Iraqi Journal of Science, 2022, Vol. 63, No. 10, pp: 4328-4341
DOI: 10.24996/ijs.2022.63.10.19

ISSN: 0067-2904

Climatic Water Balance Comparison for Selected areas in The Middle of Iraq

Samah Abdullah Muhammad* , Moutaz Al-Dabbas
Department of Geology, College of Science, Baghdad University, Baghdad, Iraq.

Received: 10/6/2021 Accepted: 17/11/2021 Published: 30/10/2022

Abstract
The climate parameters annual rainfall and average mean temperature are investigated from 2000 to 2019 for Kut, Hilla and Iskandaryia. Evidence of climate change is noticed by decreasing the mean annual rainfall and relative humidity with an increase in the annual mean temperature. The climate water balance has been calculated. Due to high temperature, increased evaporation, and low precipitation rates, there was a large water deficit. The total water surplus in the Kut area is 32.86 mm from November to February, and in Hilla and Iskandaryia is 20.4 and 27.8 mm from December to February, respectively. The climate classification for the three stations was semi-dry to dry climates. The region has a significant water deficit of up to 79.6 % of the total rainfall values indicated in Hilla station. Climate change has affected the locations near meteorological stations such as Kut, Hilla and Alexandria. All the studied climatic variables imprint water surplus or water deficit with slight changes within each geographical area.

Keywords: climate change, water balance, Kut, Hilla and Iskandaryia stations, Iraq.

مقارنة موازنة المياه المناخية لمناطق مختارة في وسط العراق

سماح عبدالله محمد* , معتز الدباس
قسم الجيولوجي , كلية العلوم , جامعة بغداد , بغداد , العراق .

الخلاصة
تم فحص المعلمات المناخية لهطول الأمطار السنوي ومتوسط درجة الحرارة من 2000 إلى 2019 في الكوت والحلة والإسكندرية. تُلاحظ أدلة على تغير المناخ من خلال تقليل متوسط هطول الأمطار السنوي والرطوبة النسبية مع زيادة متوسط درجة الحرارة السنوية. تم حساب توازن الماء في المناخ. بسبب ارتفاع درجة الحرارة وزيادة التبخر وانخفاض معدلات هطول الأمطار ، كان هناك عجز كبير في المياه. بلغ إجمالي فائض المياه في منطقة الكوت 32.86 ملم من نوفمبر إلى فبراير ، وفي الحلة والإسكندرية 20.4 و 27.8 ملم من تشرين الثاني الى شباط على التوالي. كان التصنيف المناخي للمحطات الثلاث شبه جاف إلى مناخ جاف. تعاني المنطقة من عجز مائي كبير يصل إلى 79.6٪ من إجمالي قيم هطول الأمطار المشار إليها في محطة الحلة. أثر تغير المناخ على المواقع القريبة من محطات الأرصاد الجوية مثل الكوت والحلة

*Email: samahabdullah919191@gmail.com

والإسكندرية. جميع المتغيرات المناخية المدروسة لها أثر على فائض المياه أو عجز المياه مع تغيرات طفيفة في كل موقع جغرافي.

Introduction

Iraq is currently facing a severe water shortage problem, and climate change will affect the hydrological cycle with changes to recharge, groundwater levels and resources and flow processes. These changes will impact the concentration of the total dissolved solids (TDS) in both surface water and groundwater [1 and 2]. Changes in temperature, the amount and distribution of precipitation, and atmospheric carbon dioxide concentrations will affect agriculture through changes in soil and water quality [3]. The amount of water especially freshwater is limited in Iraq as it has a semi-arid climate [3]. More than 90% of the annual rainfall occurs between November and April. Moreover, the temperature in Iraq ranges from 40 to 50°C in the summer season (June, July, August and sometimes September) to freezing point (0.0C) in the winter season (December, January and February).

The studies which address the whole hydrological cycle show likely changes in the hydrochemical characteristics and the hydraulic properties of groundwater [3, 4, and 5]. Climate change poses uncertainties to the supply and management of water resources. Understanding the impact of climate change on the hydrological cycle is essential for ensuring the sustainability of future water resources. In this research, the chosen region is for three meteorological stations, Kut, Hilla, and Iskandaryia, in Middle Iraq (Figure 1). The common climate of these areas is sub arid to arid [6 and 7]. The available climatic parameters data were collected and analyzed from NASA agency [8].

The study aims to show the climatic change consequences in Iraq by investigating the climate data, temperature, rainfall parameters for Kut, Hilla, and Iskandaryia meteorological stations for the period from year 2000 – 2019 and to investigate the climatic data to determine the climate type, water deficit, water surplus periods and climate water balance for the same period.

The study aims to clarify the effects of climate change in Iraq by studying the climatic data recorded in meteorological stations in Kut, Hilla and Alexandria for the period from 2000 to 2019, and determine the type of climate, water deficit, and periods of water surplus.

