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Evaluate the climatic conditions for the Karbala

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Abstract

This study includes determining the climatic conditions and the nature of the reservoirs in the region with the determination of the flow direction of the aquifer. The meteorological data for the Karbala station for the period 1976-2016 showed that the values of the monthly rates of temperature, precipitation, evaporation, relative humidity, wind speed and Sunshine duration are (24.19 C◦), (95.5 mm), (2828.6mm), (46.75%), (2.76 m/sec), and (8.61 h/day) respectively. Thorenthwait method was used to calculate the values of Potential Evapotranspiration (PE) then determine the annual value of WS and WD which equal 28.11mm and 941.94mm respectively. Mean monthly water surplus for the period (1976-2016) was recorded about (9.36mm) in December, (13.11mm) in January and (5.64mm) in February of the whole amount of Rainfall and Equal to 29.34 of the total rainfall. The study showed the existence of a shallow aquifer unconfined in the Quaternary deposits. The flow net map is shown by mainly that the groundwater flow in the area, it is from the northwestern parts towards the Eastern and southestern parts.

Keywords: Climatic conditions, Classification of Climate, Water balance, Water surplus, Karbala area.

تقييم الظروف المناخية في كربلاء

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الخلاصة

تضمنت هذه الدراسة تحديد الظروف المناخية وطبيعة الخزانات في المنطقة مع تحديد اتجاه الجريان للخزان الجوفي . بيانات الارصاد الجوية لمحطة كربلاء للفترة من (1976-2016) تبين ان قيم المعدلات الشهرية لدرجة الحرارة والامطار والتبخر والرطوبة النسبية وسرعة الرياح ومدة السطوع الشمسي هي (C◦ 9.1-36.2), (0.03-65.8 mm), (51.4-412.7 mm), (21.7-71.1%)، (1.3-2.1 m/s)، و(5.4-11.2 h) على التوالي. تم حساب قيم التبخر- نتح الكامن (PE) بحسب طريقة ثورنثويت ثم تحديد قيمة الزيادة المائية السنوية (WS) وهي (28.11 mm)، والنقصان المائي السنوي (WD) وهي (941.94 mm). سجل المعدل الشهري للزيادة المائية في منطقة الدراسة في الفترة ((1976-2016)) بحوالي (9.36ملم) و(13.11ملم) و(5.64ملم) في الاشهر كانون الاول وكانون الثاني وشباط على التوالي والتي تساوي 29.43% من المجموع الكلي للامطار.حيث بينت الدراسة ان الخزان ضحل غير محصور في ترسبات العصر الرباعي وان خارطة شبكة الجريان تبين وبشكل رئيسي ان اتجاه جريان المياه الجوفية هي من الاجزاء الشمالية الغربية باتجاه الاجزاء الشرقيه والجنوبيه الشرقيه.

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Introduction

Study area is located in the Mesopotamian plain 92km away from Baghdad in the southwest direction. It occupies almost 30km^2 and occurs between Eastern Longitude (44° 25 00- 43° 45 00) and Northern latitude (32° 40 00-32° 20 00). Karbala city and its suburbs are located on the edged interim between the stable platform (Al-Salman sub-zone) and the unstable platform (Mesopotamian sub-zone)[1].The geological formation outcrop in Karbala City Are Tertiary and quaternary The sediments .Climate in the area stand up to envelops western desert climate according to climatological elements. The climate of Iraq is characterized by hot–dry summers and cold–rainy winters. Roughly 90% of the annual rainfall occurs between November and April. Climate in the area stand up to envelops western desert climate according to climatological elements. The climate of Iraq is characterized by hot–dry summers and cold–rainy winters. Roughly 90% of the annual rainfall occurs between November and April. Climate disparity change is one of the most important environmental cases to be studied and evaluated because of its important impact in several sectors such as water, human, agriculture, marine resources and others. Climate change may cause dryness intensity, increase flood risk, increase soil salinity, liquid waste, decrease groundwater level, etc [2]. Lack of water security and water scarcity affect large parts of the developing world. The climate is an important factor affecting the quality of ground water and change of their levels. The increment in the amount of rainfall leads to the filtration of water within the soil layers and thus the rise in groundwater levels, as well as the lessening of concentrations of some chemical elements in water, while increased summer temperatures lead to water evaporation, thereby lowering groundwater levels and increasing salts [3].

The target of this study is to determine climatic water balance by analyzing the climatic parameters of Karbala Meteorological Station for period (1976-2016).Water resources are decreasing continuously due to increasing demand for water for different purposes, prompting researchers to conduct hydrogeological studies and researches of water reservoirs and ways of investing them, groundwater is found in the rocky openings that carry water called aquifers [4].

The dominant factors in the climate, consist of: latitude, elevation, topography, proximity to large bodies of water, and atmospheric circulation [5]. The geological, morphological, and climatic factors which determine Hydrogeological conditions from during knowledge the spatial distribution of hydrogeological bodies and determine the groundwater recharge and discharge zones and the depth of the water table, while climatic conditions have determined the rate of groundwater recharge, the intensity of groundwater flow and water loss due capillary effects, evaporation and transpiration [6].

