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Climate parameters analysis as an indication of climate Changes for Diwaniya, Nasiriya, Kut and Karbala meteorological stations - Central and southern Iraq: Karbala climate condition as a case study

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Abstract

The climate parameters (rainfall, number of rainy days and temperature) data for about seventy years from 1941 – 2009 for three Iraqi meteorological stations (Diwaniya, Nasiriya, and Kut) were investigated and gave good evidence of climate change. As well as the climatic water balance and the climatic conditions were determined at Karbala meteorological station for the years (1982-2015). The annual precipitation for Karbala station-reflect declination from 105 mm for the period 1982-1990 to about 71 mm for the years 2011- 2015 confirms the effect of global climate change. Analyzing Karbala climate parameters reflects that the total annual rainfall is (89 mm), evaporation is (2984 mm), while the mean monthly relative humidity% is 47.9%, sunshine is 8.8 h/day, temperature is 24.1 C and wind speed is 3.0 m/sec. the water surplus in the Karbala area is 8.49 mm, 12.28 mm, and 6.65 mm in December, January and February, respectively. The climate classification of the Karbala area was continental and dry climates, as well as the region, has a significant water deficit of up to 93 % of the total rainfall values.

Keywords: climate change, water balance, climate conditions, Central and southern Iraq.

تحليل المعلمات المناخية كمؤشر على التغيرات المناخية لمحطات الأرصاد الجوية في الديوانية والناصرية والكوت وكربلاء – وسط وجنوب العراق: الوضع المناخي في كربلاء كحالة دراسية

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الخلاصة

تم التحقيق في بيانات المعلمات المناخية (هطول الأمطار وعدد الأيام الممطرة ودرجة الحرارة) لحوالي سبعين عاما من 1941 إلى 2009 لثلاث محطات أرصاد جوية عراقية (الديوانية والناصرية والكوت) وقدمت أدلة جيدة على تغير المناخ. وكذلك تم ايجاد الموازنة المائية المناخية والظروف المناخية في محطة أرصاد كربلاء للأعوام (1982–2015). اظهرت معدلات هطول الأمطار السنوية لمحطة كربلاء انخفاضا من 105 ملم للفترة 1982–1990 إلى حوالي 71 ملم للأعوام 2011–2015 ي مما يؤكد تأثير التغير المناخي العالمي. وبتحليل المعلمات المناخية في كربلاء تبين أن إجمالي الأمطار السنوي يبلغ (89 ملم)، والتبخر

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(2984 ملم)، في حين أن متوسط الرطوبة النسبية الشهرية 47.9٪، والسطوع الشمسي 8.8 ساعة/يوم، ودرجة الحرارة 24.1 م، وسرعة الرياح 3.0 م/ثانية. وبلغ الفائض المائي في منطقة كربلاء 8.49 ملم و12.28 ملم و6.65 ملم في كانون الأول. يناير وفبراير ، على التوالي. التصنيف المناخي لمنطقة كربلاء هو قاريا وجافا، فضلا عن أن المنطقة تعاني من عجز مائي كبير يصل إلى 93٪ من إجمالي قيم الأمطارالساقطة.

INTRODUCTION

Shortage in water resources is experienced Iraqespeciallyin surface water. In order to fully address the grand challenge of climate change's impact on human society and ecosystems, an integrated systems approach will be needed, taking the interactions among climate change and variability, hydrologic processes, and societal adaptation into account [1]. Generally, a continued increase in average global temperature will increase the evaporation and frequency of extreme weather events such as intense storms and droughts[2,3,4,5]. The chosen region is for four governorates, Karbala, Wasit, Qadisiyah and Dhi-Qar, in central and southern Iraq (Fig.1). The available climatic parameters data of Diwaniya, Nasiriya, Kut and Karbala meteorological stations were collected and analyzed[6] This paper is aiming are to investigate the climatic change in Iraq by evaluating the available climatic data for Diwaniya, Nasiriya, Kut meteorological stations for the period from the year 1941 – 2009 and to study the climate data of Karbala Station to determine the climate type water balance and the water deficit and water surplus for the years 1982-2015.