The Meteorological Stations

Three meteorological stations were chosen. The first station (Kut - Waist Governorate) is located southern Baghdad, between longitude ($44^0\,18'\,00'' - 44^0\,25'\,30''$) east; and latitude ($33^0\,05'44'' - 33^0$ 15' 44’’) north. The second station (Hilla- Babylon Governorate) is the capital of Babylon governorate, between longitude ($44^0\,25'\,30'' - 44^0\,39'\,30''$) east and latitude ($32^0\,12'44'' - 32^0$ 24' 00’’) north. The third station (Iskandaryia - Babylon Governorate) is located southern Baghdad between longitude ($44^0\,20'\,33'' - 44^0\,25'\,33''$) east; and latitude ($33^0\,05'\,44'' - 33^0$ 15’ 44’’) north (Figure 1). Water resources are mainly controlled by the climate conditions. Accordingly, global warming will have evolving impacts on water resources and poses important challenges for sustainable development. Therefore, it is vital to focus on potential implications of climate change on Iraq water resources through studying and analyzing the available climate parameters.

Geology of the study area

The study area mainly lies within the alluvial plain of recent sediments (Quaternary period of Pleistocene –Holocene) [9 and 10]. The study area includes mainly Pliocene to Miocene age characterizing by flood plains deposits which consist of thin layers of fine sand and silt, clay and silty clay with succession layers of clay, sand and shale, and gravel within deeper layers [9 and 10]. Babylon Governorate within the study area characterized by plain surface with gentle gradient around 22 cm/km. The direction of the slope in the area is from NW toward E and SE. Some isolated sand dunes are there in southern parts of Hilla city [9 and 10].

Materials and Methods

Three representative stations were selected for the analysis of climatic parameters. Al-Kut station (Wasit) was chosen to represent the eastern parts of the Mesopotamian plain and part of the foothills of Iraq and Hilla (Babylon), and Iskandaryia station (between Baghdad and Babylon) was chosen to represent the flood plain of Mesopotamia in central Iraq. The average annual temperature, average annual relative humidity and average annual precipitation were analyzed using available data for about 19 years from the records of the studied climatic elements (from the years 2000 - 2019) [8].

The climate data (temperature and rainfall) were analyzed to investigate the water balance with determination of the mean monthly climatic parameters of sunshine, wind speed, relative humidity %, precipitation, evaporation, and temperature (Tables 1, 2 and 3).

Values of potential Evapotranspiration were determined by utilizing Thornthwiat 1948 [11], and Lerner et al., 1990 [12], methods. These methods were applied to compute water balance in the study area.

Type of climate was determined according to two climate classifications of Mather, 1974[13] and Brown and Cocheme, 1973 [14].

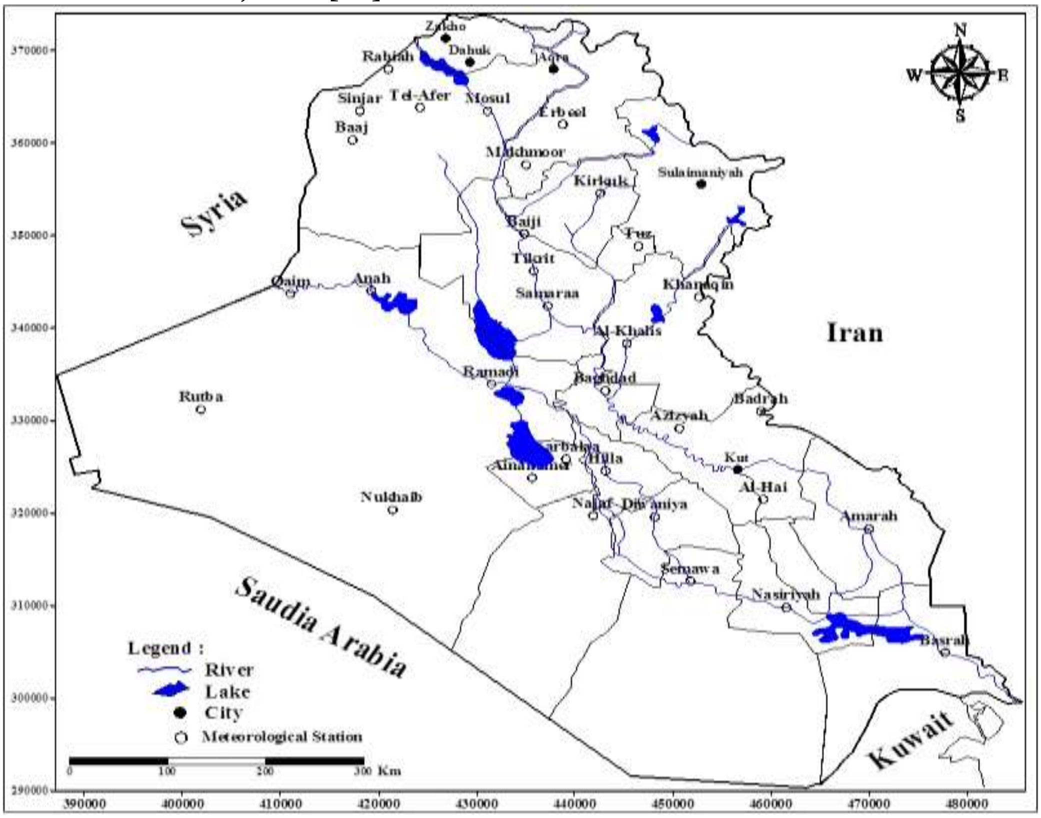


Figure 1: Location map of the study areas [4].