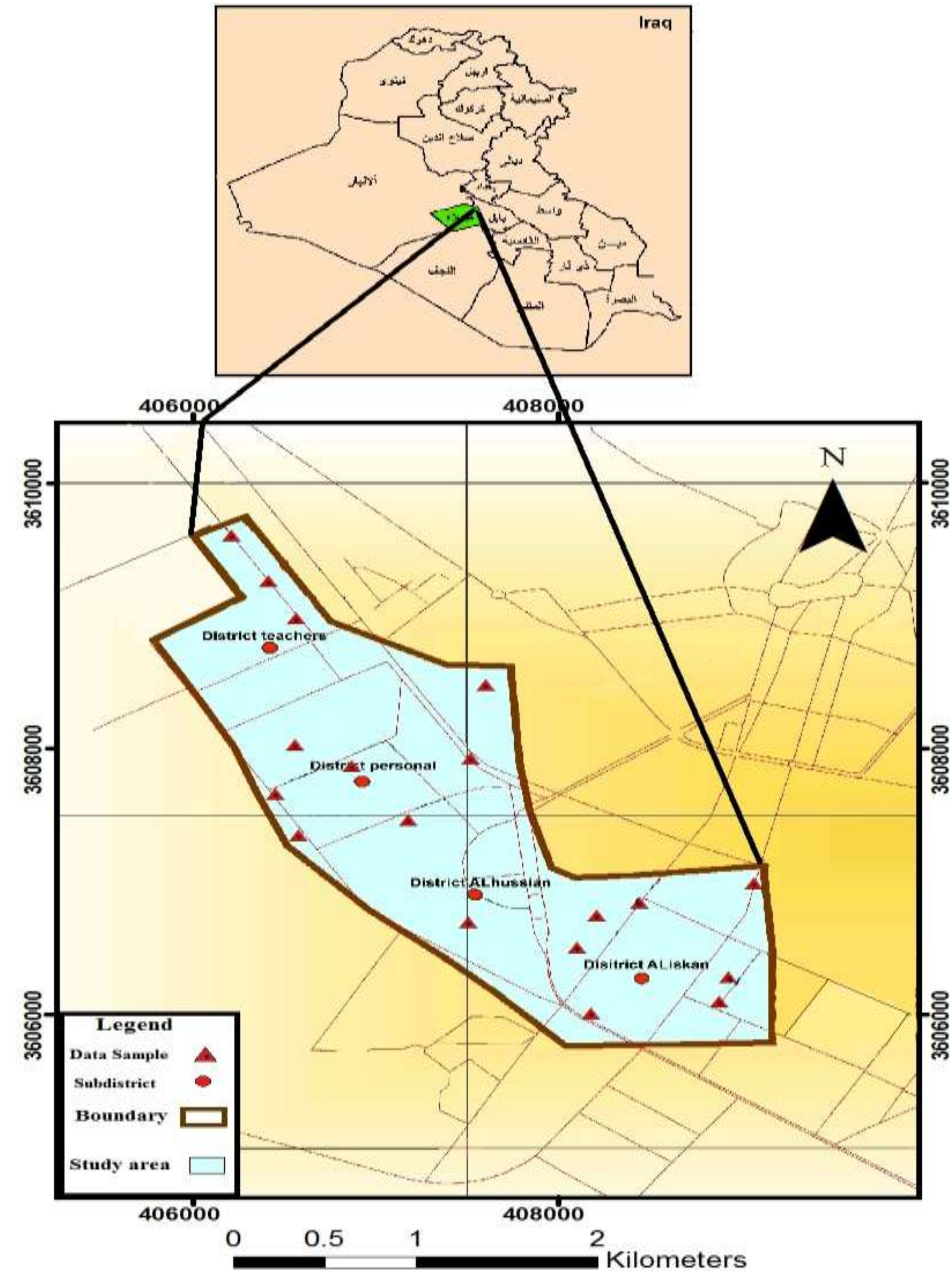

Figure 1-Location map of study area and well sites

1. Rainfall

Rainfall is of great importance in recharging groundwater aquifers especially the shallow ones where rainfall period in the area of study is limited to the months from October to January for the period from 1976 to 2016. The rainfall average recorded in March was 17.7 mm while the lowest average has been recorded in July and August as it were 0 mm Table-1. The total annual rainfall was (95.5 mm) for the period (1976-2016).

2. Relative Humidity

It is the ratio of the partial pressure of water vapor in the mixture saturated vapor pressure of water at the same temperature level. Relative humidity controls the rate of evaporation from water surfaces, soil and transpiration of plant leaves, where the greater the relative humidity, the less evaporation and transpiration.[6].The maximum and minimum mean monthly relative humidity are (72.921%) and (28.15%) in January and June respectively Table-1, and the mean annual is (46.756%)

3. Temperature

Temperature is an important factor in controlling the evaporation and evapotranspiration, where increased temperature will heat up the air. There is an important relationship between plant growth and temperature, where plants conform to certain temperature limits through which the can perform its activities. [7].In the study area the maximum and minimum mean monthly temperature are (36.81C◦) and (10.42C◦) in July and January respectively Table-1, while the mean annual of temperature is (24.19C◦).

