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Derivation Mathematical Equations for Future Calculation of Potential Evapotranspiration in Iraq, a Review of Application of Thornthwaite Evapotranspiration

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Abstract

In any natural area or water body, evapotranspiration is one of the important outcomes in the water balance equation. As a significant method and depending on monthly average temperature, estimating of potential Evapotranspiration depending on Thornthwaite method was adopted in this research review. Estimate and discuss evapotranspiration by using Thornthwaite method is the main objectives of this research review with considerable details as well as compute potential evapotranspiration based on climatologically data obtained in Iraq. Temperature - evapotranspiration relationship can be estimated between those two parameters to reduce cost and time and facilitate calculation of water balance in lakes, river, and hydrogeological basins. The relationship was obtained using Thornthwaite method in Iraq by dividing the area into seven sectors according to geographic latitude. Each sector has multi meteorological stations where thirty two stations were used with different periods of records. A mathematical relationship was obtained between mean temperature and corrected potential evapotranspiration with (97.45) to (99.84) coefficient of determination. The mean temperature has a decreasing pattern from southern east towards northern west of Iraq affected by Mediterranean Sea climate conditions, while corrected potential evapotranspiration has the opposite direction regarding increased value because of a direct relationship with temperature.

Keywords: Review of Application of Evapotranspiration, Thornthwaite Method, Iraq

اشتقاق المعادلات الرياضية لحساب مستقبل التبخر– نتح كامن في العراق ، مراجعة في تطبيقات تبخر – نتح كامن باستخدام طريقة ثورنثويت

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الخلاصة

احدى أهم النتائج في معادلة الموازنة المائية لاي منطقة طبيعية او جسم مائي هي التبخر – نتح كامن وهو أيضا عنصر مهم وحاسم في الدورة الهيدرولوجية. طريقة ثورنثويت احدى الطرق الهامة المستخدمة لتقدير التبخر – نتح كامن المعتمد بالدرجة الاساس على متوسط درجة الحرارة الشهرية. تمثلت أهداف هذه المراجعة على مناقشة تفاصيل استخدام طريقة ثورنثويت لتقدير التبخر – نتح كامن بالاضافة الى حساب التبخر – نتح كامن بالاستناد إلى البيانات المناخية المتوفرة في محطات الارصاد الجوية في العراق. تم ايجاد العلاقة الارتباطية بين درجة الحرارة والتبخر – نتح كامن باستخدام طريقة ثورنثويت في العراق من خلال تقسيم المنطقة إلى (7) قطاعات بحسب خطوط العرض الجغرافية الممتدة من الجنوب الى الشمال ،حيث تم استخدام

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(32) محطة تضمنت بيانات درجات الحرارة لفترات تسجيل مختلفة . توصل البحث الى ايجاد علاقة رياضية بين متوسط درجة الحرارة مع معامل التبخر – نتح كامن المصحح وبمعامل ارتباط تراوح بين (97.45) إلى (99.84). بينت النتائج بان متوسط درجات الحرارة تميز بوجود نمط تزايد متماثل اتجه من الجنوب الشرقي إلى الشمال الغربي من العراق متأثرًا بالظروف المناخية للبحر الأبيض المتوسط ، في الوقت الذي تناقصت قيم التبخر – نتح كامن المصحح بشكل عكسي لنمط تزايد درجات الحرارة تنظراً لارتباطه المباشر بها.

1 Introduction

In any hydrological basin, climate and hydrological conditions reflect the factors affected by morphology, soil nature and changing in climate factors [1]. Water demand has increased recently as growing population increased, where water becomes limited [2].

Water balance equation indicates relative values of inflow and outflow as well as changing of water storage [3]. As the main subject in hydrology, water balance techniques are a solution of important theoretical and practical problems [4]. The quantitative evaluation of water resources with their changes can be possibly made depending on water balance approach. In hydrological cycle, the understanding of water balance is important where the relationship between rainfalls and total loss of water in different forms can be determined [5].

Water consumed by agricultural crops or natural plants has been determined by using different methods. Water source used in plant life is a key factor to select the appropriate method. The main methods are: inflow-outflow method for large areas, external flow method, tank and lysimeter experiments, soil moisture depletion studies, soil segment experiments, integration method [6].

Consumed water by crops and evaporation estimation depending on meteorological data was developed by several formulas. Reasonably accurate results were adopted by applying some of these methods, which are mentioned as follow:

1. Theoretical and physical methods depending on vapor transfer and energy balance.
2. Empirical methods depending on temperature, radiation, and other data.

Evapotranspiration is an important outcome in the water balance equation in any natural area or water body [7]. It is a crucial component in hydrologic cycle and considered as the main requirement in the planning and designing any irrigation project [8]. Evapotranspiration is a mixed process where water is lost by transpiration from crop and soil surface evaporation. Under standard conditions, bumper crop production required a fixed water quantity to meet water lost by evapotranspiration [9].

Evapotranspiration (Evaporation and transpiration) occur simultaneously, where distinguishing between two processes is difficult. Cropped soil evaporation is mainly obtained by a fraction of solar radiation that reached the soil surface. As crop develops within time, this fraction decreases sequentially [10]. Penman and Thornthwaite in 1948, both have been developed potential evapotranspiration (PET) equation independently. Penman's equation was more mechanical compared by Thornthwaite's equation which was more experimental and simpler than Penman's equation due to less climatic data requirements [11]. Thornthwaite method used widely to estimate potential evapotranspiration, he derived his equation as he determined water balance in valleys using correlated temperature with evapotranspiration [11, 12]. Depending on observed monthly average temperatures; prediction of monthly evapotranspiration can be obtained at a meteorological station in each year. This method has accepted around the globe widely where it does not depend on strong physical and mathematical principles. Even it is a simple method to be used and giving an acceptable result, it is purely empirical and used continuously to estimate irrigation water requirement [13].