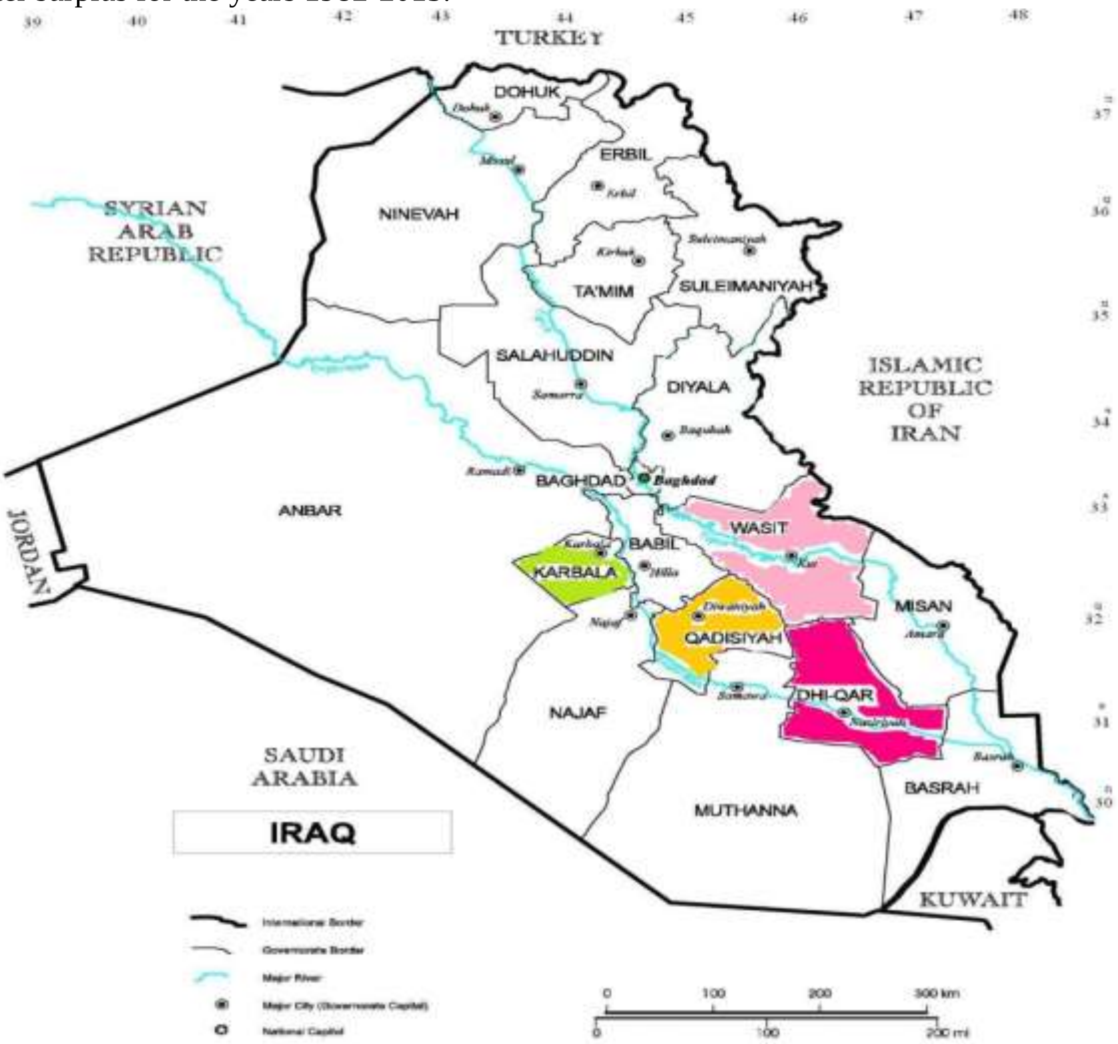

Figure 1: Location map of the study area.

MATERIALS AND METHODS

Topography plays an essential role in climate. Three stations of meteorology were chosen for climatic data investigation. Diwaniya and Nasiriya meteorological stations are chosen to represent the flood plain of Mesopotamia in the center of Iraq, and Kut meteorological station to represent the eastern parts of Mesopotamia plain and part of the foothill zone of Iraq. The available data for about 70 years records of the studied climatic elements for the 1941 – 2009 episodes [7]. Karbala meteorological station was selected to represent the western part of Mesopotamia. Climatic data of the Karbala for the years 1982 to 2015 were analyzed for determination of the mean monthly climatic parameters Table 1[4] Values of potential evapotranspiration were determined by utilizing [8] and Lerner et al., 1990 methods. These methods were applied to the computation of water balance in the study area. The type the Karbala climate was determined according to four climate classifications [9,10,11,12].

Table 1: Monthly averages of the climate data for years1982-2015 in Karbala meteorological station[6]

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average
Monthly rainfall mm	3.8	10.4	15.1	16.3	13.4	14.5	12.1	3.1	0.0	0.0	0.0	0.3	∑89 mm
RH %	46	62	72	74	61.2	55.1	43	34	30	29	32	36	47.9
Mean Air Temp C°	26.6	17.1	12.5	10.4	12.3	18.0	24.0	30.6	34.3	36.3	35.4	31.3	24.1
Monthly evaporation mm	206	107	65.4	64	98	175.6	251	348	452	472	426	319	∑2984
Monthly Sun shine hr/day	8.2	7.2	6.3	6.2	7.2	8.0	8.4	9.4	11.2	11.8	11.1	10.2	88
Wind Speed m/s	2.2	2.1	2.0	2.3	3.1	3.1	3.2	3.2	4.1	4.3	3.4	2.5	3.0

RESULTS AND DISCUSSION

Climate change is variability in rates of weather conditions.

