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Calculate the rates of Runoff and Recharge in the Al-Karma Area, East of Anbar Governorate/ western Iraq

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Abstract

This study aims to estimate the runoff and recharge values in the Al-Karma area, located East of Anbar Governorate, western Iraq. Climate data were collected from 1981 to 2023 at Baghdad Airport and Ramadi stations. The data include six parameters. The monthly average of Temperature, Relative humidity, Wind speed, Sunshine, and Evaporation in both stations (Baghdad and Ramadi) were 23.50C-22.40C, 43.07 %-50.68 %, 3.18 m/s -2.29 m/s, 8.6 h/day -8.7 h/day, and 262.3 mm-223.5 mm with total of rainfall 124.7mm and110.6mm in both stations (Baghdad and Ramadi), respectively. There is a clear variation in climatic data between the two stations. The results show that the highest parameters of (Temperature, Rainfall, Wind speed, and Evaporation) were recorded in Baghdad stations. In contrast, other parameters (Relative humidity, Sunshine) were recorded at the highest values in Ramadi stations. This variation in climatic parameters is due to elevation, Agricultural desert nature, and human activity. In this study, the Runoff and Recharge values were estimated in the study area. The results show that the runoff and recharge values in both stations (Baghdad and Ramadi) were 17.64 mm, 9.03 mm, and 13.42 mm, 9.98 mm respectively, the average calculation for the two stations was approved, which will represent the surface runoff and groundwater recharge for the Al-Karma area, which is (13.34) mm and (11.7) mm, respectively. Finally, the study area was classified as Arid and sub-arid depending on the climate data from Baghdad and Ramadi stations.

Keywords: Baghdad, Ramadi station, Runoff, Recharge, and Al-Karma area.

حساب معدلات الجريان والتغذية في منطقة الكرمة شرق محافظة الأنبار/ غرب العراق

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الخلاصة

تهدف الدراسة إلى تقدير قيم الجريان السطحي والتغذية في منطقة الكرمة شرق محافظة الأنبار/غرب العراق، وقد تم جمع البيانات المناخية من عام 1981 إلى عام 2023 في محطتي بغداد والرمادي. تتضمن ستة متغيرات درجة الحرارة (T)، هطول الأمطار (P)، الرطوبة النسبية (R.H)، سرعة الرياح (W.S)، سطوع الشمس (S. Sh)، والتبخر (PE)وقد كان المتوسط الشهري لدرجة الحرارة والرطوبة النسبية وسرعة الرياح وسطوع الشمس والتبخر في كلتا المحطتين (23.50 – 22.40 درجة مئوية، 10. 43.07 – 50.68٪،

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3.18 / – 2.29 م / ث، 8.6 – 8.7 ساعة / يوم، و262.3 – 223.5 ملم فيما كان مجموع الامطار في محطتي بغداد والرمادي 124.7ملم و110.6ملم على التوالي. هناك تباين واضح في البيانات المناخية بين المحطتين بغداد والرمادي، وتبين النتائج أن أعلى متغيرات (درجة الحرارة وهطول الأمطار وسرعة الرياح والتبخر) سجلت في محطة بغداد بينما كانت المتغيرات الأخرى (الرطوبة النسبية وسطوع الشمس) سجلت أعلى القيم في محطة الرمادي، ويرجع هذا الاختلاف في المتغيرات المناخية إلى الارتفاع والطبيعة الصحراوية الزراعية والنشاط البشري. في منطقة الدراسة، تم تقدير قيم الجريان السطحي والتغذية في منطقة الدراسة. أظهرت النتائج أن قيم الجريان السطحي والتغذية في كلتا المحطتين كانت 17.64 ملم، 9.03 ملم، 13.42 ملم، 9.98 ملم على التوالي. واعتمد حساب المعدل للمحطتين والذي سيكون يمثل الجريان السطحي وتغذية المياه الجوفية لمنطقة الكرمة وهي (١٣.٣٤) ملم و (١١.٧) ملم على التوالي .وأخيرا، تم تصنيف منطقة الدراسة إلى قاحلة وشبه قاحلة اعتمادا على البيانات المناخية لمحطتي بغداد والرمادي.

1. Introduction

Climate is defined as the weather patterns in a vast area for long enough to identify all its statistical features [1]. Iraq has a hot, dry climate characterised by long, hot summers and short, mild winters. The climate is influenced by Iraq's location between the subtropical aridity of the Arabian Desert areas and the subtropical humidity of the Arabian Gulf. Climate impacts the relationship between rainfalls and evaporation that contribute to groundwater recharge. Climate elements play a significant role in influencing water resources, both surface and groundwater, and this effect varies throughout the year's months and from year to year [2]. Agricultural systems are adversely affected when freshwater from rainfall reaches rivers and lakes without being used or invested in for irrigation. The main factors that contribute to the differences in the groundwater quality influence of climate include the high rate of evaporation [3]. To meet the water needs of the population, especially in areas suffering from surface water scarcity, several wells have also been drilled [4]. In Iraq, many studies were conducted in hydrological and climatological regions such as [5,6,7]