4. Wind Speed

The diffuse wind direction in the studied area is north and northwest, while Western, Eastern, and Southern winds are of low frequency. From the monthly rate of wind speed, the highest rate is in July (4.0m/s), while in November it is lowest (1.8m/s), Figure-2(b). Winds are firmly connected with temperatures and air pressure, the wind speed increases with the high temperatures and thus increasing its power to evaporate soil water from the surface which helps in raising water to the surface. Through the study of the climatological factors, it is shown that temperatures increase annually and directly resulting in increasing the rates of annual evaporation and shortage of relative humidity and rainfall. [7].

5. Sunshine

Sunshine is an important component of climatic parameters as it effects relative humidity, evapotranspiration and temperature. The period of sunshine with the increasing of temperature will lead to the evaporation excess; thus affecting the amount of underground water recharge; in addition to affecting the actual evaporation proportions. [8].The maximum mean monthly sunshine in study area is (11.5 h/day) in July and minimum mean monthly is (5.1 h/day) in January Table-1, whereas the mean annual sunshine is (8.61 h/day). Sunshine is strongly connected to the seasons of the year, where the sun hours, in general, are longer in summer.

6. Evaporation

Evaporation is one of the significantly main climatological factors that influence environment and is strongly connected to the other factors (temperature, relative humidity, wind speed, air pressure, evaporation surfaces, and nature of evaporation surface). Evaporation affects groundwater chemistry as extreme evaporation leads to deposition of minerals such as gypsum, calcite, and chloride salts in soils. [9].The maximum mean monthly evaporation is (452.9 mm) in July but the minimum mean monthly is (61.831 mm) in January Table-1, while the total annual evaporation is (2828.6 mm). Different relationships are occurring between climatic variables. The process of evaporation is normally related with the temperatures, wind speed, where it increases as the temperature, wind speed increase, and inversely with the rainfall and the relative humidity. Figure-2(c), Table-1.

Evapotranspiration

It's a collect term of evaporation and transpiration, defines as the total loss of water through evaporation and transpiration from the soil plant system. Thornthwait (1948) assumed that the amount of water lost through evapotranspiration from a soil surface covered with vegetation is governed by climatic factors. Vegetation is governed by climatic factors also. According to this method, the potential evapotranspiration for a given month is based on the mean monthly air temperature of that month and on the annual air temperature. [9].There many factors affecting of evaporation that can be grouped into the followings:-soil factor, plant factor, atmospheric factor and cultural factor. Evapotranspiration was computed by Thornthwiat through making a number of experiments on different types of climate based on temperature only. Evapotranspiration is computed for each month in the year Figure-4.

Climatic Setting

The climate if the study area characterized as being continental, dry and relatively hot in summer ,cold and little rain in winter and believed to be influenced by the Mediterranean Sea climate. [10].

In addition to the remarkable difference in the temperature between day and night, the wind prevalent in the area is mostly north-northwest toward southeast accompanied by sand storms especially in summer and sometimes winds come from the south and south west [11].

The climatological variables are temperature, rainfall, evaporation, relative humidity, wind speed and sunshine depend on the climate data recorded at the Karbala meteorological station during the period (1976-2016) where values of the annual and monthly averages of these variables through 40 year shown in the Table-1. The climate of the study area was characterized with a summer dry and hot, which begins from May to September, with winter cold and rainfall, which begin from October to April. Temperature has directly relationship with evaporation and sunshine duration while the relationship is invers with rainfall and relative Humidity as shown in Figure-2(a, b, c)

Hydrogeology Setting

The formation and part of the formation or group of geological formations defined as a hydrogeological unit which have permeability and porosity and allow the movement of water with different velocities, and the hydraulic characteristic determination for these formations has great importance in the investment and management of groundwater [12].

Karbala is dependent on irrigation, drinking and agriculture on the rivers and streams of the Euphrates River, in addition to rainwater, which is an important factor in agriculture. The most famous of these rivers is the Husseiniya, the main source of water in Karbala. [12]

Two aquifers are distinguished within the west regions of Karbala plain which is adjacent to the Mesopotamia plain .The lower aquifer is within carbonate rocks, exists on a depth of (70-300) m between Karbala and Al- Najaf and also it extends within shithatha plain to the west of the region, while the upper aquifer is composed of sand and gravel sediments with small amount of clay, which form the desert surface region within the surrounded area between Karbala and Al-Najaf. [13] The thickness of the aquifer is about 70 m in the middle part of the area .probably there is a hydraulic connection between these two aquifers with the aquifer that lies within the Mesopotamia plain region. In general the Mesopotamia plain sediments are composed of sequence beds of clay, silt, sand and gravel. The water bearing beds are composed mainly of sand and gravel mixtures which are range between small and large extensions [14].Generally ground water flows direction is from west to east and southeast. The aquifer is recharged from the elevated desert plain in the west, in addition to rainfall infiltration.

