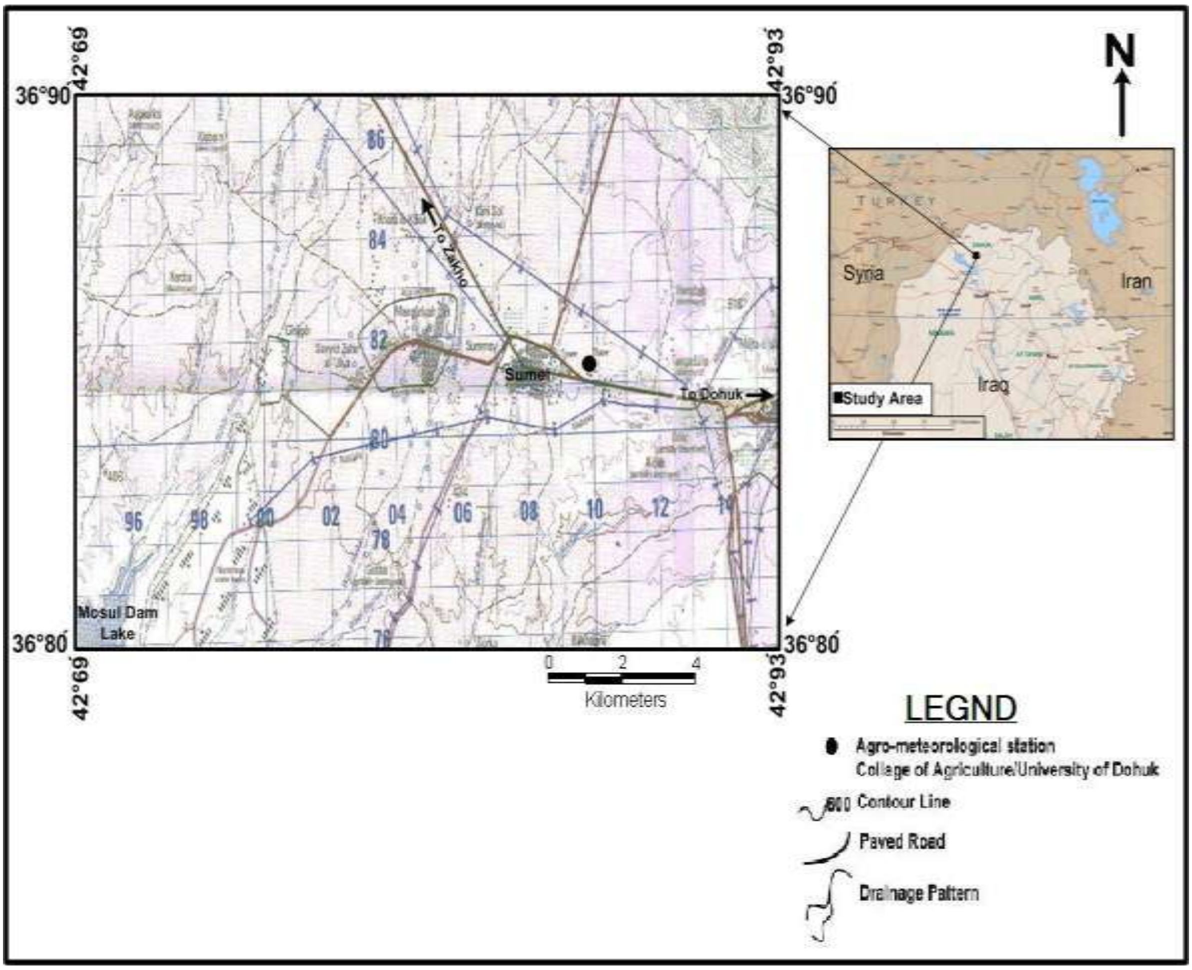


Fig. (1): Location map of the study area.

Table (2): Descriptive Statistics for PET Calculated by Each Method.

Method	Mean	St. deviation	Minimum	Maximum	Coefficient Of Variation
FAO-56 Penman-Monteith	117.1	70.1	25.2	243.5	59.8
Thornthwaite	78.8	62.3	40	240.4	79.1
Blaney-Criddle	135	87.1	29.5	328.4	64.5
Kharrufa	146	98.8	20.3	351.8	67.6
Hargreaves-Samani	327.5	194.9	74.2	665.4	59.5
Makkink	94.3	51.3	26.9	191.3	54.4
Priestley-Taylor	95.1	60.7	17.5	206.9	63.8
Hargreaves	118.2	72.4	28.1	259.1	61.2
Pan A measurement	182.7	126.3	37.2	411.4	69.1

Table (3): Model coefficients and adjusted R^2 for the different methods.