The study area is the Al-Karma District, located within the Anbar Governorate in Iraq. It is estimated to be 258.63 km². It is located east of the centre of Anbar Governorate (Ramadi) and west of the capital of Iraq (Baghdad). It is located between longitudes (43.50° - 43.52°) east and latitudes (33.20° -33.28°) north, as shown in Fig. 1. Water resources in the Al-Karma district include groundwater (wells) and channels. The Al-Karma district heavily relies on surface water, which is essential for human and economic needs and must be preserved and developed in light of climate change to increase water resources. Despite the importance of these resources, the Al-Karma district continues to face challenges in water distribution and availability, especially in light of climate change and the scarcity of water in the Euphrates River. The geology of the studied area consists of Quaternary and recent deposits (Pleistocene –Holocene) [8,9]. Most of the study area is characterised by agricultural areas. As for the water sources in the region, the Al-Tamimi and Ali Saliman Channels are the main sources of surface water supply to the region. They branch from the Euphrates River and pass through the region from southwest to northeast, with lengths of 31.5 and 5 km, respectively. The second source of water in the studied area is groundwater with an average depth of 15 meters. This study aims to estimate the runoff and recharge amount in the Al-Karma area in southern Baghdad by using the Iraqi Meteorological Organisation of Baghdad and Ramadi stations for the period (1981-2023).

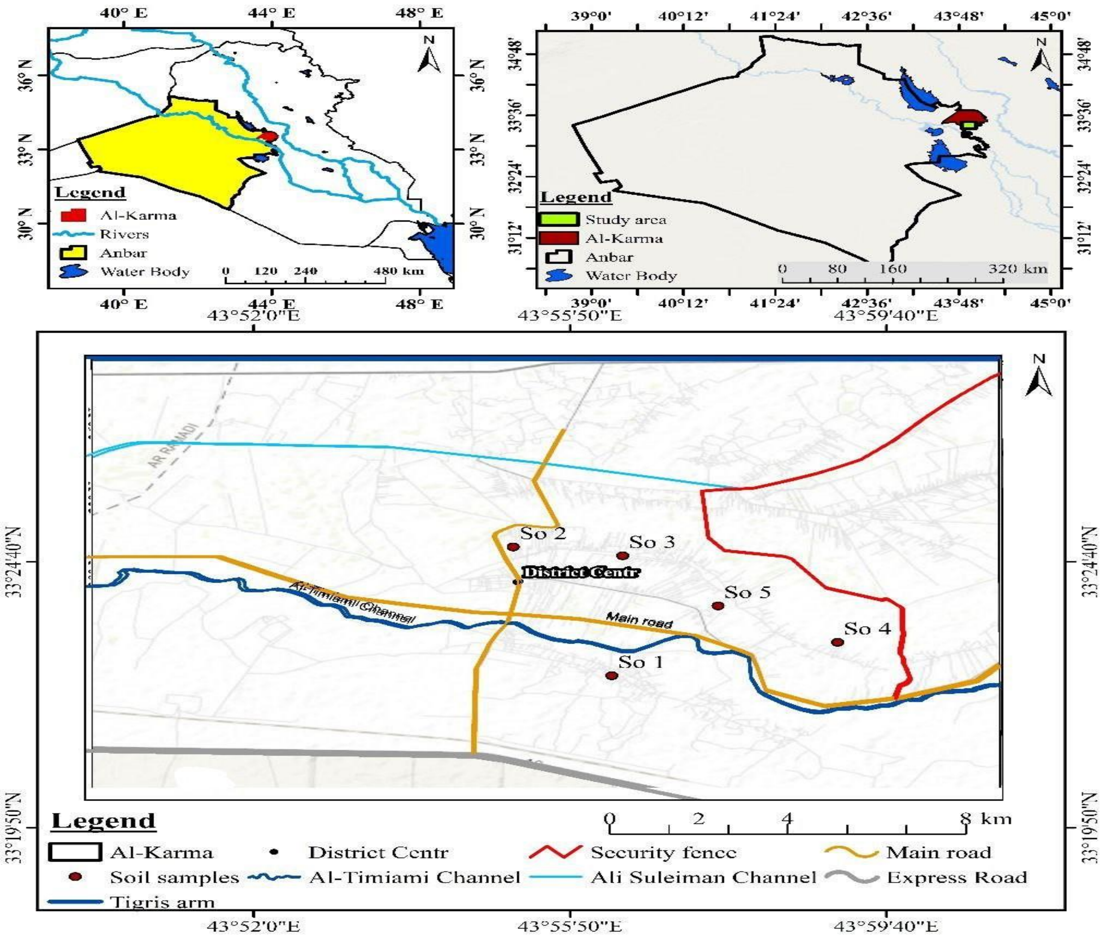

Figure 1: Map of the studied area.