The discharge area is represented by an aligned springs located east of the study area and the Razazah lake in addition to the Euphrates River and other depressions and valleys that spread in the region.

Table1-Monthly averages of the climate elements for the period (1976-2016) of Karbala meteorological station.

Months	Rainfall (mm)	Relative Humidity (%)	Temperatures (C°)	Wind speed (m/sec)	Sunshine (h/day)	Evaporation (mm)
Oct.	4.0	44.975	25.83	2.0	8.1	200.43
Nov.	13.5	61.538	17.35	1.8	6.8	100.0
Dec.	15.3	72.333	11.97	1.9	6.4	64.257
Jan.	16.3	72.921	10.42	2.1	5.1	61.831
Feb.	14.0	60.974	13.23	2.6	7.4	94.19
Mar.	17.7	51.053	17.76	3.0	8.0	167.4
Apr.	10.7	41.923	24.16	3.1	8.9	236.74
May	3.6	33.725	29.939	3.1	8.8	324.4
June	0.1	28.15	34.373	3.9	11.2	413.025
July	0.0	28.308	36.81	4.0	11.5	452.9
Aug.	0.0	30.513	36.09	3.3	11.1	409.89
Sep.	0.3	34.667	32.44	2.4	10.4	303.4
Average		46.756	24.19	2.76	8.61	
Total	95.5					2828.6

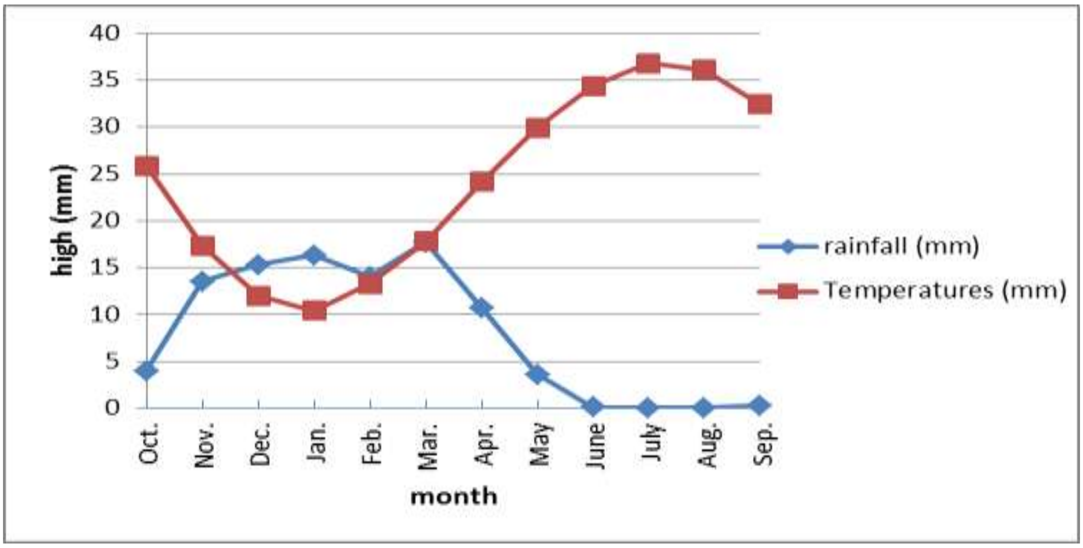

Figure 2(a)-Relationship between rainfall and temperature.

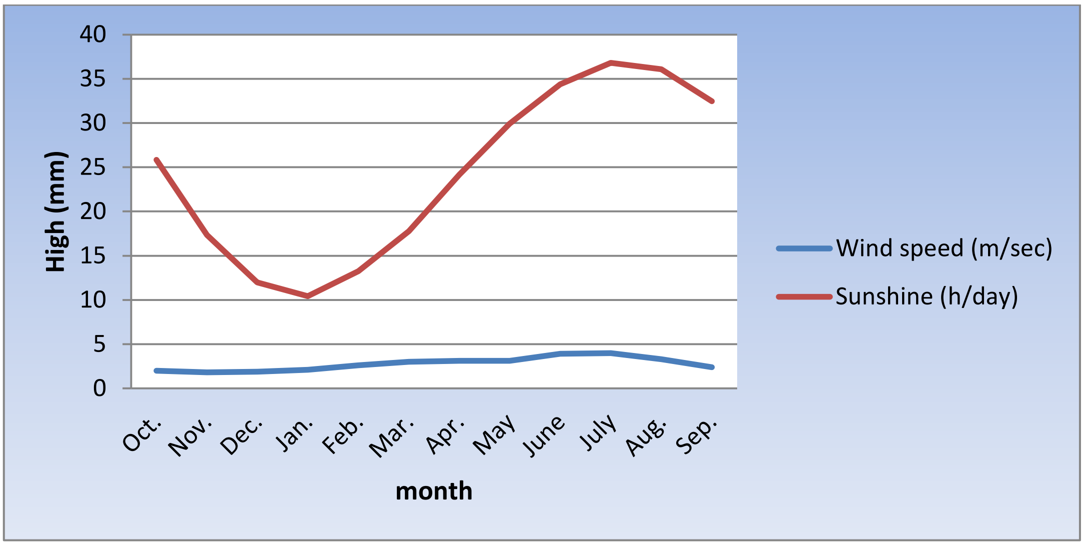

Figure 2(b)-Relationship between Wind speed and Sunshine.