Methods	Models	Bo	B1	B2	Adjusted R^2
Thornthwaite	Linear	30.5	1.091		0.952
	Double-log	2.159	0.610		0.914
	Polynomial	19.54	1.516	-0.0022	0.964
Blaney and Criddle	Linear	10.4	0.789		0.966
	Double-log	0.228	0.927		0.965
	Polynomial	-1.94	1.033	-0.0008	0.97
Kharrufa	Linear	15.6	0.691		0.966
	Double-log	0.762	0.808		0.957
	Polynomial	10.734	0.789	-0.0003	0.966
Hargreaves and Samani	Linear	1.1	0.353		0.973
	Double-log	-1.023	0.998		0.979
	Polynomial	-1.105	0.372	-0.00025	0.973
Makkink	Linear	-10.4	1.353	0.0003	0.98
	Double-log	-0.397	1.13		0.979
	Polynomial	-8.2	1.29		0.98
Priestley and Taylor	Linear	10.6	1.21		0.942
	Double-log	0.828	0.866		0.934
	Polynomial	11.2	1.101	0.00049	0.94
Hargreaves	Linear	3.5	0.96		0.985
	Double-log	0.019	0.994		0.984
	Polynomial	-4.6	1.144	0.0007	0.987
Pan A measurment	Linear	16.8	0.546		0.962
	Double-log	0.366	0.849		0.962
	Polynomial	6.35	0.71	0.00039	0.965

$$e_s = \frac{e^{\circ}(T_{max}) + e^{\circ}(T_{min})}{2} \qquad (2)$$

The actual vapor pressure (e_a) was calculated from the relative humidity

$$e_a = \frac{e^{\circ}(T_{min})\frac{RH_{max}}{100} + e^{\circ}(T_{max})\frac{RH_{min}}{100}}{2} \qquad (3)$$

where e_a actual vapor pressure [kPa], $e°(T_{min})$ saturation vapor pressure at minimum temperature [kPa], $e°(T_{max})$ saturation vapor pressure at maximum temperature [kPa], RH_{max} maximum relative humidity [%], RH_{min} minimum relative humidity [%].

Saturation vapor pressure at any given temperature (e°(T)) is calculated from the air temperature using the following relationship:

$$e^{\circ}(T) = 0.6108 \exp\left[\frac{17.27T}{T + 237.3}\right] \qquad (4)$$

where e°(T) saturation vapor pressure at the air temperature T [kPa], T air temperature [°C], exp[..] 2.7183 (base of natural logarithm) raised to the power [..]. PET of each month was then obtained by summing up the PET of the days of that month. Same procedure was followed to calculate the monthly PET by other methods except for Thornthwaite, Blaney&Criddle, and Kharrufa Methods.

2. Thornthwaite Method

Thornthwaite (1948) correlated the mean monthly temperature with PET using the following formula

$$PET = 16 * d\,(10T/I)^a \qquad (5)$$

Where PET is the monthly potential evapotranspiration (mm d^{-1}), d is the monthly correction factor which depend on latitude, T is the monthly mean air temperature (^oC), I is the annual thermal index, which is computed from the monthly thermal indices .

$$I = \sum_{J=1}^{12} i_j$$

Where $i_j = (T_j / 5)^{1.514}$; T_j is the mean air temperature in C^o for month j ; j = 1,…..,12 ; and a = $0.492 + (179*10^{-4})\, I - (771*10^{-7})\, I^2 + (675*10^{-9})\, I^3$. In general, the Thornthwaite method underestimates the PET in the arid area, while it overestimates PET in the humid area (Alkaeed *et al.*, 2006).

3. Blaney and Criddle Method

Aqrawi (2003) stated that Blaney and Criddle (1950) method is one of the most popular equations. This method has the following form:

$$PET = KP\,(0.46T + 8.13) \qquad (6)$$

Where K is correction factor which is equal to (0.0311T + 0.24), T is the mean monthly temperature (^oC) and P is mean monthly percentage of annual daytime hours.

4. Kharrufa Method

Kharrufa (1985) derived a simple and flexible equation to calculate PET values and it is expressed as:

$$PET = 0.34\, PT^{1.3} \qquad (7)$$

Where PET, P and T are as defined before.

5. Hargreaves and Samani Method

The Hargreaves and Samani (1985) method is expressed as:

$$PET = 0.0023\,(T+17.8)\,\sqrt{(Tmax.-Tmin.)}\,Ra \quad (8)$$

Where PET is daily potential evapotranspiration (mm), T is the daily mean air temperature (^oC), Tmax. is daily maximum air temperature (^oC), Tmin. is daily minimum air temperature (^oC) and Ra is the extra terrestrial radiation (MJ m^{-2} d^{-1}). The mean air temperature in the Hargreaves and samani method is calculated as an average of T_{max} and T_{min} and Ra is computed from information on location of the site and time of the year. Therefore, air temperature is the only parameter that needs to be measured continuously in order to use this method (Temesgen *et al.*, 2005).