Table 1: Monthly averages of the climatic elements for the years 2000 to 2019 in Kut station [8].

Months	Rainfall (mm)	Relative Humidity (%)	Temperature (◦C)	Wind speed (m/sec)	Sunshine (h/day)	Evaporation (mm)
OCT	3.05	26.52	28.4	3.2	8.4	109.5
NOV	17.49	43.84	19.3	3.1	7.2	106.2
DEC	19.25	53.8	13.7	3.1 1	6.8	99.8
JAN	23.00	57.5	12.8	3.2	6.7	94.7
FEB	10.2	51.4	14.7	3.3	7.8	121.3
MAR	11.2	40.1	20.3	3.5	7.9	220.4
APR	9.70	33.14	25.7	3.5	8.9	299.3
MAY	2.55	23.9	32.8	3.7	9.9	351.7
JUN	0.01	16.3	36.7	4.8	12.2	404.7
JUL	0.00	15.8	38.4	4.9	12.6	475.6
AUG	0.00	16.1	37.8	4.3	11.6	409.30
SEP	0.27	18.6	33.9	3.7	10.6	244.6
Total	96.7					2841.1
Average		33.08417	24.99	3.66	9.19	

Table 2: Monthly averages of the climatic elements for the years 2000 to 2019 in Hilla station [8].

Months	Rainfall (mm)	Relative Humidity(%)	Temperature (C◦)	Wind speed (m/sec)	Sunshine (h/day)	Evaporation (mm)
OCT	8.69	25.57	27.13	3.24	9.35	177.00
NOV	16.24	42.62	18.38	3.17	7.20	96.00
DEC	14.67	52.12	13.71	3.23	8.77	63.00
JAN	19.35	55.74	11.84	3.30	5.72	54.00
FEB	12.47	48.89	13.83	3.39	7.75	82.00
MAR	13.81	37.10	17.51	3.60	8.17	135.00
APR	13.05	30.33	25.03	3.60	8.92	202.00
MAY	1.50	22.07	30.44	3.79	10.91	297.00
JUN	0.10	15.41	34.85	4.92	12.50	333.00
JUL	0.00	15.06	35.36	5.03	12.75	396.00
AUG	0.00	15.37	34.81	4.31	11.56	351.00
SEP	0.10	17.86	30.89	3.74	10.56	265.00
Total	99.98					2451.00
Average		31.51	24.48	3.78	9.51	177.00

Table 3: Monthly averages of the climatic elements for the years 2000 to 2019 in Al-Iskandaryia station [8].

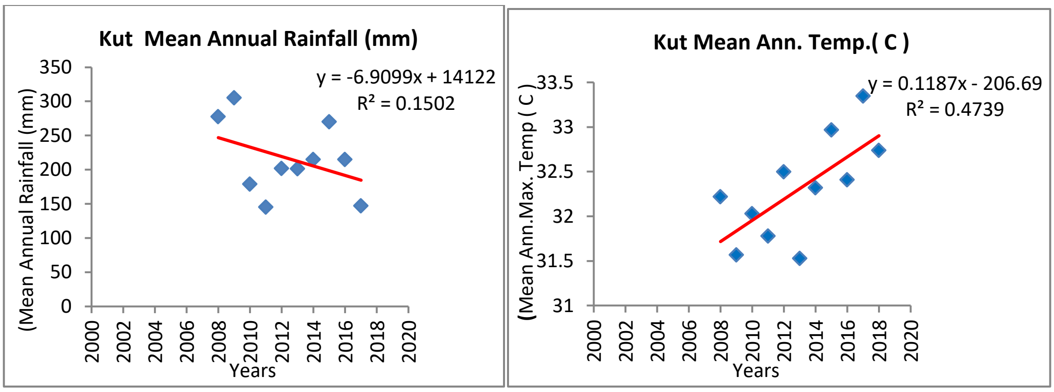
Months	Rainfall (mm)	Relative Humidity(%)	Temperature (C◦)	Wind speed (m/sec)	Sunshine (h/day)	Evaporation (mm)
OCT	3.25	26.52	27.04	3.18	8.35	164.50
NOV	19.99	43.84	19.23	3.06	7.20	83.20
DEC	19.25	53.81	12.65	3.1	6.77	59.40
JAN	23.00	57.49	12.77	3.18	6.72	54.70
FEB	11.21	51.42	14.72	3.23	7.75	81.37
MAR	11.21	40.13	20.22	3.45	7.88	142.42
APR	9.70	33.14	25.66	3.45	8.92	191.30
MAY	2.55	23.92	28.81	3.65	9.91	265.70
JUN	0.01	16.23	33.72	4.78	11.98	334.70
JUL	0.00	15.84	36.36	4.91	12.61	355.60
AUG	0.00	16.09	35.75	4.25	11.56	309.30
SEP	0.17	18.58	32.96	3.7	10.63	244.60
Total	100.33					2286.79
Average		33.08417	24.99	3.66	9.19	