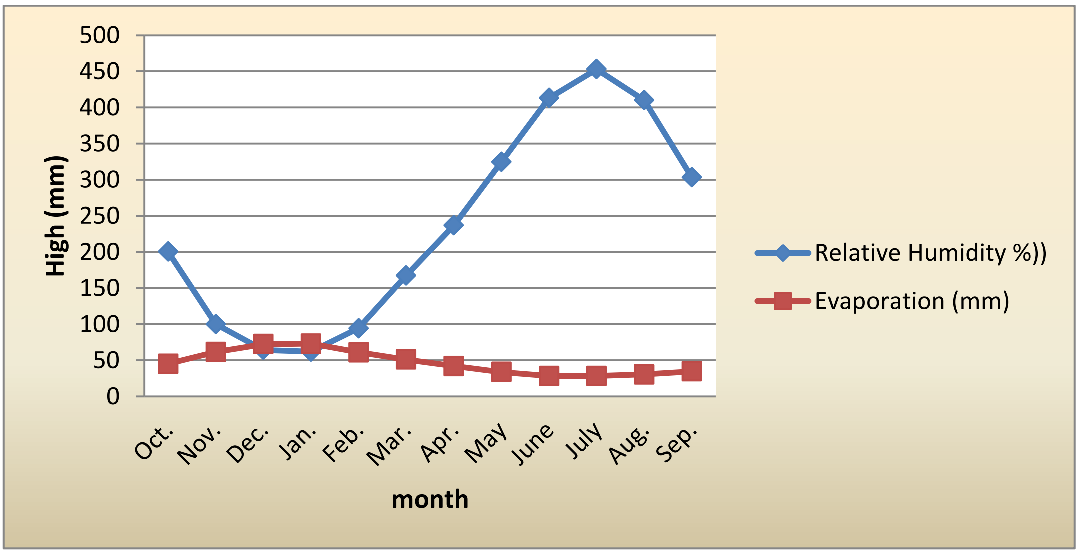

Figure 2(c)-Relationship between Relative Humidity (%) and Evaporation.

Materials and methods

Table-1 shows the monthly averages of climatic parameters for forty years and the relationship between climatic parameters in area study show in Figure-2.

From Karbala meteorological station the climatic data of the study area was determined for the period (1976-2016) with calculation the mean monthly climatic parameters. Values of potential evapotranspiration were determined by utilizing Thornthwiate1948 equation. Lerner 1990 method was applied to calculation water balance in the study area [15].Type of climate in the study area was determined by applying five climate classification (Thornthwiate1948, Lerner 1990, Al-Kubaisi 2004, Mather1974,Kettaneh and Gangopadhyaya,1974).Climate elements used to calculate the water balance of the study area are temperature, precipitation, evaporation, relative humidity, wind speed and sunshine, which taken from the Karbala meteorological station for the period from 1976 to 2016 with monthly averages as shown in Table-1.The Thorenthwait method was used to estimate the value potential Evapotranspiration (PE), which depends on the air temperature (Tc), and then calculate the value of water surplus and water deficit in the study area by depending on this value. X

Results and discussion

1. Climate

The average rainfall recorded in March was17.7mm while the lowest average has been recorded in July and August as it were 0 mm Table-1. The total annual was (95.59mm) for the period (1976-2016).

Values of Potential evapotranspiration were calculated theoretically at assumption the number of days in the month 30 days and the number of hours the sunshine 12 hours per day, they are not compatible with reality. Therefore, can be using equation (5) to obtaining values of the corrected potential evapotranspiration as shown in Table-2, by using equations below:

PE = $16(\frac{10\,t}{J})^{a}$ ……………………………….(1)

J= $\sum_{j=1}^{12} j$ ……………………………………………….(2)

j = $(\frac{t}{5})^{1.514}$ ……………………………………………….(3)

a =0.016 J + 0.5 ....(4)

Where:

PE: potential evapotranspiration (mm), t: Mean monthly air temperature (C°), J: Annual temperature parameter(C°), j: monthly temperature parameter (C°), a: Constant (2.53).

PEc = PE ×K (K=DT/360) ....(5)

Where:

PEc: Corrected potential evapotranspiration (mm), PE: potential evapotranspiration (mm),

K: Correction factor, D: number of days in the month, T: monthly average sunshine duration (hour/day).

Table 2-PEC values for the period (1976-2016) by Thornthwait (1948) method.