2 Definitions:

1. Evaporation (E): Water evaporation is defined as the change from liquid to vapor state and the net transfer of this vapor into the atmosphere [14]. Water evaporates from a variety of surfaces, such as lakes, rivers, pools, soil, and wet plants [10].
2. Transpiration (T): The transpiration consists of evaporation of the liquid water in the plant tissues and the removal of steam into the atmosphere. Crops mostly lose their water through stacks. These small openings on the leaves of the plant through which gases and water vapor [10].
3. Evapotranspiration (ET): Is simply the amount of water that is returned to the atmosphere through evaporation (loss of moisture from soil, stagnant water, etc.) and transpiration (biological use and release of water by vegetation) [15].

4. Actual Evapotranspiration (AET): The quantity of water evaporates and transpired from surface and plants respectively. If the total quantity of water is limited, then it means the actual combined loss of water from plants and soil [15].
5. Potential Evapotranspiration (PET): The quantity of water that would evaporate and transpired from surface and plants respectively, when the supply of water is unlimited [10].

3 Factors affecting Evapotranspiration:

Climate, specific crop, soil moisture supply, salinity, and vegetative cover are important factors determining the transpiration rate. Climate factors that particularly affect evapotranspiration are solar radiation, precipitation, temperature, daytime hours, humidity, and wind velocity. Multi factors affect the water amount transpired by plants, such factors are: availability of moisture within the root zone, the stage of development of the plant and the leaf surfaces nature. Effectiveness of many interrelated factors mentioned before on evapotranspiration is difficult to determine [6].

4 Evapotranspiration by Empirical Models:

Estimation of evapotranspiration using various empirical models are available, such as Blaney - Criddle 1962 [17], Penman 1948 [18], ASCE standardized Penman-Montieth (ASCE) 2005 [19], Priestley Taylor 1972 [20], Thornthwaite, 1948 [12] and Hargreaves-Samani 1985 [21] the most commonly used empirical models. Advantages, limitations and application time step of some different evapotranspiration estimation models presented in Table-1.

Table 1- Advantages, limitations and application time step of some different (ET) estimation models [14].

No.	Methods	Advantages	limitations	Application time step
1	Blaney - Criddle (1942)	Simplicity ET	Generally underestimation	Month
2	Thornthwaite (1948)	Simplicity ET	Underestimation with adjective condition	Month
3	Hargreaves and Samani (1985)	Simplicity ET	Problems of over and under estimation of ET	Week
4	Christiansen (1968)	More or less accurate to predict ET for monthly time step	Not accurate for calculating ET in a daily or shorter time step	Month

5 Temperature Based Methods:

Generally, estimate evapotranspiration by different methods has been used widely. These methods require measurements of climatological parameters. The estimating of evapotranspiration for long periods (i.e. month or week) based on empirical and temperature methods have been used widely. (Hedke 1924) [22], (Lowry and Johnson (1942) [23], (Thornthwaite, 1948) [12], (Blaney - Criddle 1950, 1962) [24], (Phelan 1962) [25], and (Doorenbos and Pruitt, 1977) [26] developed methods in areas depending on availability of air temperature climatic data only.

6 Thornthwaite Method (1948):

The most significant methods have been used in estimation potential Evapotranspiration (PE) based on the monthly average temperature. It is widely used in arid and semi-arid regions [27, 28]. Thornthwaite method is the empirical formula, although it entirely depends on the temperature relationship and has no theoretical justification, it was widely accepted, mainly due to its ease of use by means of tables and monographs. Thornthwaite (1948) developed a temperature-based experimental formula. He realized the need for a simpler expression that would easily use of available climate data. Since the temperature was a good index of energy in a zone of essential equilibrium, he developed an exponential relationship between the average monthly temperature in degrees centigrade and means monthly potential evapotranlipiration, and adjusted the result by correcting the sunlight and the days of the month, Table-2 [6].

Table 2-Constant of K used in Thornthwaite formula* (29)

Lat.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
60°N	0.54	0.67	0.97	1.19	1.33	1.56	1.55	1.33	1.07	0.84	0.58	0.48
50°N	0.71	0.84	0.98	1.14	1.28	1.36	1.33	1.21	1.06	0.9	0.76	0.68
40°N	0.8	0.89	0.99	1.1	1.2	1.25	1.23	1.15	1.04	0.93	0.83	0.78
30°N	0.87	0.93	1	1.7	1.14	1.17	1.16	1.11	1.03	0.96	0.89	0.85
20°N	0.92	0.96	1	1.05	1.09	1.11	1.1	1.07	1.02	0.98	0.93	0.91
10°N	0.97	0.98	1	1.03	1.05	1.06	1.05	1.04	1.02	0.99	0.97	0.96
00°N	1	1	1	1	1	1	1	1	1	1	1	1
10°S	1.05	1.04	1.02	0.99	0.97	0.96	0.97	0.98	1	1.03	1.05	1.06
20°S	1.1	1.07	1.02	0.98	0.93	0.91	0.92	0.96	1	1.05	1.09	1.11
30°S	1.16	1.11	1.03	0.94	0.89	0.85	0.87	0.93	1	1.07	1.14	1.17
40°S	1.23	1.15	1.04	0.93	0.83	0.78	0.8	0.98	0.99	1.1	1.2	1.25
50°S	1.33	1.19	1.05	0.98	0.75	0.68	0.7	0.82	0.97	1.13	1.27	1.36

K: is a constant to correct PET for latitude other than 0°.