6. Makkink Method

This method is expressed by the following equation,

$$PET = 0.61\,(\Delta / \Delta + \gamma) * (R_s / \lambda) \quad (9)$$

Where PET is the daily potential evapotranspiration (mm d^{-1}), Δ is the slope of the saturation vapor pressure temperature curve (kPa /^oC), γ is psychometric constant (kPa /^oC), R_s is the total solar radiation (cal $m^{-2}d^{-1}$); and λ is the latent heat of vaporization ($calg^{-1}$) and λ=0.501-0.002361T, where T is the daily mean air temperature (^oC).

7. Priestley and Taylor Method

This method is based on the following equation,

$$PET = 1.26\,(\Delta / \Delta + \gamma) * (R_n / \lambda) \quad (10)$$

Where PET is the daily potential evapotranspiration (mm d^{-1}), Δ is the slope of the saturation vapor pressure temperature curve (kPa/^oC); γ is psychometric constant (kPa^oC^{-1}); R_n is the net radiation (MJ m^{-2} d^{-1}); and λ is the latent heat of vaporization ($calg^{-1}$).

8. Hargreaves Method

This method estimates PET using the following model

$$PET = 0.0135\,(T + 17.8)\,(R_s/ \lambda) \quad (11)$$

Where PET is daily potential evapotranspiration (mm d^{-1}); T is the daily mean air temperature (^oC), R_s is the total solar radiation (cal m^{-2} d^{-1}), λ is the latent heat of vaporization (cal g^{-1}) .

Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the potential evapotranspiration (PET). Different types of evaporation pans are being used. The best known pan is the class A evaporation pan (circular pan) which was used in the study area and the sunken Colorado pan (square pan). The pan evaporation is related to the potential evapotranspiration by an empirically derived pan coefficient (Allen *et al*., 1998).

$$PET = Kp\ \ Epan \qquad (12)$$

Where Kp is pan coefficient, Epan is pan evaporation (mm d^{-1}) and PET is (mm d^{-1}). In this work, data of pan evaporation were used without multiplying by pan coefficient.

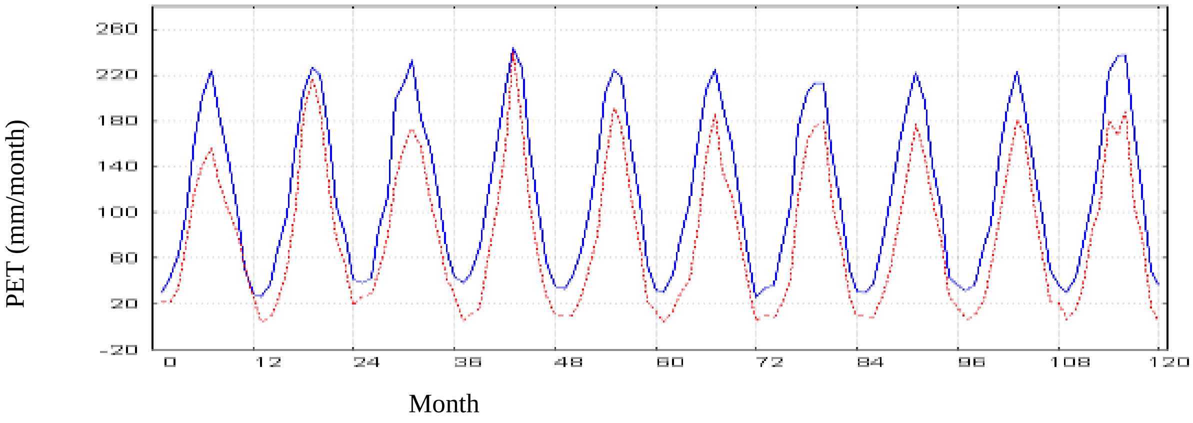
To evaluate the accuracy of each method adopted in this work, monthly PET calculated by PM method was drawn along with PET estimated by each of the other methods. One of the most important considerations in establishing a simple method other than the standard method such as the PM method is the possibility of unavailability and unreliable weather data measurement and collections. In general, a setup of the devices for the meteorological measurement at the remote areas and at a given location is difficult. Hence, accuracy of data, specifically the data of advanced input variables such as humidity and radiation would be low. Therefore, it is justifiable to develop equations that can accurately measure PET using simple and easy collected meteorological data. For this purpose, scatter diagrams were drawn to reveal the pattern of relationships between monthly PET estimated by FAO-56 Penman-Monteith method, on one hand, and monthly PET estimated by each of the other methods (Fig. 2). Then regression analysis was employed to predict PET calculated by Penman-Monteith method using corresponding data estimated by each of the other methods. For this purpose, three mathematical equations were selected. Simple linear equation, double log function and second degree polynomial equation were tested using SAS package (1989). Since prediction is the main purpose of developing these equations, adjusted coefficient of determination ($\square^2$) was used to evaluate the predictive capability of each model. Finally, calibrated equations were developed for each of the seven methods and Pan Measurement.