A. Climatic parameter analysis in the Mesopotamia flood plain

The frequency curves of Annual Rainfall (mm), Annual Number of rainy days (B) and Annual Mean temperature (^{o}C) for the years 1941–2009 were studied. The indirect relation between annual the number of rainy days and rainfall with time was noticed inDiwaniya, Nasiriya, and Kut(Figures 2, 3 and 4). Declination of precipitation were shown and reflected by the line of a general trend.

The direct relation between Annual Mean temperature (°C) and time[16] shown by the frequency curves for the years 1941 – 2009, in Diwaniya, Nasiriya, and Kut, with high-temperature values, were shown and reflected by the line of a general trend, (Figures 2-C, 3-C and 4-C).

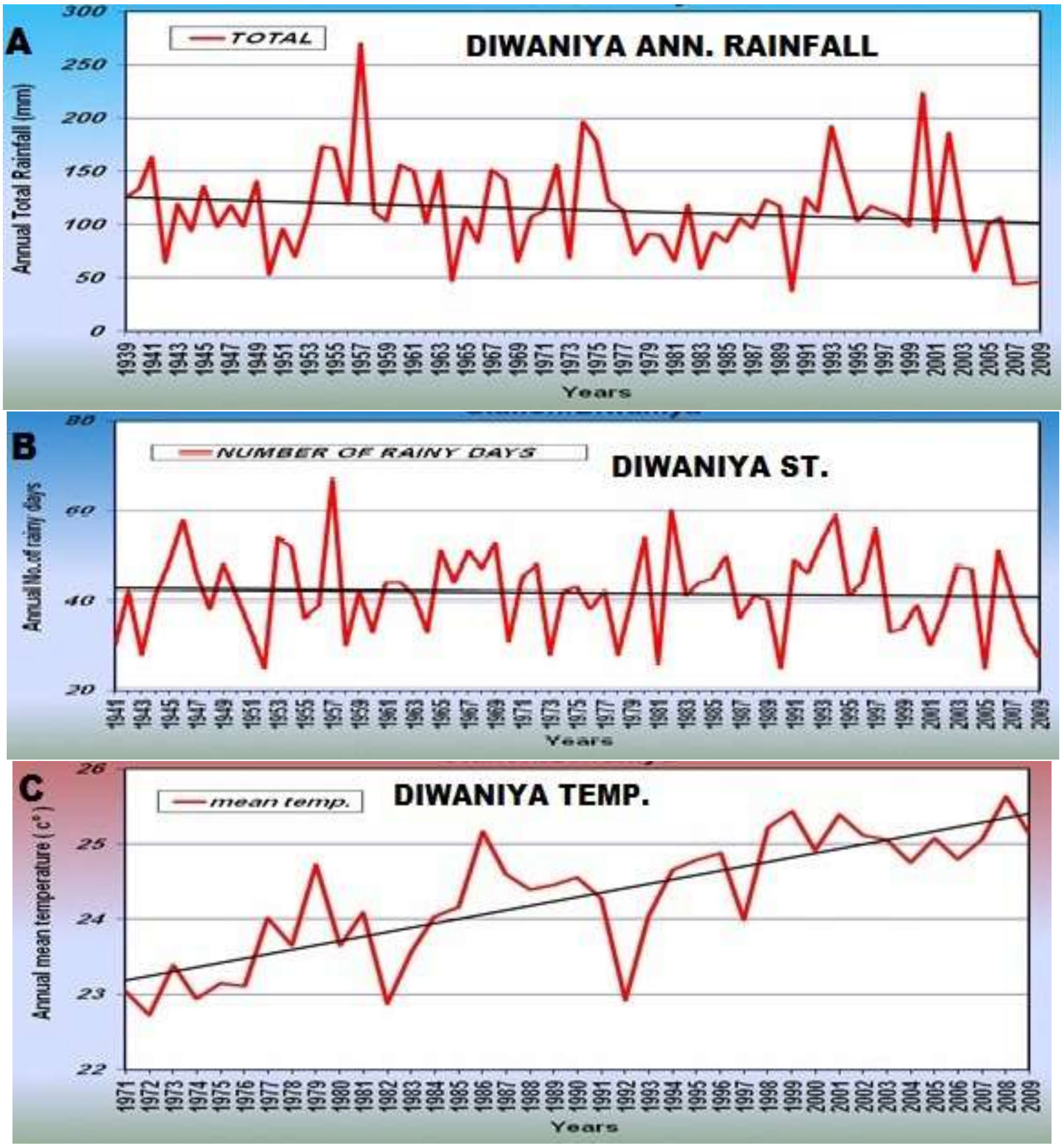

Figure 2: The trend of annual rainfall (A), Annual Number of rainy days (B) and annual mean temperature (C) at Diwaniya during 1941–2009 [6].