To calculate potential Evapotranspiration using Thornthwaite's equation, the following formula was used [4]:

$$PE = 16\left[\frac{10tn}{J}\right]^{a} \quad \text{-------- (1)}$$

$$J = \sum_{1}^{12} j \quad \text{-------- (2)}$$

$$j = \left[\frac{tn}{5}\right]^{1.514} \quad \text{-------- (3)}$$

$$a = 0.016J + 0.5 \quad \text{--------- (4)}$$

PE: potential evapotranspiration, J: Heat Index, j: Coefficient monthly temperature (° C), a: Constant, tn: Average monthly temperature (° C).

The objective of this review is discussing Thornthwaite method of estimation of evapotranspiration in details, and compute potential evapotranspiration based on climatologically data obtained in Iraq. A relationship of temperature - evapotranspiration was obtained using Thornthwaite method in Iraq. Monthly evapotranspiration controlled by temperature as a key factor can be obtained by dividing Iraqi area into seven sectors according to its geographic latitude. Each sector has multi meteorological stations where thirty two stations were used all over Iraq which located within (29.00°- 37.22°N) and (38.45°- 48.30°E). Climate of Iraq is characterized by a short cold winter with very hot summer with continental semi-arid type [30].

7 Material and Method

The following materials were used in this research review:

1- Temperature (annual and monthly records) in thirty two meteorological stations from date of stations operation until 2015 with respect their geographic coordinates [31].

2- Thornthwaite formula [12].

3- Grapher and Surfer programs demonstrating graphs and contour maps.

The method adapted in this review of evapotranspiration estimation depends on empirical methods belong to Thornthwaite formula. The basic assumption considered that temperature is an excellent parameter of the evaporative influence of the atmosphere. This method became very common due to limited data requirements [32].

Annual and monthly air temperatures of thirty two meteorological stations distributed in Iraq used to calculate potential evapotranspiration (PE) using Thornthwaite method. These stations were divided according to Iraqi geographic latitude from (30-31) in the south to (36-37) in the north of Iraq, table (3) Figure-1. Calculated potential evapotranspiration (PE) was compared with temperature in all station located in the same sector. Statistical approach was used to identify the types of equations for each group of stations using Grapher program. Finally, Surfer program was used to demonstrate the contour map of heat and corrected potential evapotranspiration (PEc) in Iraq.

Table 3 – Coordinates of meteorological stations distributed in Iraq [33].

Sta. No.	Name of Station	Location of stations		Sta. No.	Name of Station	Location of stations	
		Long.	Lat.			Long.	Lat.
1	Ainaltamer	44° 43′ 00″	32° 33′ 00″	17	Makhmoor	43° 36′ 00″	35° 45′ 00″
2	Amarah	47° 10′ 00″	31° 51′ 00″	18	Mosul	43° 09′ 00″	36° 19′ 00″
3	Anah	41° 57′ 00″	34° 28′ 00″	19	Najaf	44° 19′ 00″	31° 59′ 00″
4	Azizyah	45° 04′ 00″	32° 55′ 00″	20	Nukhaib	42° 15′ 00″	32° 02′ 00″
5	Baaj	41° 44′ 00″	36° 02′ 00″	21	Nasiriyah	46° 14′ 00″	31° 05′ 00″
6	Badra	45° 57′ 00″	33° 06′ 00″	22	Qaim	41° 01′ 00″	34° 23′ 00″
7	Baghdad	44° 14′ 00″	33° 14′ 00″	23	Rabiah	42° 06′ 00″	36° 48′ 00″
8	Baiji	43° 29′ 00″	34° 56′ 00″	24	Ramadi	43° 09′ 00″	3°3 27′ 00″
9	Basrah	47° 47′ 00″	30° 34′ 00″	25	Rutba	40° 17′ 00″	33° 02′ 00″
10	Diwaniyah	44° 59′ 00″	31° 59′ 00″	26	Samaraa	4353′ 00″	34° 11′ 00″
11	Hai	46° 03′ 00″	32° 10′ 00″	27	Samawah	45° 16′ 00″	31° 18′ 00″
12	Hilla	44° 27′ 00″	32° 27′ 00″	28	Sinjar	41° 50′ 00″	36° 19′ 00″
13	Karbalaa	44° 01′ 00″	32° 37′ 00″	29	Tel-Afer	42° 29′ 00″	36° 22′ 00″
14	Khalis	44° 32′ 00″	33° 50′ 00″	30	Tikrit	43° 42′ 00″	34° 34′ 00″
15	Khanaqin	45° 26′ 00″	34° 18′ 00″	31	Tuz	44° 39′ 00″	34° 53′ 00″
16	Kirkuk	44° 24′ 00″	35° 28′ 00″	32	Erbeel	36° 09′ 00″	44° 00′ 00″