4. RESULTS AND DISCUSSION

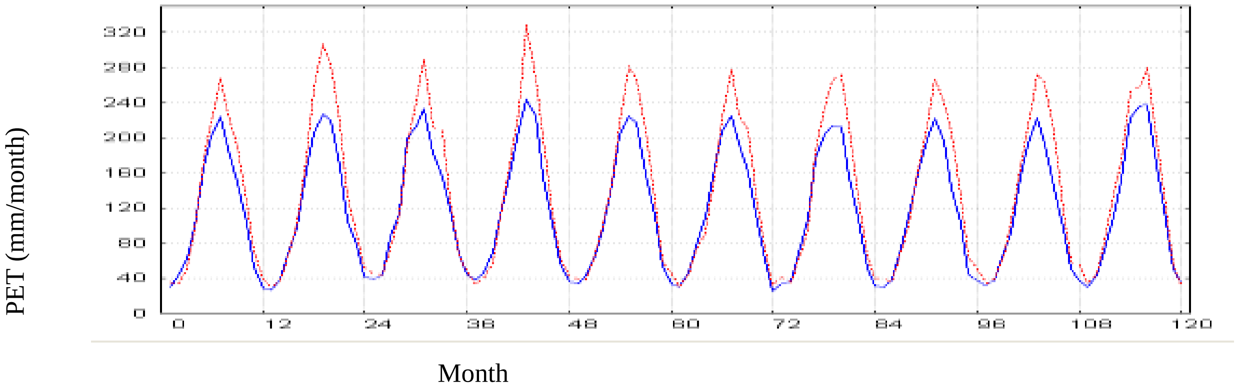
Table (2) describes the values of monthly PET calculated by each method. The lowest mean PET was estimated by Thornthwaite (78.8 mm) and the highest was estimated by Hargreaves and Samani equation (327.5). The lowest coefficient of variation (C.V.) was associated with the estimate of Makkink method and the highest was associated with the estimate of Thornthwaite method. The mean and C.V. for Penman-Monteith method were 117 and 59.8, respectively. Since PM method is, by far, the most accurate method, it was taken as a standard to evaluate other methods. Table (2) reveals that Hargreaves method is the most accurate one compared with other considered method because the mean, minimum, maximum, standard deviation and C.V. of this method had values very close to their corresponding values of Penman-Monteith method.

Figure (2) contrast monthly PET over time estimated by PM method (dark line) with PET estimated by each of the other method and by pan evaporation measurement (light line). These graphs reveal that the tested methods varied in accuracy in estimating PET in the study region. Again, Hargreaves method was the most accurate since its line graph was the closest to PM line graph (Figure 2h). Figure (2a) shows that Thornthwaite method underestimated PET at all levels of PET compared with PET estimated by PM method. This is compatible with the founding of Alkaeed *et al*. (2006). Figure (2b) and (2c) demonstrate that Blaney and Criddle method and Kharrufa method tend to overestimate PET at high level of PET and relatively accurate at other levels. Figure (2d) reveals that Hargreaves and Samani method tends to severely overestimated PET in the study area. Figure (2e) shows that evaporation from pan was close to PET at low levels of PET while it considerably overestimatedPET at high level of PET. With respect to methods based on radiation, Makkink method behaved similarly to Kharrufa and Blaney and Criddle methods (Figure 2f), while Priestley and Taylor methods were similar to Thornthwaite method (Figure 2g). As stated earlier, Figure (2h) shows that Hargreaves method was the most accurate one since its line plot match the line plot of PM method except for high level of PET where it slightly over estimated PET. Therefore, Hargreaves equation is preferred to be used to estimate PET if no calibration is applied.