1. Materials and Methods

1. The climatic data of the study area were obtained from the Iraqi Meteorological Organisation of Baghdad and Ramadi meteorological station for the period (1981-2023) (Iraqi Meteorological Organisation, 2024). The data was utilised to compute the surface runoff and recharge. Six elements, including Temperature (T), Sunshine duration (S.sh), Rainfall (P), Relative humidity (R.h), and Wind speed (W.S), were collected to determine their monthly averages. By using the Thornthwaite method [10], Potential evapotranspiration and Correct evapotranspiration are calculated by the equations (1,2,3,4,5, 6) below:

$$PE = 16\ (10\ t\ /\ J)\ a \text{ mm/month} \quad (1)$$

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

$$j = \left(\frac{t\ n}{5}\right)^{1.514} \quad (3)$$

$$a = 0.016\ J + 0.5 \quad (4)$$

Wherein:

PE = Potential evapotranspiration for each month (mm / month) t = Mean monthly air temperature (C°), n = Number month measurement, J = Annual heat index (C°)
j = monthly temperature parameter (C°), a= Constant

However, PE is a theoretical standard monthly value based on 30 days and 12 hours of sunshine per day. The actual PEc (corrected) evapotranspiration for the particular month with average temperature t° is given by:

$$PEc = PE * K \quad (5)$$

$$K = (DT/360) \quad (6)$$

Where: - PE_c represents correctly evapotranspiration (mm). K: Coefficient of correction of the hour from sunrise to sunset in the month, D is the month's Number of days, T represents the month table's average number of hours from sunrise to sunset, the correction coefficient, denoted by K, is derived monthly from Baghdad and Ramadi stations.

2. The deficit of water is excess of the corrected potential evapotranspiration more than rainfall throughout the rest of the months that year, whereas WS (i.e., water surplus) represents excess of rainfall more than the values of PEc [11] through particular months of the year, WS determined by equations (7 and 8) as below:

$$WS = P - PEc \quad (7)$$

$PEc = APE$, *when* $P > PEc$

$$WS\ \% = WS/P \times 100 \quad (8)$$

Here, WS represents Water Surplus (mm). PEc represents corrected evapotranspiration (mm). P represents the Rainfall (mm). APE represents Actual Evapotranspiration (mm). WD is determined by equations (9 and 10) as below:

$$WD = PEc - P \quad (9)$$

$$WD\ \% = 100 - WS\ \% \quad (10)$$

P = APE, if P <Pec, where in: WD: Water Deficit (mm).

During a period of water deficit, the actual evapotranspiration (APE) equals the rainfall (P) as the correct evapotranspiration (PEc) is higher than the rate of rainfall (P).

3. Calculating runoff by using the soil conservation services (SCS) and calculating groundwater recharge. The soil in the watershed and the cover conditions could be used to calculate the Curve number and Runoff [12]. This illustration shows the hydrologic soil group, vegetation type, cover type, and hydrologic conditions. Runoff was determined by equations (11 and 12) as below:

$$Rs = \frac{(P-Ia)^2}{(P+Ia)+s} \qquad P>0.2\ S \quad (11)$$

Rs: Runoff (mm) P: Total rainfall (mm). S: maximum potential retention after runoff (mm).

Ia = initial abstraction, the following empirical equation can approximate Ia: Ia=0.2*S by the reparations value Ia, the calculation becomes as below:

$$Rs = \frac{(P-0.2s)^2}{(P+0.8s)} \quad (12)$$

S: associated the cover condition and soil of the watershed through Curve Number (CN), where CN represents the range from 0 to 100, and S is linked to CN by:

$$CN = \frac{1000}{10+\frac{S}{25.4}} \qquad S \text{ in millimetre} \quad (13)$$

$$WS = Rs + Re + Sm \quad (14)$$

$$Re = WS - Rs - Sm \quad (15)$$

Re = groundwater recharge (mm), Rs = surface runoff (mm), Sm= Soil moisture.

Evapotranspiration was computed by using the Thornthwaite method.

To determine the type of climate, two classifications were used.

1. Mather (1974) [13], depending on the Aridity index (AI), which represents the ratio between rainfall and evapotranspiration,

The Aridity index is given as:

$$AI = [(P/PE)-1] * 100 \quad (16)$$

Wherever

AI = Aridity index AI on the study area, P= Rainfall (*millimeter*), PE_c = correctly evapotranspiration (mm)

2. **Al-Kubaisi** (2004) [14] classification. It was used to classify the research area's climate classification, which was based on temperature and rainfall. The study area's climate data from 1981 to 2023 was categorised as sub-arid. With the use of AI-1 and AI-2 as indicated in the equations (17 and 18) as below:

1. **Type 1 Mode**: This option is used for the possible climate zonation as Arid, Sub-arid and Humid, Moist.

$$AI\text{-}1=(1\times P)/(11.525\times t) \quad (17)$$

Where: AI: aridity index: Total rainfall (mm), t: average temperature (ºC) $t \neq 0$.