Months	t (C°)	j=(tn/5)$^{1.514}$	DT/360	PEx (mm)	PEc (mm)	Epan (mm)
Oct.	25.83	12.01	0.69	86.91	59.96	200.43
Nov.	17.35	6.57	0.56	29.56	16.55	100.0
Dec.	11.97	3.74	0.55	10.81	5.94	64.257
Jan.	10.42	3.03	0.43	7.42	3.19	61.831
Feb.	13.23	4.36	0.59	14.17	8.36	94.19
Mar.	17.76	6.81	0.68	31.49	21.41	167.4
Apr.	24.16	10.85	0.74	72.51	53.65	236.74
May	29.939	15.02	0.75	129.67	97.25	324.4
Jun.	34.373	18.51	0.93	188.53	175.33	413.025
Jul.	36.81	20.54	0.99	226.98	224.71	452.9
Aug.	36.09	19.93	0.95	215.15	204.39	409.89
Sep.	32.44	16.96	0.86	161.16	138.59	303.4
Total	290.398	J= 138.33	DT/360	1174.36	1009.33	2828.6

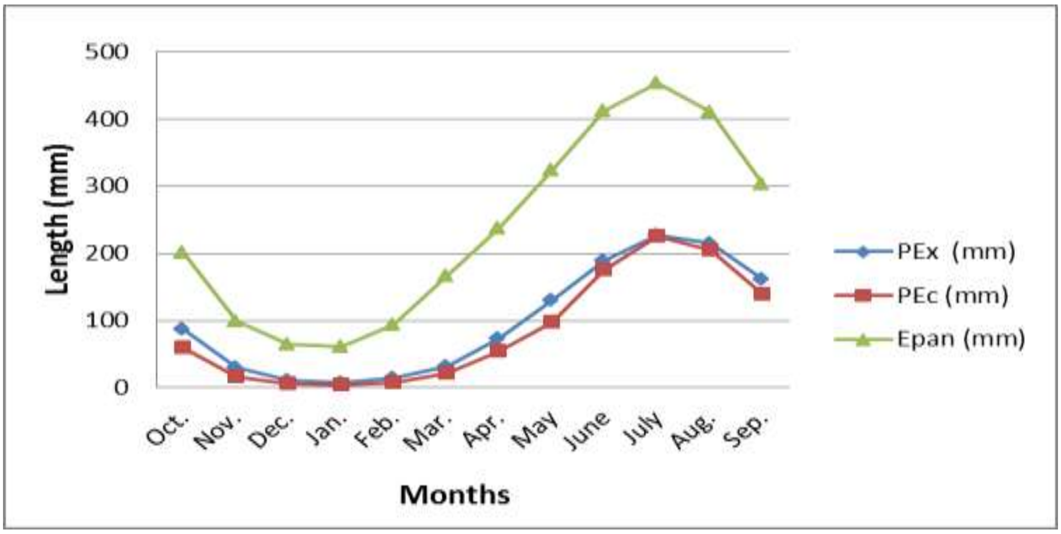

Figure 3-Graph Show evaporation, PEX and PEC correlation during months for period (1976-2016) in Karbala City.

Water Deficit (WD) & Water Surplus (WS):

The water surplus is mean increasing the values of rainfall up the values of corrected evapotranspiration through given months in the year (WS = P >PEC) [15]. While the Water Deficit is the decreasing of rainfall values related to the values of corrected evapotranspiration through the residual months in the same year (WS = P <PEC). Actual Potential Evapotranspiration (PEX) can be derived as following:

$WS = P - PEc$ ………………………………………………………………………..….... (6)

$PEc = PEx$, when $P > PEc$

$WD = PEc - P$ …………………………………………………………………….…..... (7)

$P = PEx$, when $P < PEc$

Where:

WS: water surplus (mm), WD: water deficit (mm), P: rainfall (mm), PE: potential evapotranspiration (mm), AE: actual Potential evapotranspiration (mm).

Values for the Water surplus range from 13.11mm in January to 5.64mm in February with total annual is 94.87mm as shown in Table-3.

The value of WS can be used to determine the recharge volume for groundwater after calculating runoff. In the period of water surplus, rainfall values are more than the corrected evapotranspiration, thus the corrected evapotranspiration values are equal the values of actual evapotranspiration. Water surplus is mean recharge of groundwater plus surface runoff after saturation of the soil. Moisture of the soil was depleted either through plant or Evaporation from soil [16]. Thus it was taken in account missing portion of water which is potential evapotranspiration Figure-3. In the period of water deficit, rainfall values are less than values of correct evapotranspiration; therefore rainfall values are equal actual evapotranspiration values. The values of monthly averages PEX, WD and WS are illustrated in Table-3. As follows:

Table 3-The monthly values for rainfall, Corrected potential evapotranspiration and water surplus (1976-2016)