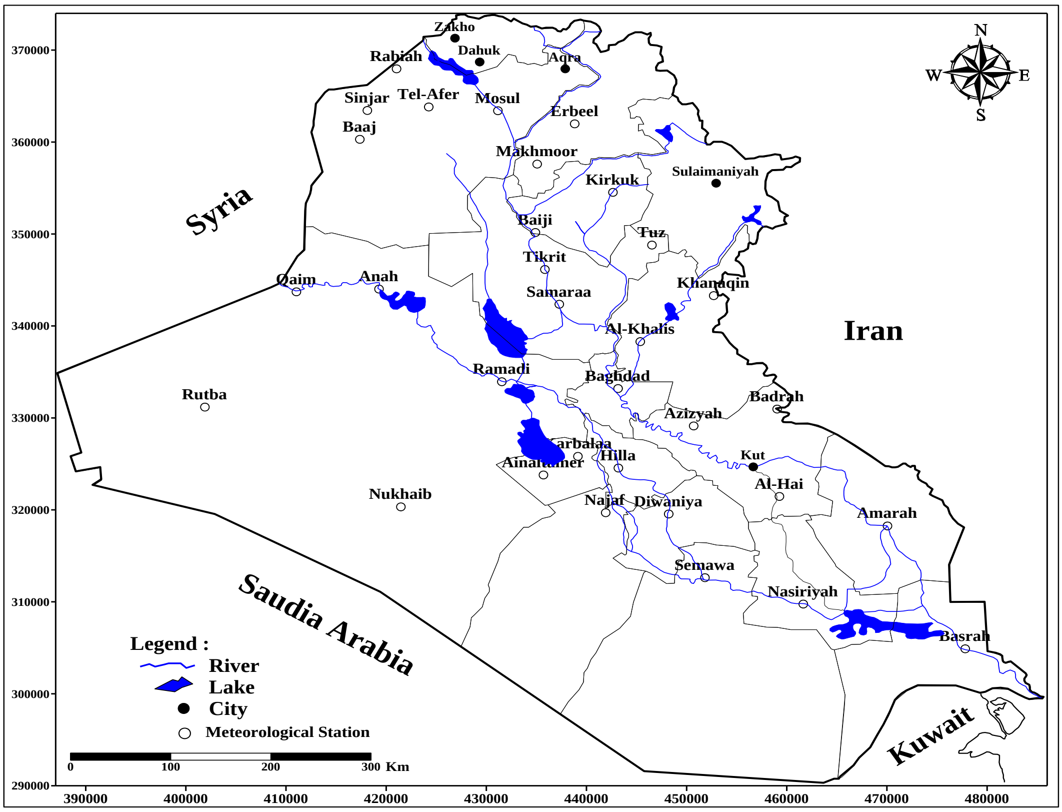

Figure 1- Meteorological stations distribution and location map in Iraq.

8 Results and discussion:

Table-4 shows the seven groups of meteorological stations distributed in each Iraqi sector. Using Thornthwaite formula [8] showed in equations (1,2,3 and 4) previously mentioned, Table-2 shows the calculating of annual corrected potential evapotranspiration (PEc) based on the correction factor for sunlight and the number of daylight according to the latitude. Appendix (1) shows monthly mean temperature and (PEc) calculated in fourteen stations within seven sectors. Results of mean annual temperature and annual summation of (PEc) shown in Table-5.

Table 4 - Groups of meteorological stations distributed in each sector [33].

Sector No.	Sum of Station	Geographic latitude	Stations
1	2	30°-31°	Basrah and Nasriyah
2	4	31°-32°	Amarah, Diwaniyah, Najaf and Samawah
3	6	32°-33°	Aintamer Aziziyah, Hai, Hella, Karbala and Nukhaib
4	5	33°-34°	Badra, Baghdad, Khalis, Ramadi, Rutba
5	6	34°-35°	Anah, Khanaqin, Qaim, Samaraa, Tikrit and Tuz
6	3	35°-36°	Baiji, Kirkuk and Makhmoor
7	6	36°-37°	Erbeel, Baaj, Mosul, Rabiah, Sinjar and Tel-Afar

Table 5- Mean annual temperatures and calculated (PEc) [33]

St. No.	Annual Mean Tem. (C)	Sum of corrected (PEc) (mm)	Duration (years)	St. No.	Annual Mean Tem. (C)	Sum of corrected (PEc) (mm)	Duration (years)
1	22.3	1579	20	**17**	22.7	1792	19
2	24.8	2318.1	35	**18**	20.1	1327.3	70
3	21	1388.1	38	**19**	24.4	2185.6	40
4	24	2014.6	15	**20**	22.3	1579.1	20
5	20.5	1361.5	17	**21**	25.1	2257.2	73
6	24.5	2330.1	15	**22**	21	1383.5	20
7	22.7	1674.4	66	**23**	18.5	1122.6	31
8	22.4	1697.3	30	**24**	22.1	1515.1	25
9	24.9	2132.1	67	**25**	19.7	1182.2	35
10	24.3	2033.1	38	**26**	23.1	1845.1	26
11	24.4	2139.2	68	**27**	24.7	2242.7	38
12	23.3	1773.7	25	**28**	20.5	1399.5	42
13	24.1	2087.4	38	**29**	21	1464.7	25
14	22	1511.5	17	**30**	23	1910	24
15	22.8	1751.8	60	**31**	22.8	1768	17
16	22.2	1662.4	68	**32**	21.3	1488.1	40

Depending on the Table-5, Figure-(2 and 3) show the mathematical relationship between monthly mean temperature and monthly corrected potential evapotranspiration (PEc) calculated in each group within (7) sectors. Table-6 shows the obtained equation of mathematical relationship between temperature and (PEc) in each sector.