2. **Type 2 Mode**: This option is used to evaluate the sub-zones.

$$AI\text{-}2=2*\sqrt{p}/t \quad (18)$$

AI: represents the aridity index, P: Total rainfall (mm), t: represents the average temperature (℃). $t \neq 0$

3. Results and Discussion

3.1 Elements of climate

The average monthly values of six variables (T), (P), (R.H.), S.sh, WS, and Evap) [15] at Baghdad and Ramadi stations for the period (1981 -2023) are shown in Table 1. Rainfall is sometimes the primary source of lakes and rivers, and it is crucial for recharging groundwater in semi-arid and arid regions [16]. The total annual rainfall was recorded at the Baghdad and Ramadi stations as 124.7 mm and 110.6 mm, respectively (Fig. 2-A). Between 1981 and 2023, Monthly temperature varied between (10.1-35.4 °C), (9.4-34.5 °C) in Baghdad and Ramadi stations, respectively (Fig. 2-B)., and Monthly Relative Humidity varied between (23.5-68.74%), (31-74.98 %) in Baghdad and Ramadi stations, respectively (Fig. 2-C). Monthly Wind speeds varied between (2.5-4.1 m/sec) and (1.7-2.8 m/sec) in Baghdad and Ramadi stations, respectively (Fig. 2-D). Monthly Sunshine varied between (5.8-11.55 h/day), (5.4-11.8 h/day) in Baghdad and Ramadi stations, respectively (Fig. 2-E). Monthly Evaporation varied between (69.2-518.7 mm) and (66-435.7 mm) in Baghdad and Ramadi stations, respectively (Fig. 2-F).

Table 1: Mean monthly climatic parameters at Baghdad and Ramadi stations for the period (1981-2023) (Iraqi Meteorological Organisation 2024).

Months	Rainfall		R.H (%)		Temp. (c)		Wind Speed(m/sec)		sunshine(h/day)		Evapo.(mm)	
	Bagh.	Ram.	Bagh.	Ram.	Bagh.	Ram.	Bagh.	Ram.	Bagh.	Ram.	Bagh.	Ram.
Oct.	6.2	6.6	40.94	50.5	25.3	24.3	2.7	1.7	8.01	8.4	223.7	203.8
Nov.	21.8	15.6	57.55	63.47	16.9	16.1	2.5	1.8	6.92	6.7	110.6	116.6
Dec.	18	14.3	68.06	74.98	11.9	11.5	2.6	1.8	5.8	5.4	75	74.7
Jan.	24.9	19.8	68.74	74.9	10.1	9.4	2.7	2	5.89	6	69.2	66
Feb.	16.2	18.3	58.35	64.1	12.8	11.7	2.9	2.4	7.04	7.3	100	93.2
Mar.	18.5	15.5	48.52	55	17.5	16.1	3.4	2.6	7.66	7.8	173.6	149.8
April.	15.5	14.9	40.52	48.5	23.4	22.2	3.3	2.5	8.54	8.4	249.1	197
May.	3.4	5.2	30.71	40	29.5	27.7	3.4	2.6	9.81	9.4	354.3	279.9
Jun.	0	0.1	24.13	33	33.6	32.1	4	2.8	11.55	11.7	466.7	368.5
Jul.	0	0	23.5	31	34.9	34.5	4.1	2.8	11.47	11.8	518.7	435.7
Aug.	0	0	25.39	33.844	35.4	33.6	3.6	2.4	11.23	11.4	465	400.5
Sep.	0.1	0.3	30.42	38.82	31.3	29.8	2.9	2.1	9.97	10.3	342.1	296.9
total	124.7	110.6									3148	2682.6
Average			43.07	50.68	23.55	22.42	3.18	2.29	8.66	8.72	262.33	223.55