Month	P (mm)	PEc(mm)	APE(mm)	WS(mm)	WD(mm)
Oct.	4.0	59.96	4.0	0	55.96
Nov.	13.5	16.55	16.55	0	3.05
Dec.	15.3	5.94	5.94	9.36	0
Jan.	16.3	3.19	3.19	13.11	0
Feb.	14.0	8.36	8.36	5.64	0
Mar.	17.7	21.41	17.7	0	3.71
Apr.	10.7	53.65	10.7	0	42.95
May	3.6	97.25	3.6	0	93.65
Jun.	0.1	175.33	0.1	0	175.23
Jul.	0.0	224.71	0.0	0	224.71
Aug.	0.0	204.39	0.0	0	204.39
Sep.	0.3	138.59	0.3	0	138.29
Total	95.5	1009.33		28.11	941.94

Where:
WS: Water surplus (mm).
WD: Water deficit (mm).
PEX: Actual Evapotranspiration (mm).

Total value of annual water surplus equal (28.11mm) from total value of the rainfall, it's confined between (December-February) due to rainfall is more than corrected evapotranspiration (PEc). Annual rainfall and (WS) value used to calculate the ratio of water surplus as the equations:

$WS\,\% = WS/P \times 100$ ……………………………………………………………...….(8)

$WS\% = 28.11 / 95.5 \times 100 = 29.43\%$

$WD\% = 100 - WS\%$ …..……………………………………………………………...(9)

$WD\% = 100 - 29.43\,\% = 70.57\,\%$

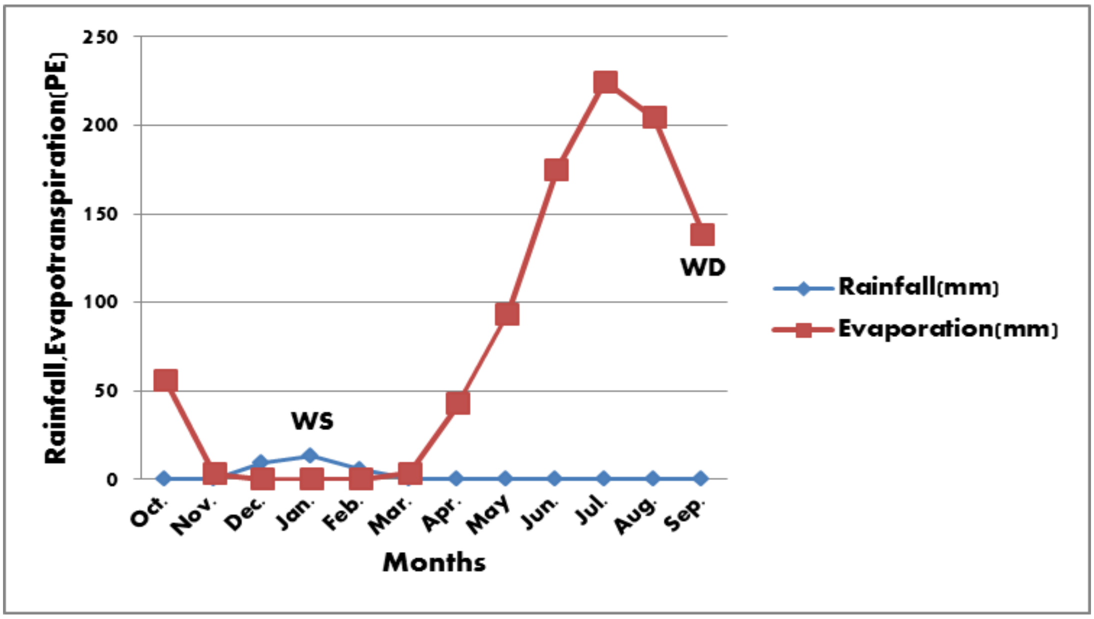

Figure 4-Graph show water surplus and water deficit for study area during months for period (1976-2016) in Karbala City.

Classification of the Climate

Climate is classified according to the different targets, which are, the variation of the climatic elements on which they depend, and the difficulty to gather them in one classification [16].There are several methods in determining the type of the prevailing climate depending on the determination of the number of coefficients including moisture, aridity and humidity factors such as:(Mather, 1974), and (Al-Kubaisi,2004),(Kettaneh and Gangopadhyaya,1974).

Various techniques (methods) are used for classification of climate including the difference elements of climate, three classifications will be used to determine the type of climate in West Karbala as following:

Classification was proposed by (Kettaneh and Gangopadhyaya, 1974) based on humidity index (H.I) which indicate the ratio of rainfalls to corrected potential evapotranspiration, as illustrated in (Tab.4,5).

$H.I. = P/PEc$ ………………………………………………………………………..(10)

Where:

H.I: Humidity index.

P: rainfall (mm).

PEC: Corrected potential evapotranspiration (mm).

Table 4-Calculation of Humidity index (H.I) According to classification of (Kettaneh and Gangopadhyaya,1974)in Karbala City for period (1976-2016).