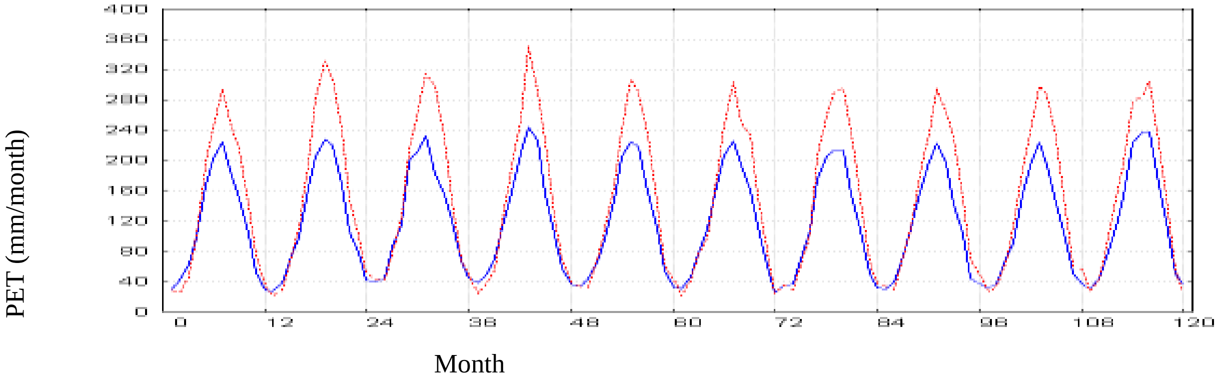
The scatter diagrams in Figure (3) show the pattern of relationship between PET of PM method, on one hand, and PET estimated by each of other method and pan evaporation on the other hand. This Figure shows existence of strong relationships between the PET of corresponding pairs of methods. Therefore, SAS package was



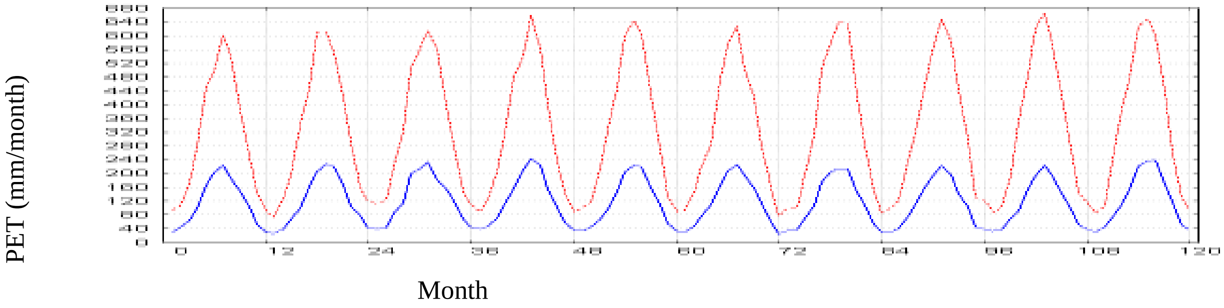
a. Thornthwaite *versus* **Penman-Monteith.**



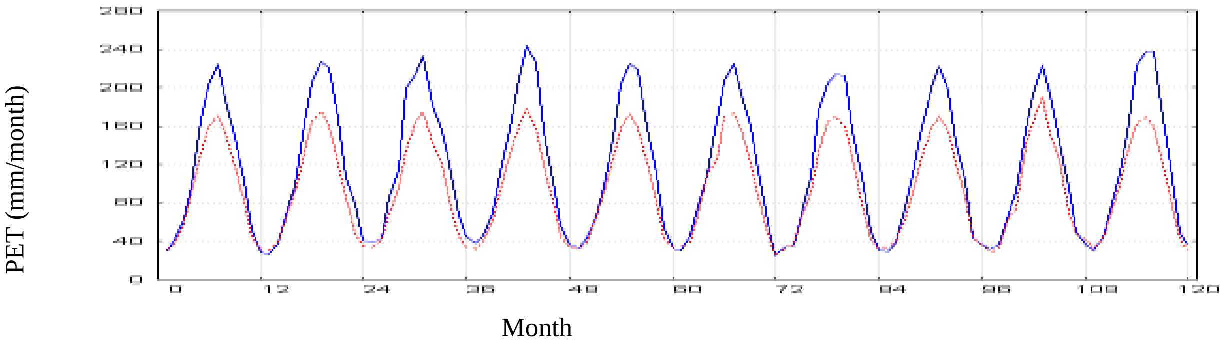
b. Blaney and Criddle *versus* **Penman-Monteith.**



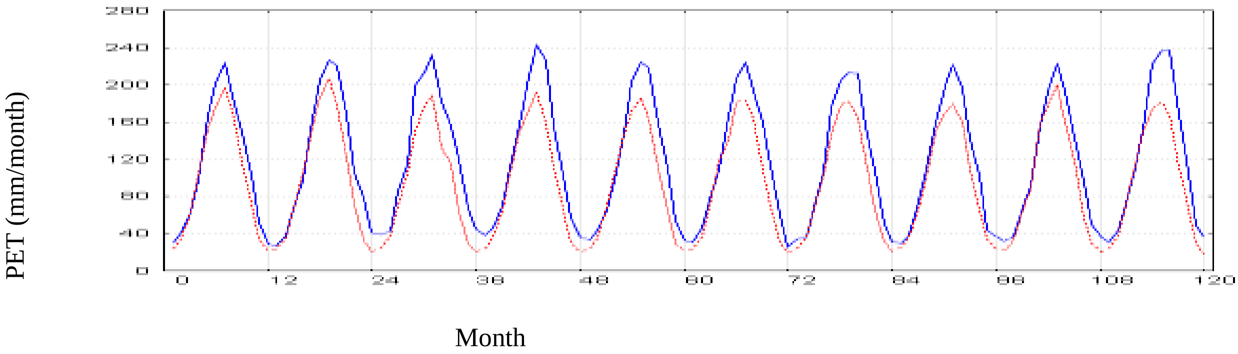
c. Kharrufa *versus* **Penman-Monteith.**