Results and Discussion

A. Climatic parameter analysis:

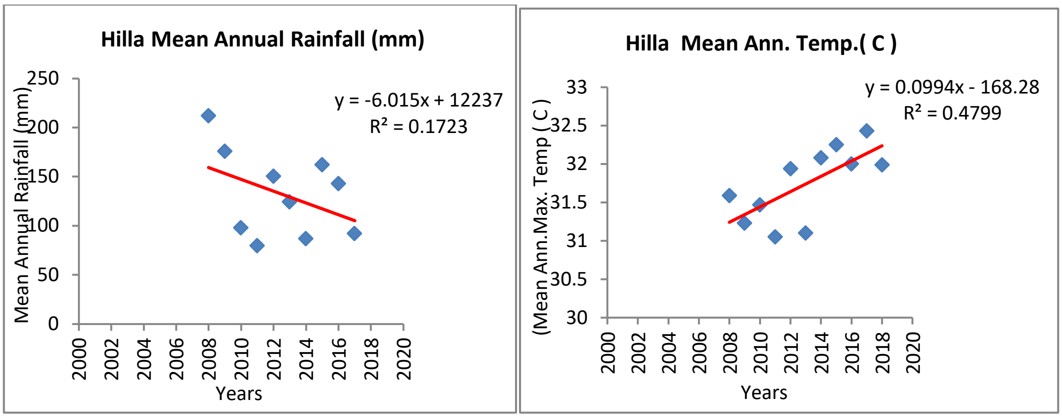
The frequency curves of annual rainfall (mm) (A), and average annual mean temperature (C^o) were studied. The annual relative humidity % and the annual rainfall (mm) have inverse relation with time, while the reverse is true for the temperature in all the three stations (Figures 2 ,3 and 4).

Such results are in accordance with Adamo, et al., 2020 [4], and Majeed, et al., 2020,[15] conclusions that Iraq face sever global climate change impacts.



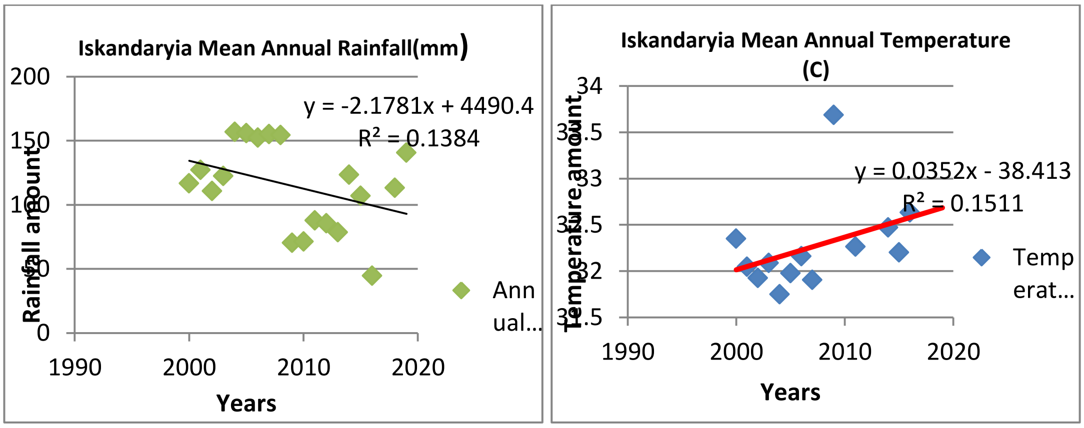
(A) **(B)**

Figure 2: The trend of Annual Rainfall (mm) (A), Annual Mean Temperature (C^o) (B), at Kut during 2000–2019.



(A) **(B)**

Figure 3: The trend of Annual Rainfall (mm)(A), Annual Mean Temperature (C^{o}) (B) and for Hilla during 2000–2019.



(A) (B)

Figure 4: The trend of Annual Rainfall (mm)(A), Annual Mean Temperature (C^{o}) (B) and for Iskandaryia during 2000–2019.

B. Water Availability Climate Elements

Water availability elements include rainfall and relative humidity, essential elements in the climate classification and climate water balance.

Rainfall (mm):

Rainfall is one of the significant climatic factors, where no rain characterizes the rainfall period in Kut, Hilla and Al-Iskandaryia stations during July and August and few drops in June and September, with rainy months from October to May. Rainfall impacts the groundwater amount and soil moisture and is a vital climate parameter in the climate water balance and recharging water to the groundwater. The monthly rainfall average for the period (2000-2019) is shown in Tables 1, 2, and 3. The maximum value of rain was noticed in January for the three stations.