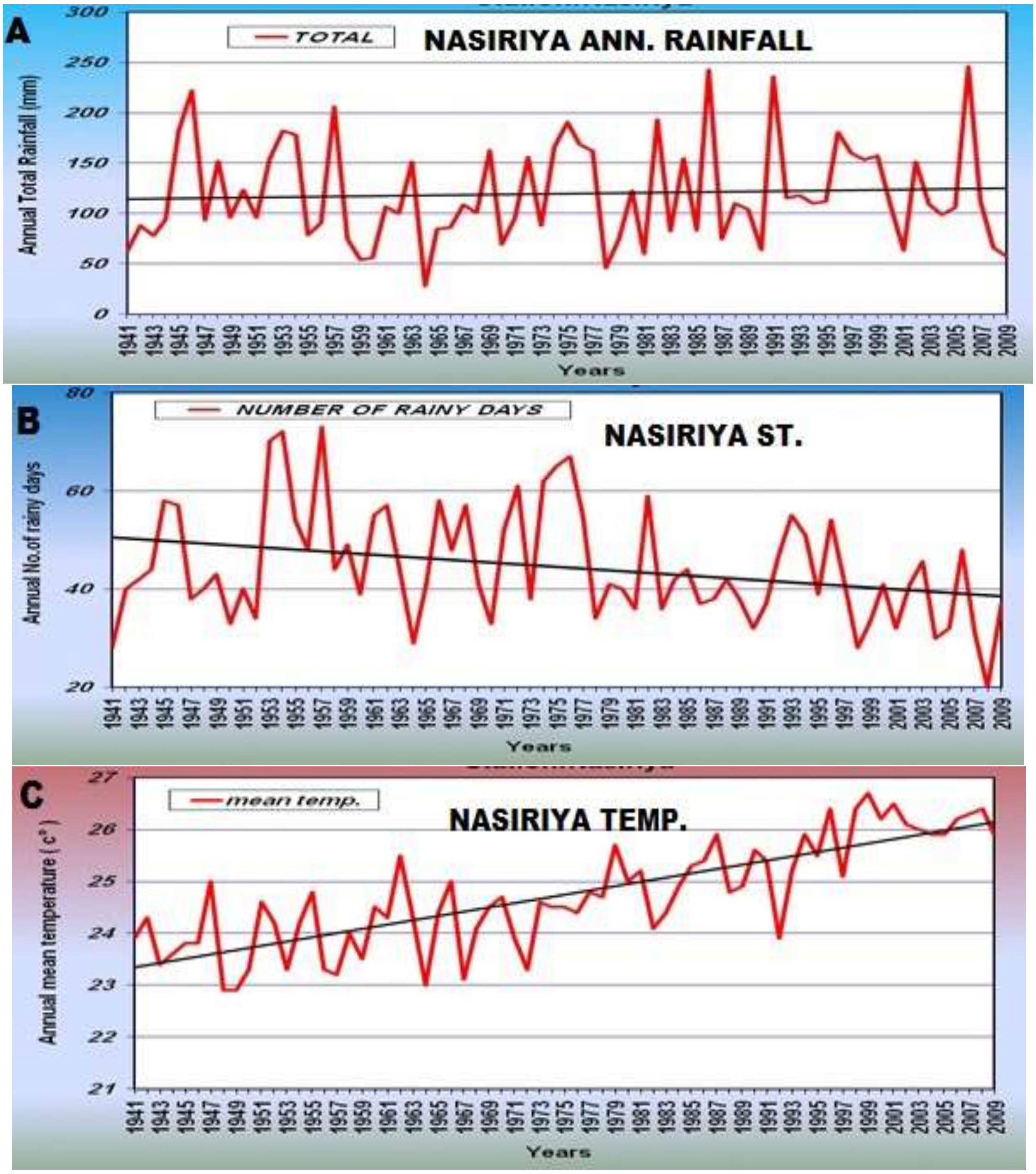

Figure 3: The trend of annual rainfall (A), annual number of rainy days (B) and annual mean temperature (C) at Nasiriya during 1941–2009 [6].