Table 6 - Equations obtained between temperature and (PEc) in each sector

Sector No.	Station No.	Equation and alternate equation	R-squared %
1	9 and 21	log (PEc) = 3.74303 * log (T) + -7.30851 PEc = T ^(3.74303) * 0.000669814	99.84
2	2,10,19 and 27	log(PEc) = 3.62641 * log(T) + -6.91808 PEc = T ^(3.62641) * 0.000989726	99.81
3	1,4,11,12,13 and 20	log (PEc) = 3.28486 * log (T) + -5.77718 PEc = T ^(3.28486) * 0.00309742	99.15
4	6,7,14,24 and 25	log (PEc) = 2.97073 * log (T) + -4.73113 PEc = T ^(2.97073) * 0.00881649	97.45

5	3,15,22,26,30 and 31	log (PEc) = 3.02967 * log (T) + -4.92707 PEc = T ^(3.02967) * 0.00724772	98.96
6	8,16 and17	log (PEc) = 3.0942 * log (T) + -5.14115 PEc = T ^(3.0942) * 0.00585097	99.74
7	5,18,23,28,29 and 32	log (PEc) = 2.61248 * log (T) + -3.54622 PEc = T ^(2.61248) * 0.0288333	98.93

It seems that sector (4) has a lower coefficient of determination (R-squared) among other sectors. This sector located within latitude (33-34) and has five meteorological stations distributed on wide range in middle of Iraq from west to east. Four of these stations are closed together (Badra, Khalis, Baghdad and Ramadi) while Rutba station is located almost near the Iraqi – Jordanian border. The recorded mean temperatures in four stations which located in the middle and eastern side of Iraq was ranged (22.016 - 24.546 °C) and potential evapotranspiration was ranged (1511.515 - 2330.101 mm), while mean temperatures in Rutba station was (19.738) and potential evapotranspiration was (1182.171 mm) due to desert climate. This difference affects on potential evapotranspiration calculated in this station compared to other stations in the same sector.