Relative Humidity RH (%):

Relative humidity % is the amount of water vapour absorbed by air, which depends on the air temperature of air and water. Relative humidity % is correlated inversely with the temperature, the evaporation and the wind speed; and directly with the rainfall. The highest monthly average of relative humidity % for the three stations appeared in January (Tables 1, 2 and 3).

Water Losses Climate Elements

The essential elements of water losses are temperature, evaporation, sunshine, and wind speed.

Mean Air Temperature (C^o):

Temperature is variable periodically in the water year and is a vital parameter for climate water balance. Temperature represents an essential factor in evaporation and Evapotranspiration, which results from warming air. Temperature is correlated inversely with the rainfall and the relative humidity and positively with the evaporation. The monthly temperature averages for the period (2000-2019) indicate that the highest temperature average appeared in July, while the lowest appeared in January for the three stations.

Mean Monthly Evaporation (mm) :

Evaporation is a crucial element in water balance and the hydrological cycle. It is one of the water loss parameters connected with other factors temperature, wind speed, sunshine, and area of evaporation surfaces. The water quality and quantity are affected by evaporation. High evaporation leads to the deposition of salts in the soil like the evaporate minerals. Evaporation is correlated inversely with rainfall and relative humidity and positively with temperature. The highest monthly evaporation averages appeared in July, while the lowest appeared in January for the three stations.

Sunshine (h/day):

Sunshine is a solar number of hours in one day, and hour brightness functions as a solar influence on the temperature and relative humidity and affects the actual Evapotranspiration. It is one of the climate elements that significantly affects the amount of evaporated water. Sunshine is strongly connected to the year's seasons, where the sun hours, in general, are longer in summer and the increase in sunshine hours means an increase in temperature and evaporation. The highest monthly averages of sunshine are indicated during July, while the lowest appeared in January for the three stations.

Wind Speed (m/sec):

The wind has a significant role in the amount of evaporation. The rate of evaporation increases with the excess of the wind speed. The wind is firmly connected with temperatures and air pressure. The wind speed increases with the high temperatures. The most prevailing wind direction in the studied areas is northwest during most of the season. The maximum values of monthly averages wind speed appeared in July, while the minimum appeared in November.

Potential Evapotranspiration (PE):

The potential Evapotranspiration (PE) is an essential indicator in the budget. Water evaporation is the maximum possible surface water or the amount of evaporation resulting from the saturated ground with water covered with dense vegetation. Actual Evapotranspiration is the real amount of evaporation and transpiration of the surface under climatic factors. Actual water evaporation is very important in determining the factors of water balance in an area.

Potential evaporation (PE) is a key budget indicator. Water evaporation is the amount of evaporation produced from the saturated ground with water covered with dense vegetation. Actual Evapotranspiration is the true amount of evaporation and transpiration under climatic factors. Actual water evaporation is significant in determining the water balance factors in an area.

Thornthwiate (1948) [8] assumes a strong correlation between the mean temperature and other variables such as wind speed and sunshine. The correlation is shown in the following Wilson (1971) equation [16]:

$$PEx = 16\ [10tn / J]^{a}\ \text{mm/month} \qquad \text{…… 1}$$

$$J = \sum_{j-1}^{j=n} j \quad \text{for the 12 months} \qquad \text{…… 2}$$

$$j = [tn / 5]^{1.514} \qquad \text{…… 3}$$

a = (675 10-9) J3 - (771 10-7) J2 + (179 10-4) J + 0.492

$$\therefore a = 0.016\ J + 0.5 \qquad \text{…… 4}$$

The (a) value = 2.67664

Where:

PEx = monthly potential evapotranspiration (mm / month).

t = mean air temperature (C°) for each month.

n = monthly measurement number.

J = yearly heat index (C°)

j = temperature parameter (C°) for each month.

a = Constant.

Each month's evapotranspiration potential (PE) value is based on 30 days and 12 h of daily sunshine. The corrected evapotranspiration (PEc) values can be calculated [16]:

$$PEc = PEx \quad * DT/360 \qquad \text{…… 5}$$

Where:

PEc : potential Evapotranspiration (mm) the Corrected value.

PEx : potential Evapotranspiration (mm).

D: days number in each month.

T: average number of hours between sunrise and sunset in the month .

The monthly potential evapotranspiration values and the highest value of PEc appeared in July for the three studied stations, while the lowest appeared in December for Kut and Iskandaryah and January for Hilla station (Tables 4,5, and 6). After computing the values of potential Evapotranspiration (PEx) according to the equation (1) and correcting them according to the equation (4), these two equations applied by Thornthwaite (1948) become the monthly temperature-dependent. According to the evaporation values, the following correlation was recognized: The period from January to December is determined by: Epan > PEx > PEc. The observed difference between the three evaporation values refers to the differences in the measuring ways (field and calculated values).