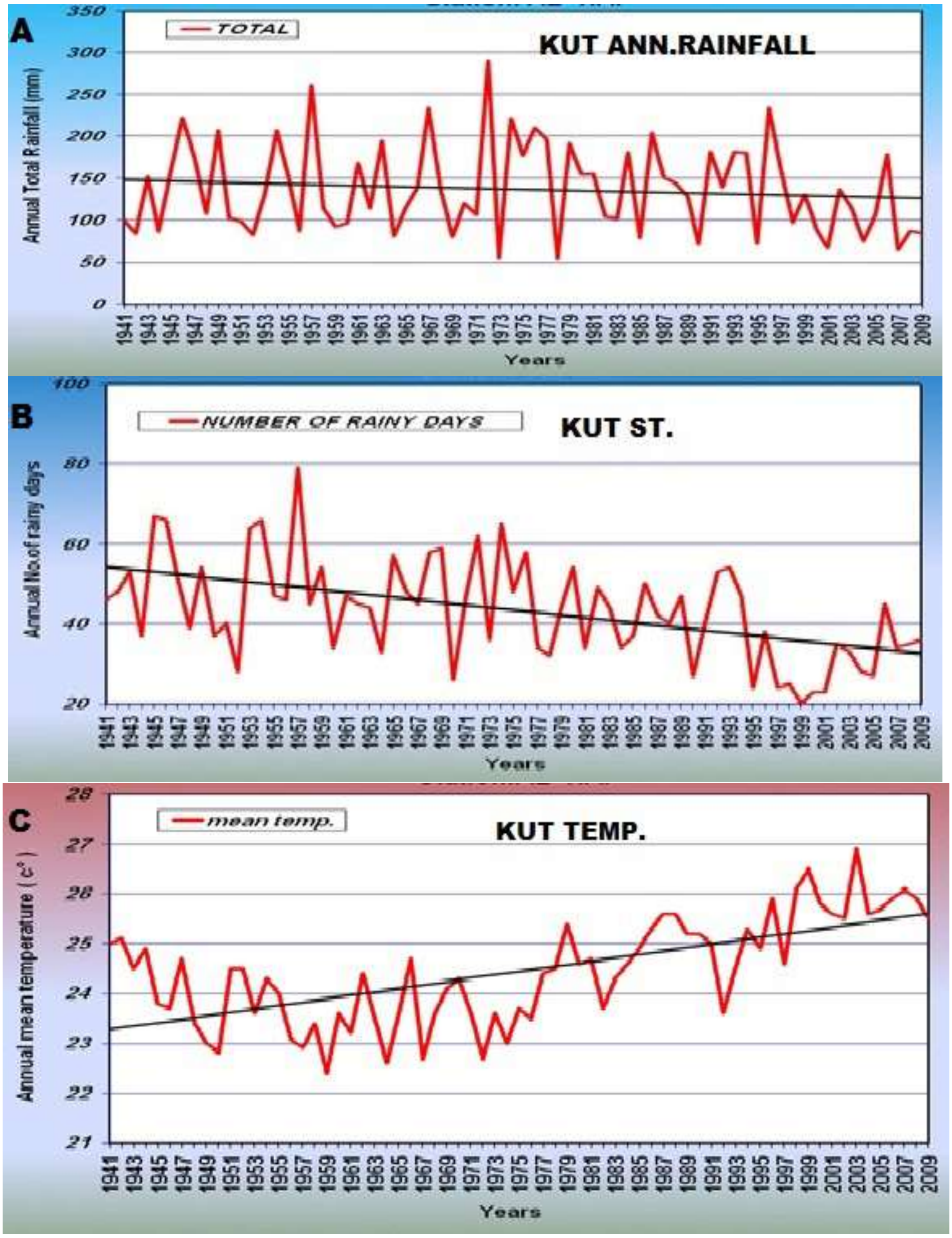

Figure 4: The trend of annual rainfall (A), annual nnumber of rainy days (B) and annual mean temperature (C) Kut during 1941–2009 [6].

B. Analysing of the climatic parameters of Karbala Meteorological Station:

The evaluating the climate parameters in hydrological and hydrogeological studies aimed to develop a formula for the water balance of the Karbala basin**.**

Water Availability Climate Elements

Water availability elements, including rainfall and relative humidity, are important in the climate classification and climate water balance.

Rainfall

Rainfall is one of the significant climatic factors, where the rainfall period in the Karbala area is characterized by the absence of rainfall in summer (June-August and little amount in September), with rainy months from October to May. Rainfall has an impact on the groundwater amount and soil moisture. The monthly average rainfall for the period (1982-2015) is shown in Table 1. The maximum precipitation existed in January (16.3 mm)and 0.3 mm in September. The mean annual rainfall of the study area reached (89.0 mm). The average means annual precipitation in mm for the years 1982-2015 decreased from 105 mm for the years 1982 -1990 to about 71 mm for the years 2011-2015 (Table 2).

Table 2: Average means annual precipitation for the Karbala meteorological station for a period 1982-2015.

No. of years	Average means annual rainfall in mm
1982-1990	105
1991-2000	90
2001-2010	79
2011-2015	71

Relative Humidity

Relative humidity (RH) percentages are the amount of water vapor absorbed by air, which depends on the air temperature and water. The RH is correlated indirectly with the evaporation, the temperature, and the wind speed; and directly with the rainfall. The highest monthly average of relative humidity % for the period (1982-2015) appeared in January (74 %), while the lowest appeared in July (29 %).

Water Losses Climate Elements

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

Mean Air Temperature

Temperature is variable periodically in the water year. It represents an important factor in the evaporation and evapotranspiration, which results in warming air. It also is correlated indirectly with rainfall and relative humidity, generally with the evaporation. The monthly temperature averages of 1982-2015 indicated that the highest temperature average appeared in July (36.3 Cº) while the lowest appeared in January (10.4 C°).