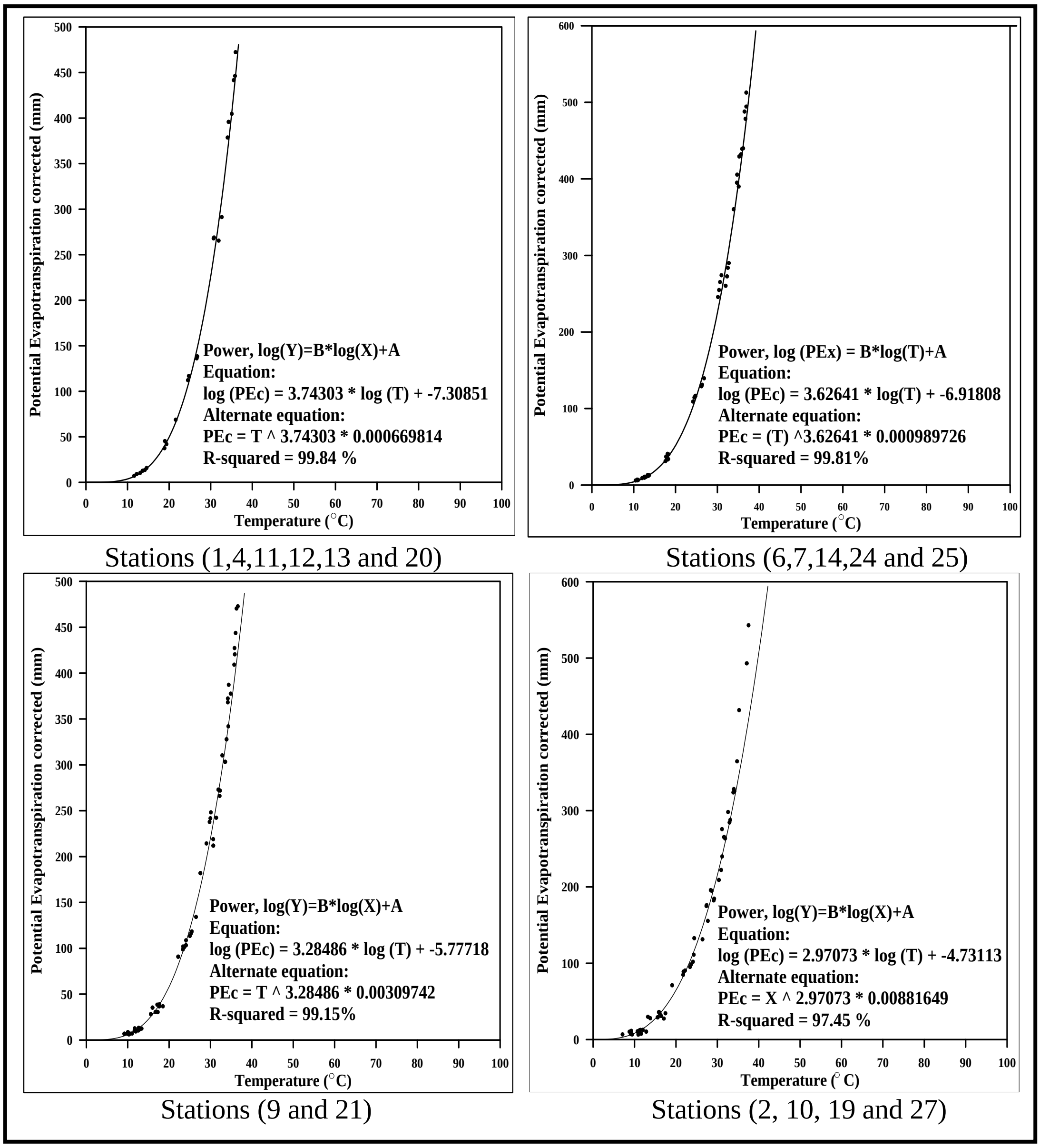

Figure 2 - Mathematical relationship between temperatures and (PEc) in seventeen stations distributed in Iraq.

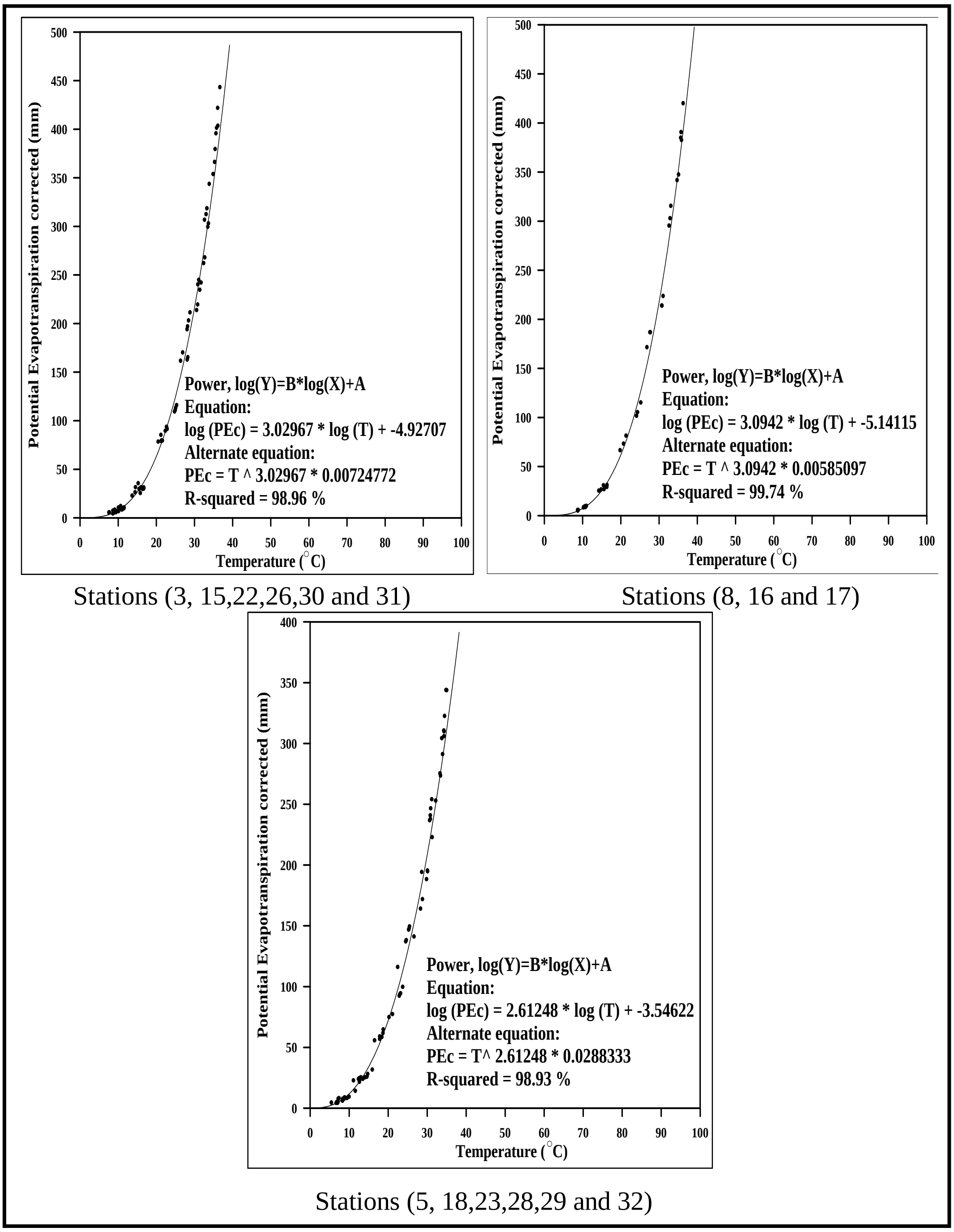

Figure 3 - Mathematical relationship between temperatures and (PEc) in fifteen stations distributed in Iraq.

Figure-4 shows the mean temperature of thirty two stations based on results obtained in Table-5, while Figure-5 demonstrated the distribution of (PEc) in Iraq. A symmetrical decreased pattern of mean temperature has been indicated from southern east towards northern west as reflects of highly relative humidity rates in the northern west part of Iraq according to its geographic location. The climate condition of Mediterranean Sea reduces mean annual and monthly temperatures in this area of Iraq. In the other hand, the (PEc) as shown in Figure-5 has the opposite direction of increased values of Evapotranspiration due to a direct relationship with temperature.