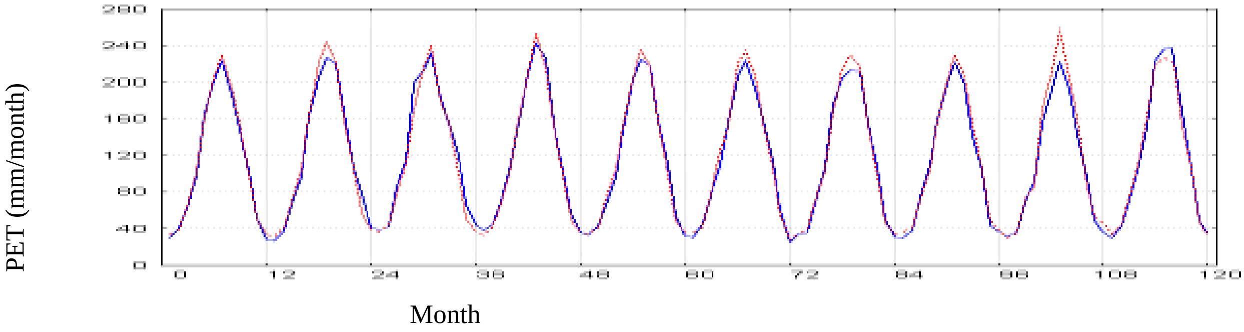
d. Hargreaves and Samani *versus* **Penman-Monteith.**



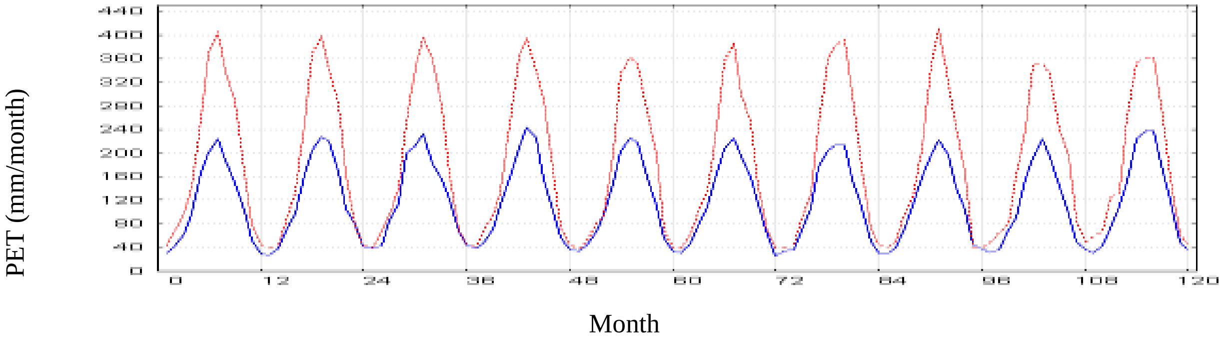
e. Makkink *versus* Penman-Monteith.



f. Priestley and Taylor *versus* **Penman-Monteith.**

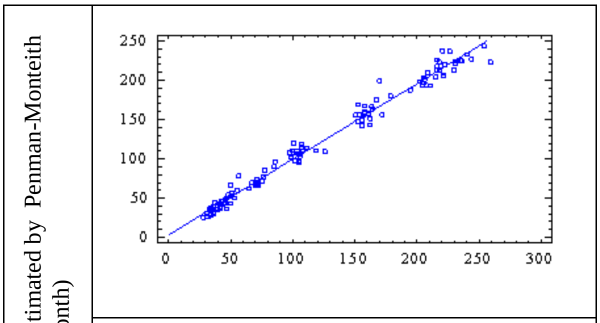


g. Hargreaves *versus* **Penman-Monteith.**

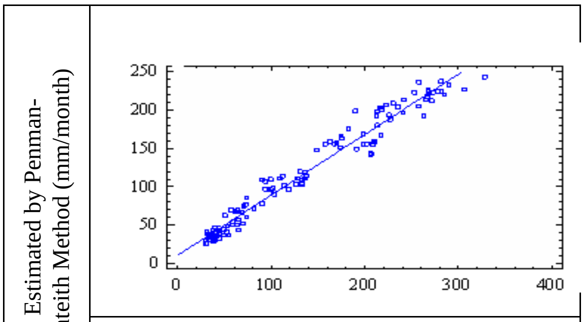


h. Pan Evaporation *versus* Penman-Monteith.