Mean Monthly Evaporation from class (A) Pan

Evaporation is an important element in water balance and hydrological cycle, and 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 is affected by evaporation. High evaporation leads to salt deposition in the soil, like the evaporate minerals. Evaporation is correlated inversely with the rainfall and the relative humidity; and normally with the temperature. The monthly evaporation for the years 1982-2015 reflects the highest average of evaporation in July (472 mm) and the lowest in January (64 mm). The annual evaporation of the study area reached 2984 mm.

Sunshine

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 real evapotranspiration. It is one of the climate elements that greatly affects the amount of evaporated water. Sunshine increases with an increase in temperature and evaporation. The mean monthly sunshine for the period (1982-2015) indicates the maximum in July (11.8 hours/day), and the lowest appeared in January (6.2 hours/day).

Wind Speed

The wind has a significant role in the amount of evaporation. The rate of evaporation increases with the excess wind speed. The wind is firmly connected with temperatures and air pressure. The wind speed increases with high temperatures. The prevailing wind direction in the studied area is northwest during most of the season. The monthly averages of wind speed for the period (1982-2015) reflect the maximum in July (4.3 m/sec), and the lowest appeared in December (2.0 m/sec).

Potential Evapotranspiration (PE)

The PE is an essential indicator in the budget, and 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. So actual water evaporation is significant in specifying included factors of water balance to an area which helps to determine the amount of drainage and the amount of storage in shallow basins and subsurface percolation.

[8] developed a relationship for calculating the consumptive use of the crop. Assuming a better correlation with the mean temperature, moisture, wind speed and sunshine. The relationship is shown in the following equation[13] :

PEx =16 [10tn / J] ^{a} mm/month …...………………..…1

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

j = [tn / 5]1.514 ………………………….. 3

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

∴ a =0.016 J+0.5 ………………………..... 4

The value of (a) equals = 2.67664

Where:

PEx = Potential evapotranspiration for each month (mm / month).

t = Monthly mean air temperature (C°)

n = number of monthly measurement.

J = Annual heat index (C°)

j = Monthly temperature parameter (C°)

a = Constant.

However, the value of the potential evapotranspiration (PE) is a theoretical standard; the monthly values are based on 30 days and 12 hr of sunshine per day, the values of the corrected potential evapotranspiration (PEc) could be determined from the following equation [13]:

PEc = PEx ……………………..… 5

Where:

PEc: Corrected potential evapotranspiration (mm).

PEx: potential evapotranspiration (mm).

D: number of days in the 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 (293.58 mm), while the lowest appeared in January (4.02 mm)(Table 3). After computing the values of potential evapotranspiration (PEx) according to equation (1) and correcting them according to equation (4), these two equations applied by [8] become the monthly temperature dependent. According to the evaporation values, the following correlation was recognized, the period from January to December is characterized by the following relation: Epan> PE >PEc.
The evaporation from the ground E (A) pan is (2984 mm) and the rate of evaporation of the corrected potential evapotranspiration (PEc) is (1077.2 mm), while the rate of the potential evapotranspiration (PEx) is (1231 mm). The observed difference between the three values refers to the differences in the measuring ways (field and calculated values).

Table 3: Corrected potential evapotranspiration values calculated for the period (1982-2015) using [8]

Months	Temp. (C°)	$j=(tn/5)^{1.514}$	DT/360	PEx (mm)	PEc (mm)	Epan (mm)
Oct.	26.5	12.48	0.71	95.32	67.67	206
Nov.	17.05	6.4	0.6	29.28	17.56	107
Dec.	12.4	3.95	0.53	12.48	6.61	65.4
Jan.	10.3	2.98	0.53	7.59	4.02	64
Feb.	12.33	3.92	0.55	12.29	6.75	98
Mar.	17.5	6.66	0.68	31.39	21.34	175.6
Apr.	23.7	10.54	0.71	70.69	50.18	251
May	30.1	15.14	0.82	134.05	109.92	348
Jun.	34.3	18.45	0.93	190.16	176.87	452
Jul.	36.2	20.02	1.01	290.68	293.58	472
Aug.	35.4	19.36	0.95	206.93	196.58	426
Sep.	31.4	16.14	0.84	150.12	126.10	319
Total	23.9X12 = 287	J= 136.04		1231	1077.2	2984

Water shortage and Water surplus

According to [14], the actual Potential evapotranspiration (APE) could be derived as follows:

APE = PEc when $P \geq PEc$

APE = P when $P < PEc$

In the first case (water surplus) values of rainfall is more than the corrected potential evapotranspiration. The actual potential evapotranspiration is equal to the corrected potential evapotranspiration values. In the second case (water deficit), rainfall is less than corrected potential evapotranspiration, actual potential evapotranspiration is equal to rainfall 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 = PWhere:
WS: Water surplus (mm).
WD: Water deficit (mm)
P: Rainfall (mm)
APE: Actual potential evapotranspiration (mm)
PEc: Corrected potentialevapotranspiration (mm)

The water surplus and water deficit are calculated without using the soil moisture (equal to zero). The monthly averages of APE, WS and WD are shown in Table 4. The water surplus amount is (27.74 mm) from total rainfall (89.85 mm) and it is limited between December and February because rainfall exceeds PEc; therefore, the water surplus ratio from the annual rainfall is represented as:

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

WS% =27.74 /89.85 ×100 = 30. 87%

This percentage represents the groundwater recharge and surface runoff. While the water deficit amount is (1014.07 mm) from PEc, which equals (69.13 %) of total rainfall as the following equation:

$$WD\% = 100 - WS\% \quad \text{...........................9}$$

Wd% = 100 – 30.87 % = 69.13 %

Table 4: Measurements of water shortage and surplus for Karbala Station for the years 1982-2015.