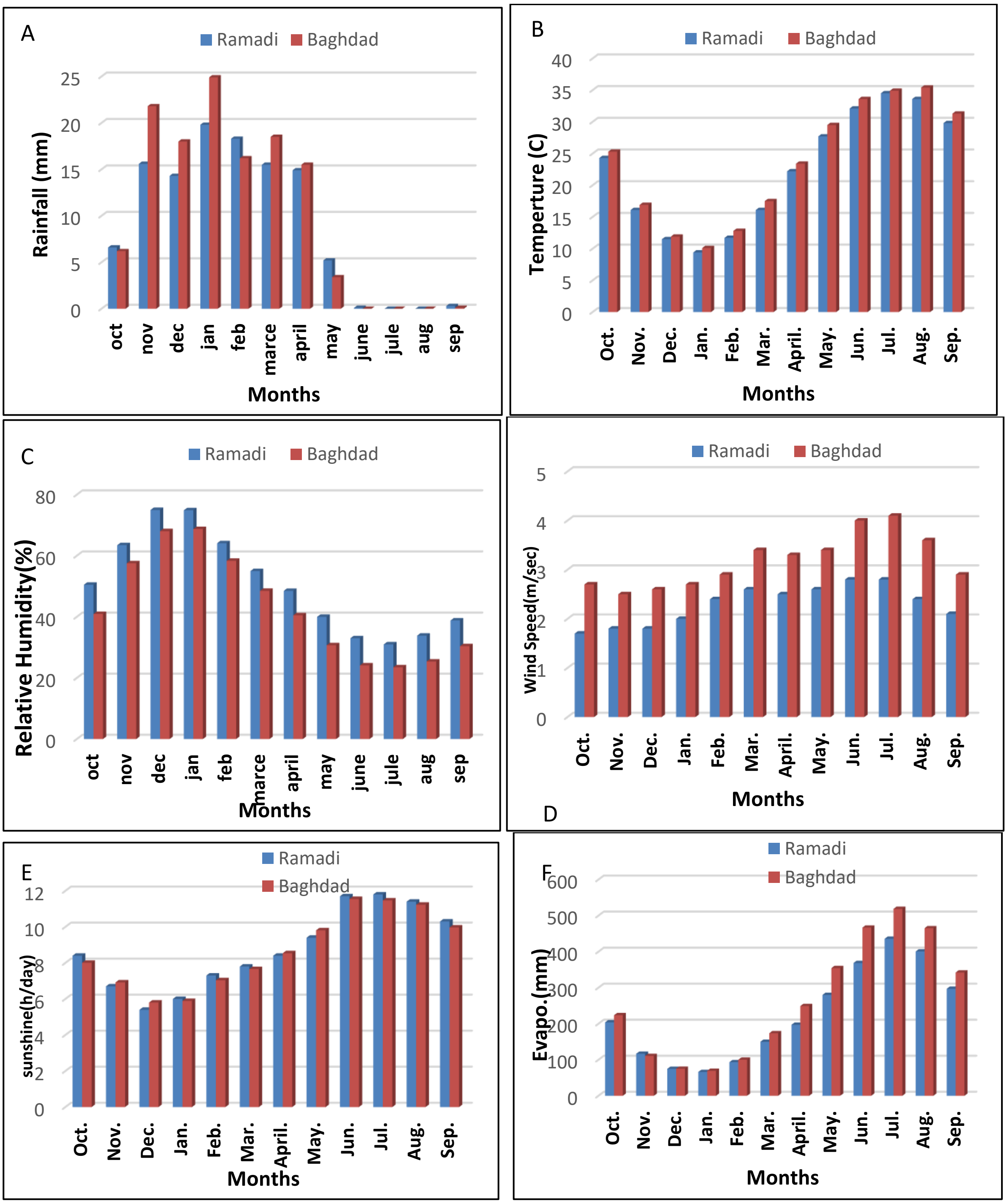

Figure 2: The elements of water availability for the period (1981-2023) at Baghdad and Ramadi stations.: (A) Average monthly of Rainfall (mm), (B) Average monthly of air temperature (ºC), (C) Average monthly of relative humidity (%), (D) Average monthly of wind speed (m/sec); (E) Average monthly of sunshine (hour/day), (F) Average monthly of evaporation (mm).

Evapotranspiration was calculated for the study area using the Thornthwaite method [10], as shown in Table 2. Potential evapotranspiration combines evaporation and transpiration, various processes of the climate that are carried out. The monthly evaporation-transpiration in the Baghdad and Ramadi stations for the period (1981- 2023). characterised by:

The annual evapotranspiration value is 964.84 mm in Baghdad and 937.60 mm in Ramadi. The highest evaporation-transpiration value occurs in August. The minimum value is 198.75 mm, which appears in January. 4.01 mm in Baghdad, and the highest evaporation-transpiration value occurs in July. The minimal value occurs at 201.46 mm in January, 4.21 mm in Ramadi.

Table 2: Monthly mean values of evapotranspiration for periods (1981-2023) at Baghdad and Ramadi meteorological stations, values calculated using the Thornthwaite method

Months	T(C°)		j=		PE (mm)		K		PEc (mm)	
	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.
Oct.	25.3	24.3	11.64	10.95	86.77	85.45	0.69	0.72	59.78	**61.81**
Nov.	16.9	16.1	6.32	5.87	30.15	30.85	0.58	0.56	17.11	**17.22**
Dec.	11.9	11.5	3.72	3.53	12.03	13.41	0.50	0.47	5.80	**6.24**
Jan.	10.1	9.4	2.90	2.60	7.83	8.14	0.51	0.52	4.01	**4.21**
Feb.	12.8	11.7	4.15	3.62	14.56	14.00	0.55	0.57	7.93	**7.95**
Mar.	17.5	16.1	6.66	5.87	33.03	30.85	0.66	0.67	21.47	**20.72**
Apr.	23.4	22.2	10.35	9.55	70.72	68.32	0.71	0.70	47.15	**47.82**
May	29.5	27.7	14.69	13.36	129.76	118.16	0.84	0.81	100.56	**95.64**
Jun.	33.6	32.1	17.89	16.70	182.48	170.19	0.96	0.98	176.77	**165.93**
Jul.	34.9	34.5	18.95	18.62	201.56	203.44	0.99	0.99	197.53	**201.46**
Aug.	35.4	33.6	19.36	17.89	209.21	190.56	0.97	0.98	198.75	**187.06**
Sep.	31.3	29.8	16.07	14.92	151.54	141.58	0.83	0.86	127.99	**121.53**
Total			**132.70**	**123.49**	**1129.63**	**1074.95**			**964.84**	**937.60**

The monthly rainfall in Baghdad station was higher than PE values in the months (January, December, February and November), there was an increase in water (WS), as shown in Figure 3. If the rainfall were less than the PE values, we would have WD, as shown in Table 3. As for Ramadi station, the rainfall was higher than PE values in January, December and February, as shown in Figure 4. If the rainfall were less than the PE values, we would have WD, as shown in Table 3.