Table 4: Corrected potential evapotranspiration values calculated for the period (2000-2019) using Thornthwaite (1948) method for Kut [8]

Months	Temp. (ºC)	j	DT/360	PEx (mm)	PEc (mm)	Evaporation (mm)
Oct.	28.40	13.870	0.723	40.252	29.116	109.5
Nov.	19.30	7.728	0.6	22.367	13.420	106
Dec.	13.70	4.600	0.585	13.280	7.776	99.8
Jan.	12.80	4.150	0.576	11.976	6.909	94.7
Feb.	14.70	5.118	0.606	14.782	8.968	121.3
Mar.	20.30	8.343	0.680	24.153	16.431	220.4
Apr.	25.70	11.923	0.741	34.578	25.645	299.3
May	32.80	17.250	0.852	50.112	42.720	351.7
Jun.	36.70	20.449	1.016	59.451	60.442	404.7
Jul.	38.40	21.900	1.085	63.690	69.104	475.6
Aug.	37.80	21.384	0.998	62.183	62.114	409.3
Sep.	33.90	18.134	0.883	52.691	46.543	244.6
Total		154.848		449.521	389.193	2936.9

Table 5: Corrected potential evapotranspiration values calculated for the period (2000-2019) using Thornthwaite (1948) method for Al-Iskandaryah [8].

Months	Temp. (ºC)	j	DT/360	PEx (mm)	PEc (mm)	Evaporation (mm)
Oct.	27.04	8.187	0.7190	97.546	70.138	164.50
Nov.	19.23	5.823	0.599	38.467	23.078	83.20
Dec.	12.65	3.830	0.583	12.250	7.144	59.40
Jan.	12.77	3.868	0.578	12.581	7.279	54.70
Feb.	14.72	4.456	0.602	18.527	11.167	81.37
Mar.	20.22	6.122	0.678	44.112	29.913	142.42
Apr.	25.66	7.770	0.743	84.570	62.850	191.30
May	28.81	8.724	0.853	116.044	98.990	265.70
Jun.	33.72	10.210	0.998	178.289	178.038	334.70
Jul.	36.36	11.008	1.086	218.992	237.866	355.60
Aug.	35.75	10.825	0.995	209.173	208.265	309.30
Sep.	32.96	9.979	0.885	167.484	148.293	244.60
Total		143.438		1198.04	1083.028	2286.79

Table 6: Corrected potential evapotranspiration values calculated for the period (2000-2019) using Thornthwaite (1948) method for Al-Hilla [8].

Months	Temp. (ºC)	j	DT/360	PEx (mm)	PEc (mm)	Evaporation (mm)
Oct.	27.13	12.942	0.805	98.460	79.274	177.00
Nov.	18.38	7.177	0.599	33.990	20.392	96.00
Dec.	13.71	4.607	0.755	15.276	11.540	63.00
Jan.	11.84	3.688	0.492	10.230	5.0379	54.00
Feb.	13.83	4.667	0.602	15.640	9.427	82.00
Mar.	17.51	6.669	0.703	29.774	20.938	135.00
Apr.	25.03	11.454	0.743	78.987	58.701	202.00
May	30.44	15.403	0.939	134.780	126.578	297.00
Jun.	34.85	18.906	1.0416	195.065	203.192	333.00
Jul.	35.36	19.328	1.097	202.990	222.866	396.00
Aug.	34.81	18.878	0.995	194.530	193.686	351.00
Sep.	30.89	15.755	0.880	140.393	123.575	265.00
Total		139.474		1075.213	1150.119	2451.00

Water deficit (WD) and water surplus (WS)

According to Lerner et al., 1990[9], the actual Potential evapotranspiration (APE) is derived as:

APE = PEc when $P \geq PEc$

APE = P when $P < PEc$

In the case of water surplus, the precipitation values are more than the corrected Evapotranspiration, and the actual potential Evapotranspiration equals the corrected potential evapotranspiration values. In the case of water deficit, the precipitation is less than the corrected potential Evapotranspiration, and the actual potential Evapotranspiration is equal to the precipitation values as expressed in the following:

$$WS = P - PEc \quad \text{……………………...6}$$

$P > PEc$, $APE = PEc$

$$WD = PEc - P \quad \text{…...........................7}$$

$P < PEc$, $APE = P$

Where:

WS: Water surplus (mm).

WD: Water deficit (mm)

P: Rainfall (mm)

APE: potential Evapotranspiration (mm) actual.

PEc: potential Evapotranspiration (mm) corrected.

The monthly averages of APE, WS and WD are shown in (Tables 7, 8 and 9). The water surplus amount is limited between December to February for the three stations because rainfall exceeds PEc; therefore, from the annual rainfall, the water surplus ratio is :

$$WS\ \% = WS/P \times 100 \quad \text{..........................8}$$

$WS\% = 183.34 / 263.36 \times 100 = 69.61\%$

This amount indicates the surface runoff and the recharge of the groundwater. While the water deficit amount is (477.42 mm) from PEc, which equals (30.39 %) of total rainfall, as shown in the following equation:

WD% = 100 – WS% 9

WD% = 100 – 69.61 % = 30.39%

Table 7: Measured average monthly of water deficit and water surplus for Kut Station for the period (2000 - 2019).