Months	P (mm)	PEc (mm)	APE (mm)	WS (mm)	WD (mm)
Oct.	3.8	67.67	3.8	0	63.87
Nov.	10.4	17.56	10.4	0	7.16
Dec.	15.1	6.61	6.61	8.49	0
Jan.	16.3	4.02	4.02	12.28	0
Feb.	13.4	6.75	6.75	6.65	0
Mar.	14.5	21.34	14.5	0	6.84
Apr.	12.1	50.18	12.1	0	38.08
May	3.1	109.92	3.1	0	106.82
Jun.	0	176.87	0	0	176.87
Jul.	0	293.58	0	0	293.58
Aug.	0	196.58	0	0	196.58
Sep.	0.3	126.10	0.3	0	125.8
Total	89	1077.18	61.58	27.42	1015.6

Karbala Climate Classification

There are several climate classifications to define the climate type. Three methods were applied as follows:

A- Mather (1974) classification:

According to the climate index (CI) of [11], the climate is classified into three classes 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 is a negative value, they represent a dry climate, and when CI is a positive value represent a humid climate. According to this classification, the CI = - 91.7, and the climate type is arid, as shown in Table 5.

Table 5: Classification of the climate applying Mather, [11].

Claimant Type	Range of CI	CI in studied area
Dry-sub humid	**0.0 to -33.3**	**-91.7**
Semi-Arid	**-33.3 to -66.7**	
Arid	**-66.7 to -100**	

B- Brown and Cocheme, 1973 classification:

According to [9] classification the humidity index (H.I) depended on the ratio between rainfall and potential evapotranspiration comparable to equation 11, as shown in Table 6.

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

H.I: Humidity index.

P: Annual rainfall (mm).

PE: Potential evapotranspiration (mm).

From equation 11, the value of H.I = 0.083, reflecting a very dry climate.

Table 6: Classification of the climate application [9].

Climate type		**Range HI**
Humid		HI > 1
Moist	Not humid	HI< 1< 2HI
Moist to Dry		2HI< 1< 4HI
Dry		4HI< 1< 10HI
V. Dry		10HI < 1

C- Al-Kubaisi ,2004 Classification:

It isbasedon mean annual temperature and precipitation as in the equations:

$$AI - 1 = 1.0 \times P / (11.525 \times t) \qquad \text{------------------- 12}$$

$$AI- 2 = 2\sqrt{p} /t \qquad \text{----------------- 13}$$

Where:

AI: Annual dryness index.

P: Mean annual rainfall (mm).

t: Mean annual temperature (C°).

The parameter AI-1is indicates the dominated climate, and the parameter AI-2 reflects a modification of the latter climate (Table7).

Table 7: Classification of climate according to [2].

Part 1	**Indication**	**Part 2**	**Indication**
AI 1 > 1.0	Humid to Moist	AI.2 ≥ 4	Humid
		2.5 ≤AI.2 < 4	Humid to Moist
		1.85 ≤AI.2 < 2.5	Moist
		1.5 ≤AI.2 < 1.85	Moist to sub arid
AI. 1 < 1.0	Sub arid to Arid	1.0 ≤AI.2 < 1.5	Sub arid
		AI.2 < 1.0	Arid

By applying the two equations 12 and 13, the value of (AI-1) and (AI-2)will be :
AI- 1 = 0.32
Comparing this value with the climate type in Table 7 reflects sub-arid to an arid climate.
AI- 2 = 0.74
Furthermore, when comparing this value with the values in Table7, it reflects a sub-arid climate.

D- Koeppen classification

Koeppen classification is one of the most commonly used systems for classifying the world climate [15]. It recognizes five major climate types based on the annual and monthly averages of temperature and precipitation, where the temperature is measured in (C°) and precipitation in (cm/month). Application of this classification system reveals that the climate is classified as BWh class (desert), as shown in Figure 5.