WS % = 36.96 % in Baghdad station WS % = 30.75 % in Ramadi station

WD % = 63.04 % in Baghdad station WD % = 69.25 % in Ramadi station

Table 3: Water surplus and water deficit for the studied area for the period (1981-2023)

Months	Rainfall (mm)		PEc (mm)		APE (mm)		WS (mm)		WD (mm)	
	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.	Bag.	Ram.
Oct.	6.2	6.6	59.78	61.81	6.2	6.6	0.00	0	53.58	55.21
Nov.	21.8	15.6	17.11	17.22	17.1	15.6	4.69	0	0.00	1.62
Dec.	18	14.3	5.80	6.238	5.8	6.24	12.20	8.062	0.00	0
Jan.	24.9	19.8	4.01	4.208	4.0	4.21	20.89	15.59	0.00	0
Feb.	16.2	18.3	7.93	7.948	7.9	7.95	8.27	10.35	0.00	0
Mar.	18.5	15.5	21.47	20.72	18.5	15.50	0.00	0	2.97	5.22
Apr.	15.5	14.9	47.15	47.82	15.5	14.9	0.00	0	31.65	32.92
May	3.4	5.2	100.56	95.64	3.4	5.2	0.00	0	97.16	90.44
Jun	0	0.1	176.77	165.9	0.0	0.1	0.00	0	176.77	165.83
Jul.	0	0	197.53	201.5	0.0	0	0.00	0	197.53	201.46
Aug.	0	0	198.75	187.1	0.0	0	0.00	0	198.75	187.06
Sep.	0.1	0.3	127.99	121.5	0.1	0.3	0.00	0	127.89	121.23
Total	124.7	110.6	964.84	937.6	78.5	76.59	46.06	34.01	886.30	861.00

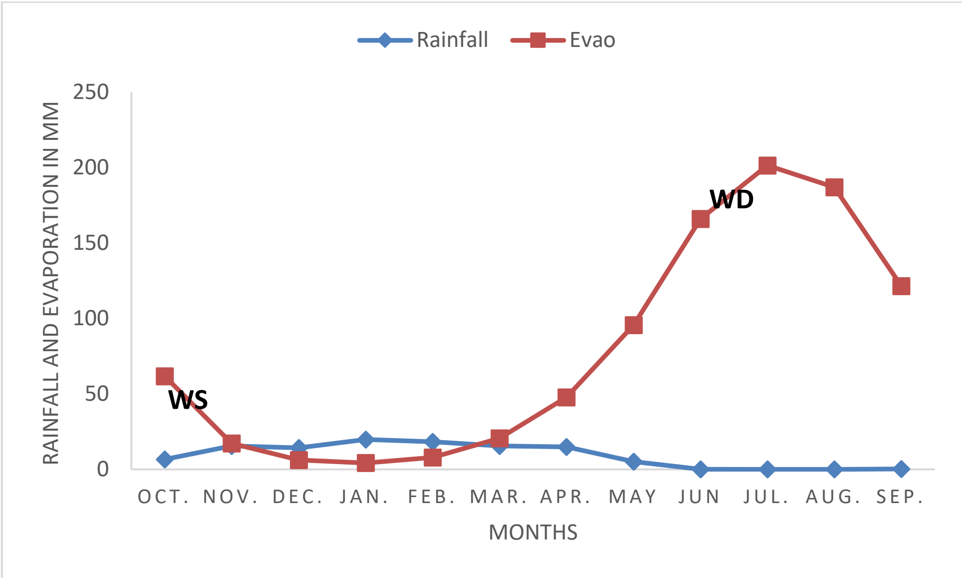

Figure 3: Water surplus and water deficit in the studied area in Baghdad for the period (1981-2023).