Month	P (mm)	PEc (mm)	PEx (mm)	WS (mm)	WD (mm)
Oct.	3.05	29.116	40.252	0	29.116
Nov.	17.49	13.420	22.367	4.069	0
Dec.	19.25	7.776	13.280	11.473	0
Jan.	23	6.909	11.976	16.090	0
Feb.	10.2	8.968	14.782	1.231	0
Mar.	11.2	16.431	24.153	0	5.231
Apr.	9.7	25.645	34.578	0	15.945
May	2.55	42.720	50.112	0	40.170
Jun.	0.01	60.442	59.451	0	60.432
Jul.	0	69.1044	63.690	0	69.104
Aug.	0	62.114	62.1831	0	62.114
Sep.	0.27	46.543	52.691	0	46.273
Total	96.72	389.193	449.521	32.864	328.388

Table 8: Measured average monthly of water deficit and water surplus for Hilla Station for the period (2000- 2019).

Month	P(mm)	PEc (mm)	PEx (mm)	WS (mm)	WD (mm)
Oct.	8.69	79.274	98.460	0	70.584
Nov.	16.24	20.392	33.990	0	4.152
Dec.	14.67	11.540	15.276	3.129	0
Jan.	19.35	5.0379	10.230	14.312	0
Feb.	12.47	9.427	15.640	3.042	0
Mar.	13.81	20.938	29.774	0	7.128
Apr.	13.05	58.701	78.987	0	45.651
May	1.5	126.578	134.780	0	125.078
Jun.	0.1	203.192	195.065	0	203.092
Jul.	0	222.866	202.990	0	222.866
Aug.	0	193.686	194.530	0	193.686
Sep.	0.1	123.575	140.393	0	123.475
Total	99.98	1075.212	1150.118	20.483	995.716

Table 9: Measured average monthly of water deficit and water surplus for Al-Iskandaryah Station for the period (2000 – 2019)**.**

Month	P (mm)	PEc (mm)	PEx (mm)	WS (mm)	WD (mm)
Oct.	3.25	70.138	97.546	0	66.888
Nov.	19.99	23.078	38.467	0	3.091
Dec.	19.25	7.1448	12.250	12.105	0
Jan.	23.00	7.279	12.581	15.718	0
Feb.	11.21	11.167	18.527	0.046	0
Mar.	11.21	29.913	44.112	0	18.708
Apr.	9.70	62.850	84.570	0	53.152
May	2.55	98.990	116.044	0	96.440
Jun.	0.01	178.038	178.289	0	178.028
Jul.	0.00	237.866	218.992	0	237.866
Aug.	0.00	208.265	209.173	0	208.265
Sep.	0.17	148.293	167.484	0	148.123
Total	100.33	1083.028	1198.04	27.869	1010.565

The Climate Classification

There are several climate classifications to determine the type of climate[17 and 18]. Two of these classifications were used to find the type of climate as follows :

A- Mather (1974) [13] **classification:**

Climate has been classified into three classes according to the climate index of Mather (1974) [13], based on the relationship between rainfall and Evapotranspiration. The climate Index is given as:

$$CI = [(P/PE)-1] *100 \qquad \text{.........................10}$$

Where:

CI = Climate index

P = Rainfall

PE = Potential evapotranspiration.

When (CI) negative value represents a dry climate, and (CI) positive value means a humid climate. According to this classification, the climate index (CI) = - 52.75, and the climate type is Semi-arid, as shown in (Table- 10).

Table 10: Classification of the climate according to Mather, 1974[13].

Climate Type	Range of Climate index	Climate index in studied area
Dry-sub humid	0.0 to -33.3	
Semi-Arid	-33.3 to -66.7	-52.75
Arid	-66.7 to -100	

B- Brown and Cocheme, 1973 [14] classification:

According to the classification of Brown and Cocheme (1973) [14], the humidity index (HI) depended on the ratio between rainfall and potential Evapotranspiration, comparable to the following equation 11, as shown in (Table -5).

$$H.I = P/ PE \qquad \text{……………...11}$$

H.I: Humidity index.
P: Annual rainfall (mm).
PE: Potential Evapotranspiration (mm).
From equation 11, the HI = 0.47, reflecting the climate is between moist and dry .

Table 11: Classification of the climate according to Brown and Cocheme, 1973**[14]**.

HI > 1	Wet	1
0.5 < HI < 1	Moist	2
0.25 < HI < 0.5	Between moist and dry	3
0.1 < HI < 0.25	Dry	4
HI < 0.1	Very dry	5

Conclusions

1- The frequency curves of annual rainfall (mm) and mean annual temperature (C^o) for three Iraqi stations (Kut, Hilla and Iskandaryia) for the years 2000–2019 were studied.