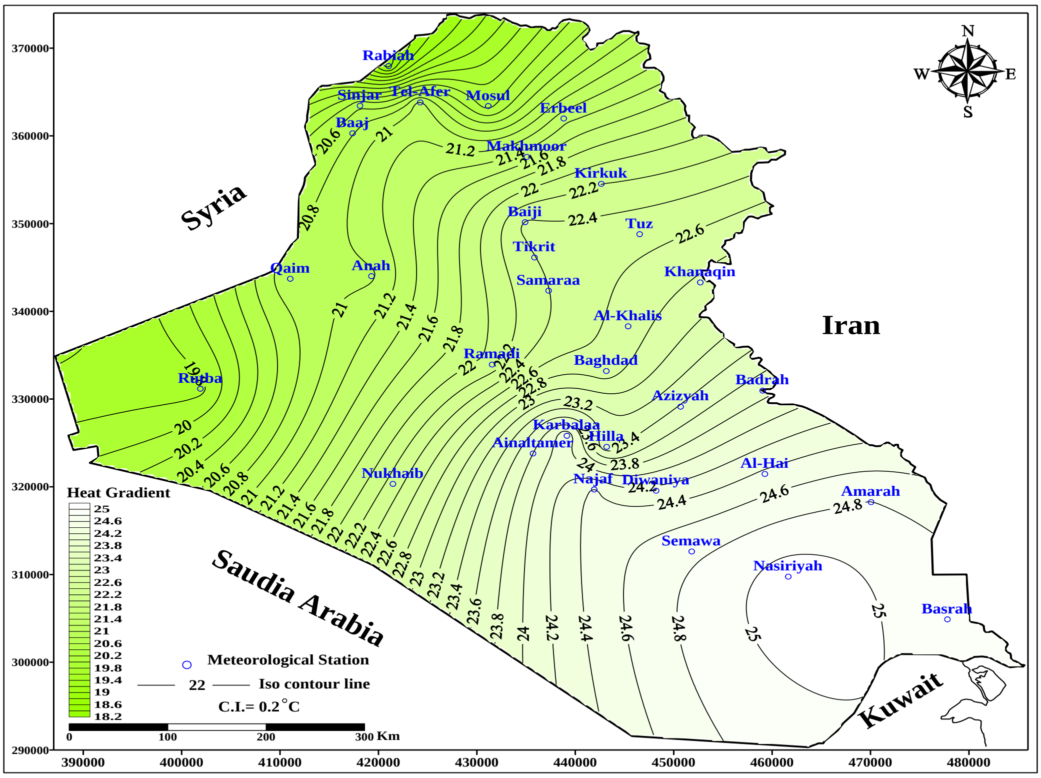

Figure 4 - Mean annual Temperature contour map in Iraq.

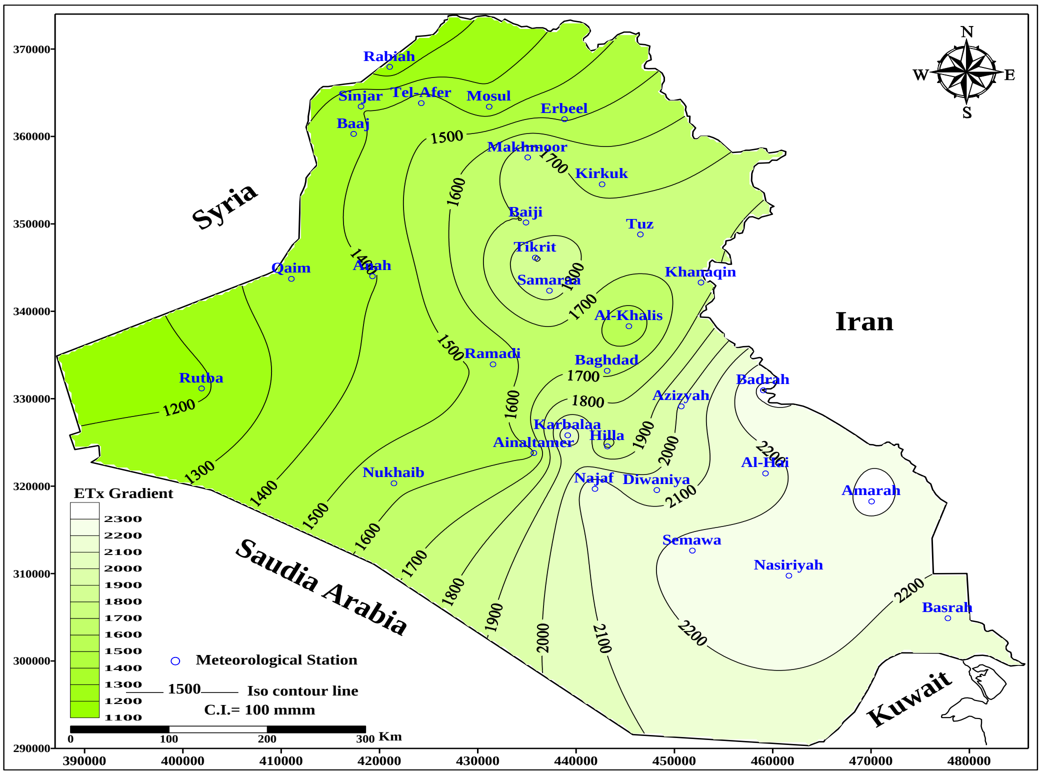

Figure 5 - Annual (PEc) Contour map in Iraq.