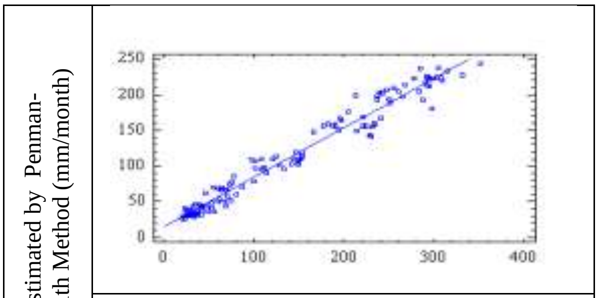
Fig. (2): PET over time estimated with Penman-Monteith method (dark lines) and with each of the other methods (light lines).



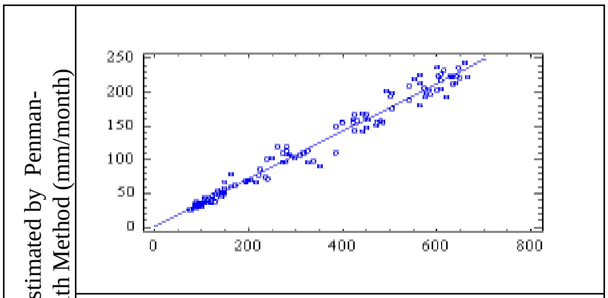
PTE estimated by Thornthwaite Method (mm/month)
A



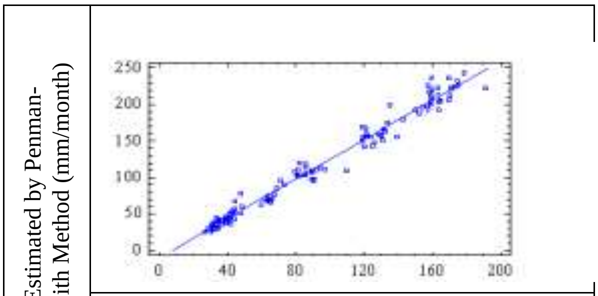
PTE Estimated by Blaney and Criddle (mm/month)
B



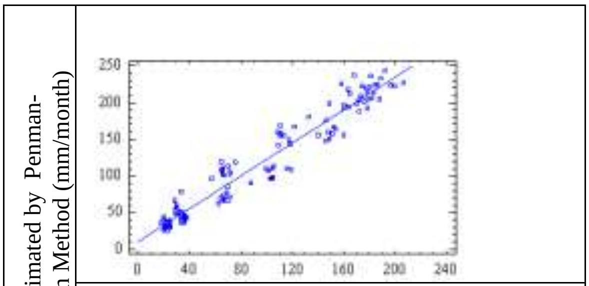
PET Estimated by Kharrufa Method (mm/month)
C



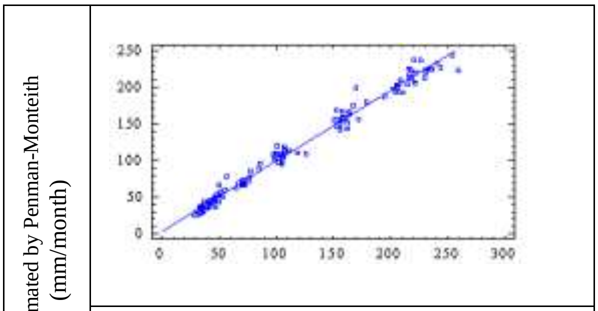
PET Estimated by Hargreaves and Samani Method (mm/month)
D



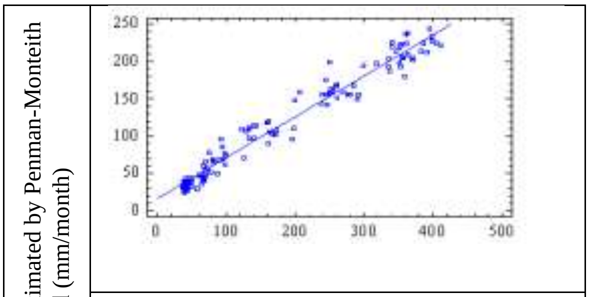
PET Estimated by Makkink Method (mm/month)
E



PET Estimated by Priestley and Taylor Method (mm/month)
F



PET Estimated by Hargreaves Method (mm/month)
G



PET Estimated by Epan Measurement Method (mm/month)
H

Fig. (3): The scatter diagram and linear regression line for PET estimated by Penman- Monteith method, on one hand, and PET estimated by each of the other methods, on the other hand.