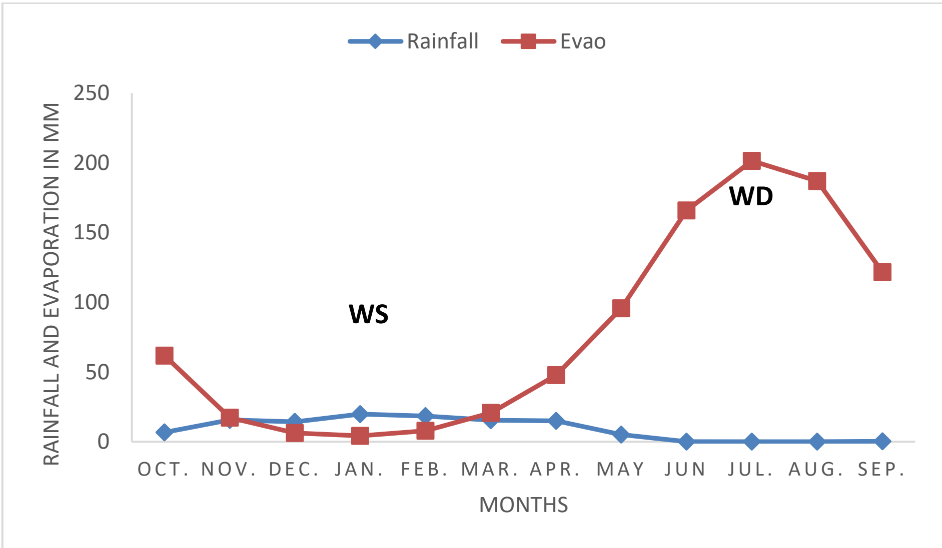

Figure 4: Water surplus and water deficit in the studied area in Ramadi for periods (1981-2023).

From the results above, the maximum WS was found in Baghdad stations compared to Ramadi station due to differences in climatic parameters, especially in rainfall and Evaporation values.

Soil Conservation Service (SCS)

It is among the most widely used techniques for calculating surface runoff (Rs) values using currently available rainfall data. The advantages of the curve number method include its simplicity and its correlation with watershed runoff-producing characteristics such as soil type, vegetation type, and surface conditions [17]. The drawback of the runoff curve number method is that it relies solely on rainfall, ignoring other meteorological factors, such as temperature, wind, transpiration, and evaporation [18]. The rates of leakage from the soil vary significantly depending on the type of soil; therefore, scientists divided the soil into several groups based on its ability to filter water.

Table 4: Four SCS hydrologic soil groups are defined [12].

Hydrologic soil group	Definition
A	Soils have low runoff potential, high rate of water transmission, and high infiltration rates even when thoroughly wetted., well to excessively drained sand or gravel.
B	Soils with moderately fine to moderately coarse textures. And moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures.
C	When completely wet, soils have low rates of water transfer and infiltration. They are mostly composed of soils with a layer that prevents water from moving downward and soils with a moderately fine to fine texture.
D	These soils feature very poor rates of water transfer, a clay pan or layer at or near the surface, a persistent high water table, and very low infiltration rates and heavy runoff.

Table 5: HSG classification according to the new surface soil texture [12]

HSG	Soil textures
A	**Sand, loamy sand, or sandy silt**
B	**Silt loam or loam**
C	**Sandy clay loam**
D	**Clay loam, silty clay loam, sandy clay, silty clay, or clay**

Table 6: Runoff curve number [12].

Soil type	A	B	C	D
Cover Type		Curve Number		
Water	100	100	100	**100**
Forest Land	38	63	75	**82**
Follow Land	68	79	86	**89**
Agricultural Land	67	78	85	**89**
Built up Land	**77**	**85**	**90**	**92**

The soil in the study area is silty clay loam [19]. The study area is Group D. These soils contain a clay layer at or near the surface, a consistently high water table, very low infiltration rates, significant runoff, and very poor water transfer rates, according to Tables 4, 5 and 8, which show that the soil is composed of silt and clay. 5 samples were collected from the soils of the study area as shown in Figure 5, and the classification [20] was used to determine the type of soil to calculate CN

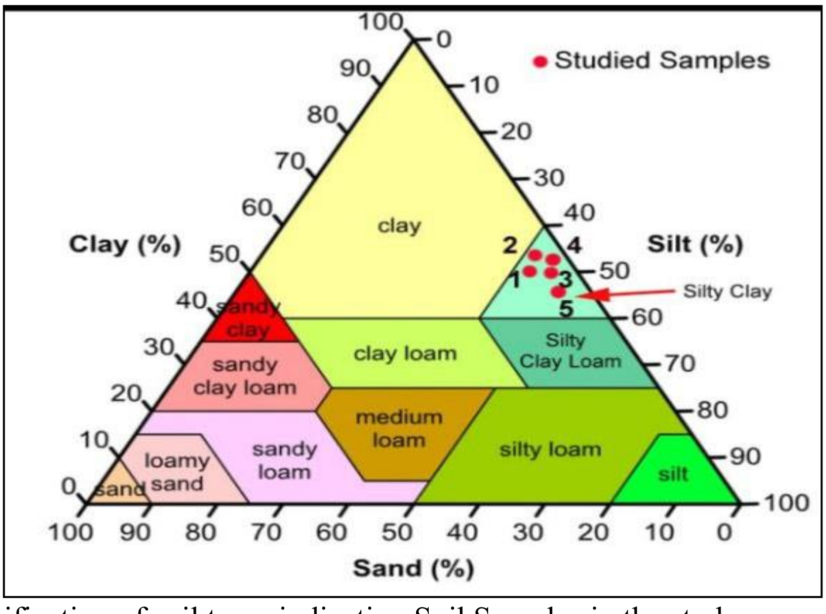

Figure 5: classification of soil type, indicating Soil Samples in the study area

Table 7: The outcomes of examining grain size and type of texture of AL-Karma area soil.