2- There is a negative relationship between annual precipitation and time with a noticeable decrease in precipitation amounts. The total annual rainfall recorded in Kut station is 99.98 mm, while in Hilla station (96.7 mm), and in Iskandaryia station, it is 100.33 mm.

3- Positive relationship between mean annual temperature (C^o) and time reflects a remarkable increase in temperature values. As noticed, the temperature in the Kut station is 24.99 C^o. At the same time, Hilla station recorded 30.89C^o, and in the Iskandaryia station is 24.99 C^o.

4- A large water deficit was detected due to high temperature and thus increased evaporation rate. There was a total water surplus in the Kut area of 32.86 mm from November to February. While the Hilla and Iskandaryia stations recorded a total water surplus of 20.4 and 27.8 mm from December to February, respectively.

5- The climate classification for the three stations was semi-dry to dry climates. The region has a significant water deficit of up to 79.6 % of the total rainfall values, as indicated in Hilla station.

6- The results show the effect of climate change even on the close geographical location of the meteorological stations such as Kut, Hilla and Iskandaryia.

References:

[1] J., Buchdahl "Climate Change, review, of global contemporary and prehistoric," 1999. Http://cdiac.org.gov.

[2] M.E., Stuart et al., "A review of the impact of climate change on future nitrate concentrations in groundwater of the UK," *Science of the Total Environment Science of The Total Environment*, Volume 409, Issue 15, 1 July 2011, pp. 2859-2873.

[3] S.K., Thair. and H.M., Hasan "PredictedClimate ChangeImpact ongroundwater Flowfor the Upper Zoneof Iraqi Aquifers," *Journal of Southwest Jiaotong University*, 55(2). 2020.

[4] N., Adamo et al., "Global Climate Change Impacts on Tigris Euphrates Rivers Basins," *Journal of Earth Sciences and Geotechnical Engineering*, 10(1), PP: 49-98. 2020.

[5] M., Al-Dabbas, et al., "Impact of Climate change on the hydrochemistry of daibaga unconfined aquifer, Kurdistan," *Earth and Environmental Science,* (ISSN:1755-1307), 2021.
[6] M.A., Al-Dabbas, and S.M.A., Razzaq, "Climatic Analysis and Climatic Water Balance Determination for Al-Yusufiyah Area, Southern Baghdad, Iraq," *Iraqi Journal of Science,* 58(3A) 2017, pp. 1246-1255.
[7] M. A., Al-Dabbas, and E.A., AL-Ali, "Computation of Climatic Water Balance for Greater Musaiyab Project Site in Babylon Governorate-Central of Iraq," *Iraqi Journal of Science,* 57(2C), 2016, pp. 1445-1451.
[8] Climatic data, 2020.data-access-viewer/ NASA, https://power.larc.nasa.gov/.
[9] S.Z., Jassim,. and J.C., Goff, "Geology of Iraq," *1st edition* printed inCzech Republic. 318P. 2006.
[10] H.K.S., Al Jiburi "Summary of Hydrogeological and Hydrochemical Study of Al-Kut Quadrangle," *(Sheet NI-38-15), S.C. Of Geological Survey & Mining Dep. Of Mineral Investigation*. pp3. 2009.
[11] C.W., Thornthwait, "An Approach toward a Relation Classification of Climate, Geographical Review," 32, 1948. PP: 55-60.
[12] N.D., Lerner, et al., "Groundwater recharge- a Guide to understanding and estimating natural recharge," *Association of Hydrogeologist,* Hanover, 1990. 8,X, PP:75-91.
[13] J.R., Mather, "Climatology Fundamentals and Applications," *McGraw-Hill Book Co.,* New York. 1974.
[14] L.M., Brown, and J., Cocheme, "A study at the agromeleorblogy of the High Land of eastern Africa," *WMO, Geneva, Tech*. Note, No. 1251973 ..
[15] H.T., Majeed, et al. "Decadal Surface Temperature Trends in Iraq using NOAA/ESRL Gridded High Resolution Data," *1st International Conference on Pure Science (ISCPS) Journal of Physics: Conference Series 1660,* 012078, IOP Publishing, 2020, doi:10.1088/1742-6596/1660/1/012078.
[16] E.M., Wilson, "Engineering hydrology," *McGraw-Hill Press Ltd*. 1971.
[17] I. A. Al- Ali and M.A. Al- Dabbas, "Evaluating the Climatic Change Effect on the Water Quality of Euphrates River from Haditha to Al-Hindiya/ Iraq" Review of International Geographical Education (RIGEO), 11(5), 4470-4481. doi: 10.48047/rigeo.11.05.325.
[18] I. A. Al- Ali and M.A. Al- Dabbas, "The Effect of Variance Discharge on the Dissolved Salts Concentration in the Euphrates River upper reach, Iraq" Iraqi Journal of Sciences (IJS), Vol. 63, No 9, 3842- 3853. 2022.