Climatic Zone	**Range HI**
Humid	HI ≥ 1
Moist	2HI > 1 > HI
Moderate to Dry	10 HI > 1 > 2HI
Dry	10 HI ≥ 1

Table 5- Calculation of Humidity index (H.I) According to classification of (Kettaneh and Gangopadhyaya, 1974) in Karbala City for period (1976-2016).

Months	**P (mm)**	**PEc (mm)**	**H.I**	**Kettaneh and Gangopadhyaya,1974**
Oct.	4.0	59.96	0.066	Dry
Nov.	13.5	16.55	0.815	Moist
Des.	15.3	5.94	2.575	Humid
Jan.	16.3	3.19	5.109	Humid
Feb.	14.0	8.36	1.674	Humid
Mar.	17.7	21.41	0.826	Moist
Apr.	10.7	53.65	0.199	Moderate to Dry
May	3.6	97.25	0.037	Dry
Jun.	0.1	175.33	0.0005	Dry
July.	0.0	224.71	0	Dry
Aug.	0.0	204.39	0	Dry
Sep.	0.3	138.59	0.002	Dry

That four classification is for (Mather, 1974 [17]) were the climate type is based on the value of climate index to find three classes which related to the rainfall and evapotranspiration as in the following equation:

$CI = [(P/PE) - 1] * 100$ ………………………………………………………… (11)

Where:
CI = Climate index
P = Rainfall
PE = Potential evapotranspiration.

The positive value of the (C.I) is indicating to humid climate while Negative value indicates to dry climate. This classification refer to that the climate type is arid in study area due to the climate index value (C.I) = - 90.53, as exhibited in Table-6.

Table 6- Classification of the climate in the study area, according to (Mather, 1974 [17]) in Al-Karbala City for period (1976-2016).

Claimant Type	Range of C.I	C.I in studied area
Dry-sub humid	0.0 to -33.3	- 90.53
Semi-Arid	-33.3 to -66.7	
Arid	-66.7 to -100	

The classification suggested by (Al-Kubaisi,2004) is used to determine the climate type and the aridity index by using the yearly dryness treatment depending on the amount of rainfall and temperature according to the following equation:

$AI - 1 = (1.0 \times P) / (11.525 \times t)$ $(t\ not\ equal\ zero)$ ………………………………… (12)

$AI - 2 = 2p / t$ ………... ………………………………………………………..(13)

Where:
AI: Aridity index
P: Annual rainfall (mm)
t: Annual Temperature (C°).

Value of (AI-1) considered the classification of prevailed type of climate, whereas (AI-2) value considered the classification after amendment as shown in Table-7. [16]

$AI - 1 = (1 \times 95.5) / (11.525 \times 24.8) = 0.334$

$AI - 2 = 2 * 95.5/24.8 = 0.788$

According to this classification the values of (AI-1) and (AI-2) indicates that the type one of climate is Sub arid to arid and arid in type two Table-7.

Table 7-Classification of the climate according to (Al-Kubaisi, 2004) in Karbala City for period (1976-2016) [15]

<table>
<tr><th colspan="2">Type.1</th><th>Evaluation</th><th>Type.2</th><th>Evaluation</th></tr>
<tr><td colspan="2" rowspan="4">AI-1>1.0</td><td rowspan="4">Humid to moist</td><td>AI-2>4.5</td><td>Humid</td></tr>
<tr><td>2.5 <AI-2< 4.0</td><td>Humid to moist</td></tr>
<tr><td>1.85<AI-2<2.5</td><td>Moist</td></tr>
<tr><td>1.5<AI-2<1.85</td><td>Moist to sub arid</td></tr>
<tr><td colspan="2" rowspan="2">AI-1<1.0</td><td rowspan="2">Sub arid to arid</td><td>1.0 ≤ AI-2<1.5</td><td>Sub arid</td></tr>
<tr><td>AI-2<1.0</td><td>Arid</td></tr>
<tr><td>In the study area</td><td>AI.1=0.334</td><td>Sub arid to arid</td><td>AI.2=0.788</td><td>Arid</td></tr>
</table>

Conclusions

- By conducting analyzes and calculating the annual averages of the climatic parameters it is shown that the total annual rainfall is (95.5 mm), evaporation is (2828.6mm), relative humidity is (46.756%), sunshine (8.61 h/day), temperature (24.19C◦) and wind speed (2.76m/sec).
- There is water surplus in study area of (9.36mm), (13.11mm), (5.64mm) in December, January and February respectively, that type of climate in the study area is arid. The water surplus (WS) was calculated equal to 28.11mm, equal to 29.43% from total annual rainfall.
- Through comparison between of the annual rainfall rate for each year from 1976 to 2016 with total annual rainfall (95.5mm), this means that the climate of the region tends to drought.
- Climate of study area is concept as an arid according to (Al-Kubaisi,2004,Ketanah and Gangopadhyaya,1974, Mather, 1974) climatic classification.
- The direction of the groundwater movement is from the recharge area (west) to the discharge area (east and southeast). The aquifer is recharged from the elevated desert plain in the west, in addition to rainfall infiltration.

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