Table (4): Original and calibrated equations of each method.

Method	Original Equation	Calibrated Equation
Thornthwaite	PET = 16 * d (10T/I)^a	PET= 30.5 + 17.456 d (10T/I)^a
Blaney- Criddle	PET = KP (0.46T + 8.13).	PET = 10.4+ KP (0.363T + 6.415).
Kharrufa	PET = 0.34 PT$^{1.3}$	PET = 15.6 + 0.235 PT$^{1.3}$
Hargreaves-Samani	PET = 0.0023 (T+17.8) √(Tmax.-Tmin.) Ra	PET = 1.1 + 0.000812 (T+17.8) √(Tmax.-Tmin.) Ra
Makkink	PET = 0.61 (Δ /Δ + γ) * (R_s /λ)	PET = -10.4 + 0.825 (Δ /Δ + γ) *(R_s /λ)
Priestley-Taylor	PET = 1.26 (Δ /Δ +γ) * (R_n /λ)	PET = 10.6 + 1.525 (Δ /Δ +γ) * (R_n /λ)
Hargreaves	PET = 0.0135 (T + 17.8) (R_s/λ)	PET = 3.5 + 0.013 (T + 17.8) (R_s/ λ)
Pan measurement	PET = Kp Epan	PET = 16.8 + 0.546 kp Epan

employed to fit linear, double log, and second degree polynomial equations. This will allow selecting the best model for each relationship. The obtained models can then be used for prediction PET estimated by PM method using corresponding data estimated by each of the other methods. Table (3) presents models coefficients and adjusted coefficient of determination ($\square^2$) for each model. The table reveals high predictive capability for all methods and all models. The values of R^2 ranged between 0.914 and 0.987.

Although direct comparison between $\overline{R^2}$ for double log function and the other two models not valid due to the difference in the values of the dependent variables, values of R^2 for double log function were lower than the corresponding values of simple linear equation and polynomial equations. In addition to that, $\overline{R^2}$ of simple linear equation are high enough to obtain accurate estimate. Polynomial function had $\overline{R^2}$ slightly better than simple linear equation for Thornwaite (1948), Blaney and Criddle(1950), Hargreaves (1975) methods, and pan evaporation measurements. The difference in the $\overline{R^2}$ values among the tested models for each method ranged between 0.2% and 1.2% .For Priestley and Taylor method $\overline{R^2}$ of simple linear equation exceeded R^2 of polynomial equation by 0.2%. For other methods $\overline{R^2}$ of both functions were almost equal. Since the difference between $\overline{R^2}$ of simple linear equations and polynomial equations is very low, it *is* recommended to use simple linear equations. Adjusted coefficient of determination of simple linear equation for the different methods ranged from 0.942 (for Priestley and Tylor method) to 0.985 (for Hargreaves method). For thermo-based methods Hargreaves and Samani method had the best performance ($\overline{R^2}$ = 0.973), while for radiation based methods Hargreaves method was the best ($\overline{R^2}$ = 0.985). The R^2 for pan evaporation was 0.962 which also indicates high predictive capability. Therefore, any method can be used to predict PET of Penman-Monteith method. However, Hargreaves method is recommended because it had the highest predictive capability.

Table (4) presents the original and calibrated equation for each method. Depending on the availability of meteorological data, any of these calibrated equations could be used to precisely estimate PET of PM method. Although, the predictive capabilities of these methods are not equal, the differences are relatively small. Since meteorological stations may not gather all climatic data, one can use the equation with available data to precisely predict values for PET. This work was based on data for a limited area, therefore, it would be advantageous to develop equations using data that cover the entire area of the region.

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مقارنة بين بعض الطرائق المستخدمة في تقدير التبخر- النتح الممكن (الكامن) في منطقة سيميل إقليم كردستان العراق

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ملخص

تم حساب تقدير التبخر- النتح الممكن (الكامن) الشهري لمنطقة سيميل بأستخدام طريقة FAO-56 Pennman-Monteith و طرائق أخرى. و من ثم تم تقدير التبخر- النتح الممكن المحسوبة بطريقة FAO-56 Pennman-Monteith وذلك بأستخدام النتح الممكن المستخرج بالطرائق الأخرى مستخدمين ثلاثة نماذج رياضية. أظهرت النتائج بأن المعادلة الخطية البسيطة كانت هي الأفضل لهذا الغرض. لقد كانت لجميع الطرائق قابلية جيدة في تقدير التبخر- النتح الممكن المحسوبة بطريقة FAO-56 Pennman- Monteith غير أن طريقة Hargreaves كانت الأفضل من بينها.

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