9 Conclusions

1- A mathematical relationship can be obtained between mean temperature with corrected potential evapotranspiration (PEc) using Thornthwaite formula with (97.45) to (99.84) coefficient of determination in seven sectors.

2- Mean temperature has a symmetrical decreased pattern from southern east towards northern west of Iraq infected by Mediterranean Sea climate conditions, while corrected potential evapotranspiration (PEc) has the opposite direction of increasing values due to the direct relationship with temperature.

Appendix 1- Mean monthly temperature and (PEc) calculated in sixteen stations within seven sectors of Iraqi latitude.

Station	Station No. 2		Station No. 4		Station No. 5		Station No. 7	
Month	Mean T	PEc	Mean T	PEc	Mean T	PEc	Mean T	PEc
January	11	5.7	10.6	6.5	7.21	4.94	9.511	6.26
February	13.5	11.5	13	12	8.93	8.14	12.1	12.24
March	18	36	17.7	38.6	13.1	25.07	16.17	33.77
April	24.8	115.9	23.4	98.3	18.8	64.54	22.29	89.96
May	30.7	264.7	30	241.3	25.32	146.61	28.48	195.41
June	35.3	428.8	34.3	367.7	30.71	236.53	32.68	297.69
July	37	512	36.1	443.3	33.82	304.08	34.85	364.13
August	36	478	35.8	408.8	33.36	275.13	34.2	325.14
September	32.5	283.3	31.4	241.9	28.86	171.65	30.46	208.71
October	26.9	139	25.4	115.9	22.92	92.21	24.2	101.41
November	18.3	33.5	17.2	30.1	14.1	25.03	16.49	30.52
December	12.6	9.1	12.2	9.8	8.71	7.57	10.9	9.06
Station	Station No. 8		Station No. 9		Station No. 11		Station No. 12	
January	8.93	5.43	12.3	8.72	11.16	6.71	9.99	6.44
February	11.07	9.65	14.6	15.39	13.44	12.05	12.73	12.87
March	15.53	30.61	19.07	44.89	17.71	36.24	17.2	38.10
April	21.45	81.13	24.83	116.33	23.72	100.72	23.46	101.58
May	27.79	186.47	30.88	268.41	30.18	247.85	29.1	213.91
June	32.95	302.60	34.13	378.25	34.49	386.87	32.92	309.94
July	35.83	390.39	35.61	441.20	36.38	469.99	34.95	377.26
August	34.79	341.37	35.15	404.24	35.89	426.93	34.39	341.56
September	30.76	213.61	32.01	265.01	32.39	271.55	30.75	218.54
October	24.17	101.37	26.72	135.74	26.59	133.78	25.11	113.07
November	15.69	26.62	19.46	41.57	18.59	36.40	16.78	30.22
December	10.31	7.97	13.69	12.31	12.68	10.04	11.72	10.15
Station	Station No. 13		Station No. 15		Station No. 17		Station No. 19	
Month	Mean T	PEc	Mean T	PEc	Mean T	PEc	Mean T	PEc
January	10.38	5.67	9.75	6.43	8.83	4.81	10.53	5.52
February	13.1	11.70	11.61	10.34	10.79	8.43	13.33	11.76
March	17.68	37.24	15.55	29.44	14.93	26.30	17.81	36.75
April	24.18	108.33	21.35	78.68	20.79	72.99	24.27	108.58
May	29.86	237.41	28.27	196.76	27.68	186.46	30.48	254.35
June	34.27	371.94	33.11	312.24	33.15	315.21	34.75	394.49
July	36.69	472.37	35.87	401.12	36.37	419.70	36.98	494.03
August	35.95	420.10	34.95	353.51	35.94	382.34	36.26	439.43
September	32.31	265.71	30.63	213.47	31.13	223.44	32.39	272.11
October	25.57	117.94	24.85	109.11	25.29	114.91	26.31	129.09
November	17.36	29.98	16.77	31.01	16.41	28.92	17.66	30.87
December	12.02	8.94	11.3	9.67	10.81	8.47	12.1	8.60
Station	Station No. 22		Station No. 24		Station No. 26		Station No. 28	
Month	Mean T	PEc	Mean T	PEc	Mean T	PEc	Mean T	PEc
January	7.73	5.42	9.17	6.69	9.46	5.39	7.21	4.94
February	10.12	10.29	11.37	11.70	11.55	9.48	8.93	8.14
March	14.59	31.23	16.01	35.53	16.08	31.09	13.1	25.07
April	20.56	78.14	21.95	88.66	22.74	93.32	18.8	64.54

May	26.42	161.36	27.5	175.60	28.51	202.86	25.32	146.61
June	30.95	239.99	31.7	265.02	32.7	306.44	30.71	236.53
July	33.57	299.15	34.07	327.76	36.16	421.63	33.82	304.08
August	32.77	267.74	33.03	283.99	35.5	379.28	33.36	275.13
September	28.33	165	29.33	184.17	31.8	241.84	28.86	171.65
October	22.9	91.12	23.49	94.86	25.39	115.70	22.92	92.21
November	14.49	25.93	15.72	28.89	16.77	29.79	14.1	25.03
December	9.15	8.10	11.53	12.15	10.97	8.21	8.71	7.57

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