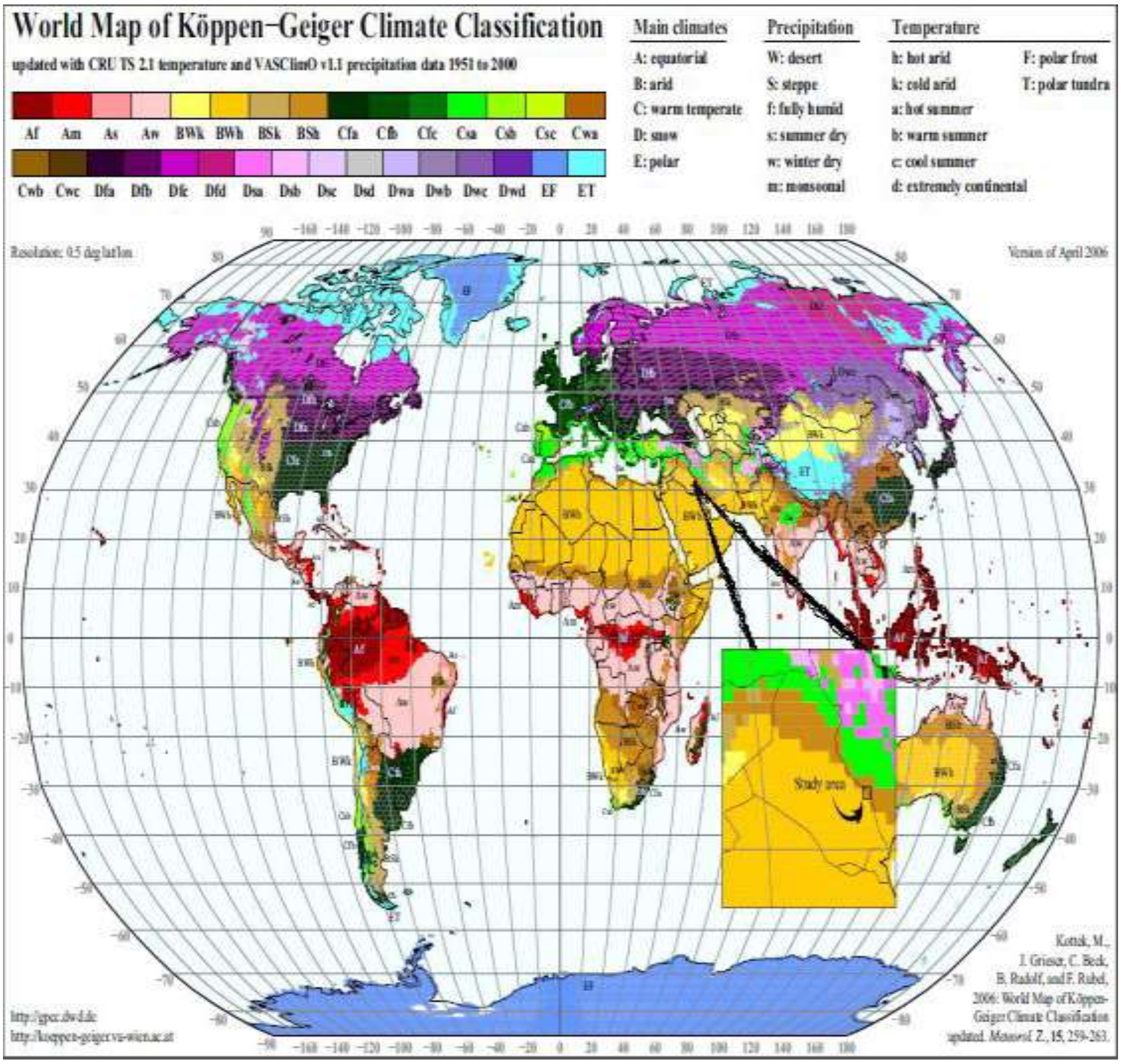

Figure 5: Koeppensworldclimate classification [15].

CONCLUSIONS:

The frequency curves of Annual Rainfall (mm), Annual Number of rainy days (B) and Annual Mean temperature (^{o}C) for the years 1941–2009 were studied.

A negative relationship between an annual number of rainy days and precipitation with time were indicated for Diwaniya, Nasiriya, and Kut meteorological station, with a remarkable decrease in rainfall amounts. At the same time, the positive relationship between annual mean temperature (°C) and time noticed reflects a remarkable increase in temperature values.

The annual averages of the Karbala station climatic parameters for the years (1982 – 2015). The means annual precipitation for years (1982-2015) is decreased from (105 mm) for the years 1982 -1990 to about (71 mm) for the years 2011-2015.

The climate parameters analysis reflects that the total annual rainfall is (89 mm), evaporation is (2984 mm), while the mean monthly relative humidity% is 47.9%, sunshine is 8.8 h/day, the temperature is 24.1C, and wind speed is 3.0 m/sec. The climate water balance has been calculated. When analyzing the results, it was found that there was a large water deficit due to high temperature and, thus increased evaporation rate.

There is a water surplus in the Karbala area of 8.49 mm, 12.28 mm, and 6.65 mm in December, January and February, respectively. The climate classification of the Karbala area was continental and dry climates, and the region has a significant water deficit of up to 93 % of the total rainfall values. The contribution of this research to knowledge is one of the most effective tools to provide feedback on the area's climate and the groundwater quality to policymakers and environmentalists.

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