Sample Number	Percentage of Sand%	Percentage of Silt%	Percentage of Clay %
1	13.9	47.5	38. 6
2	12.4	43.8	43.8
3	10.7	49.2	40.1
4	10.2	47.7	42.1
5	10.3	53.8	35.9

Table 8: The research area's monthly runoff values.

Month	P		WS		CN	S	Rs	
	Bag.	Ram.	Bag.	Ram.			Bag.	**Ram.**
Oct.	6.2	6.6	0.00	0			0	**0**
Nov.	21.8	15.6	4.69	0		31.39	5.14	**0**
Dec.	18	14.3	12.20	8.062		31.39	3.19	**1.63**
Jan.	24.9	19.8	20.89	15.59		31.39	6.93	**4.07**
Feb.	16.2	18.3	8.27	10.35		31.39	2.38	**3.33**
Mar.	18.5	15.5	0.00	0			0	**0**
Apr.	15.5	14.9	0.00	0			0	**0**
May	3.4	5.2	0.00	0			0	**0**
Jun.	0	0.1	0.00	0	89		0	**0**
Jul.	0	0	0.00	0			0	**0**
Aug.	0	0	0.00	0			0	**0**
Sep.	0.1	0.3	0.00	0			0	**0**
Total	**124.6**	**110.6**	**46.06**	**34.01**			**17.64**	**9.03**

To calculate the Rs and Re depend on water surplus WS using the equations as follows:
WS= Rs+ Re+Sm
Re = WS – Rs -Sm
Re = groundwater recharge (mm), Rs = surface runoff (mm), Sm= Soil moisture.
Soil moisture = 15 mm
Re= 46.06 - 17.64 - 15 → Re=13.42 mm for Baghdad
Re= 34.01 - 9.03 - 15 →Re= 9.98 mm for Ramadi
Re % = Re/ P *100 →Re % = (13.42 /124.6) *100= 10.8 % for Baghdad
Re% = (9.98/110.6) * 100= 9.03% for Ramadi represents the percentage of groundwater recharge from the rainfall.

As the study area is located between Baghdad and Ramadi stations, the surface runoff and groundwater recharge rates were measured for these two stations. The surface runoff rate was 13.34 mm, while the groundwater recharge value was 11.7 mm.

Classification of climate:

1. Mather classification

Table 9: Climate classification according to [13]

AI on Studied area	Range of AI	Climate type
Dry-sub humid	0.0 to -33.3	
Semi-Arid	-33.3 to -66.6	
Arid	**-66.6 to -100**	**-88.96 in Baghdad** **-89.71 in Ramadi**

Dependent on the classification suggested by Mather (1974). The values of the Aridity Index (AI) are as follows:
AI = {(124.6/1129.63) -1} *100= - 88.96 in Baghdad station and -89.71 in Ramadi station. Therefore, the aridity Index is -88.08 and -89.71 at the Baghdad and Ramadi stations, so the study area is an arid region.

2. Al-Kubaisi Classification

This classification was proposed by [14] to determine the climate type and aridity index based on the average temperature (T) and the amount of rainfall (P) in two stations (Baghdad and Ramadi), as shown in Table 10.
According to the Total rainfall and average temperature of the study area, where AI-1 = 0.459 and AI-2 = 0.947 and AI-1 = 0.428 and AI-2 = 0.938 in Baghdad and Ramadi stations, respectively, the climate classification of the studied area can be classified as sub-arid and arid in both stations.

Table 10: Climate classification according to [14].

Type .1	Evaluation	Type. 2	Evaluation
		AI-2> 4.5	**Humid**
AI -1> 1.0	Humid to moist	2.5< AI-2< 4.0	**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**
In the study area **AI-1= 0.459 in Baghdad and 0.428 in Ramadi**	**Sub arid to arid**	**AI-2== 0.947 in Baghdad and 0.938 in Ramadi**	**Arid**

Conclusions

In the Al-Karma area, Runoff and recharge values were calculated using climate data from 1981 to 2023 at Baghdad and Ramadi stations. The parameters of Temperature (T), Rainfall (P), Relative humidity (R.H.), Wind speed (W.S.), Sunshine (S. Sh.) and Evaporation (PE) were studied. The results show that the highest values of T, P, W.S. and PE were recorded at the Baghdad station, while the other parameters, R.H. and S.Sh., were recorded at their highest values in Ramadi station. This variation in climatic parameters is attributed to elevation, agricultural practices, the desert's natural characteristics and human activities. The average of runoff and recharge values in both stations (Baghdad and Ramadi) were 17.64 mm, 9.03 mm, 13.42 mm, and 9.98 mm, respectively. Depending on the climate data of both stations, the study area was classified as Arid and Sub-arid. Finally, the water surplus (WS) and deficit (WD) were estimated at two stations (Baghdad and Ramadi). It was found that the measurements were 46.06 mm and 34.01 mm at the Baghdad station, while those at the Ramadi station were 886.30 mm and 861mm.

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