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Climate Parameter Uses as Indices For Assessment of Climate Change and Water Balance in Erbil Sub-Basin North –Iraq

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Abstract

The main goal of this study was to assess the climatic parameters in a valuable basin in northern part of Iraq, Erbil central sub-basin. Rainfall, relative humidity, temperature, evaporation, sunshine duration, and wind speed are the climate variables used in this study. The investigated periods (1980-2021) of Erbil meteorological data were used to assess the climatic and drought conditions in the studied basin. The results show a noticeable drop in relative humidity and rainfall over the past two decades, as well as a considerable rise in temperature and evaporation. The mean annual rainfall was 416mm, relative humidity is 48.74% used as term of water availability, and mean annual temperature is 22°C, total annual evaporation was 2257.59mm, sunshine duration was 8.2 hours/day, and wind speed is 1.7m/s were used as water loss elements. Kharufa technique was applied to determine the potential evapotranspiration, water deficit and water surplus periods. According to the findings, there is a total of 2257.59 mm of potential evapotranspiration, water excess, and water deficit, 89.22mm, and 1953.95mm, respectively. Annual surface runoff was 37.85mm, and annual recharge from rainfall was 13.07%. Alkubaisi classification for climate type were utilized to identify the Erbil central sub-climatic basin's type. The results showed that the climate is arid based on the initial categorisation, moist to sub-arid according to the second cataloguing, and dry according to the third cataloguing.

Keywords: Climate change, climate parameters, water balance, climate classification, and Erbil sub-basin

استخدام المعلومات المناخية كمؤشرات لتقييم تغير المناخ والموازنة المائية لحوض اربيل الثانوى – شمال العراق

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الخلاصة

الهدف الأساسي من الدراسة الحالية هو تقييم متغيرات الأرصاد الجوية والتوازن المائي في حوض أربيل الثانوي ، وهو حوض مهم للغاية في المنطقة الشمالية من العراق.المتغيرات المناخية المستخدمة في الدراسة الحالية هو هطول الأمطار ، والرطوبة النسبية ، ودرجة الحرارة (المتوسط ، والدنيا ، والحد الأقصى) ، والتبخر ، ومدة ضوء الشمس ، وسرعة الرياح. في الدراسة الحالية تم تحديد نوع المناخ لمنطقة البحث وحالة الجفاف

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وبيان كمية الامطار الساقطة باستخدام البيانات المناخية خلال السنوات 1980 إلى 2021 من محطة الأرصاد الجوية في أربيل. وأظهرت النتائج انخفاضًا ملحوظًا في الرطوبة النسبية وهطول الأمطار خلال العقدين الماضيين ، فضلاً عن ارتفاع كبير في درجات الحرارة و التبخر. بلغ متوسط هطول الأمطار السنوي 416 ملم ، والرطوبة النسبية 48.74٪ كمصطلح توافر المياه ، ومتوسط درجة الحرارة السنوية 21.98 درجة مئوية ، والتبخر السنوي الكلي 2257.59 ملم ، ومدة سطوع الشمس 8.2 ساعة / يوم ، وسرعة الرياح 1.7 متر / ثانية كعناصر فقدان الماء. تم تطبيق تقنية خاروفة لتحديد فترات التبخر والنتح المحتملة وعجز المياه وفترات فائض المياه. وفقًا للنتائج ، بلغ مجموع التبخر السنوى 2257.59 ملم من التبخر المحتمل ، وفائض المياه 89.22 ملم وعجز المياه 1953.95 ملم ، على التوالي. بلغ الجريان السطحي السنوي 37.85 ملم ، والتغذية السنوية من الأمطار كانت 13.07٪. استخدمت تصنيق Alkubaisi لتحديد نوعية المناخ السائد فى السنوات الاخيرة . وأظهرت النتائج أن المناخ رطب إلى جاف حسب التصنيف.وهذا يؤتى مؤشر بان المناخ الموجود فى مدينة اربيل قد تغير خلال اربعين السنة الماضية وهومؤشر واضح بأن مناخ المدينة متأثرة بظاهرة الاحتباس الخرارى.

1. Introduction

Due to growing usage of the world's resources in recent years, humans have been impacted by global climate change. As a result, between 1850 and 1990, the average yearly air temperature over the world increased by around 0.5°C. Due to the growing usage of fossil fuels, carbon dioxide levels have grown by around 25%. Both respiration and volcanic eruptions release carbon dioxide (CO_2) [1]. The waters disperse it, and plants eat it during photosynthesis. There are currently 359 parts per million by volume (ppm) of CO_2 in the atmosphere, a concentration that is increasing as a result of anthropogenic emissions. The semi-arid climate of Iraq has scorching, dry summers and chilly, wet winters. Rainfall occurs between November and April, with May being the exception. While, May to October months, are the hottest and with no rain [2]**.** In Iraq, the highest recorded temperatures vary from above 48°C in July and August to below zero °C in January [3]. Hydrologic catchments are influenced hydrological mechanisms like evaporation and precipitation, and the interaction of rivers and aquifers because they are part of the universal water cycle. If the basin's meteorological circumstances and climatic factors are known, the valuable notion of the water balance may be utilized **[**4]. Meteorological and water balance study aimed to clarify and obtain a good imagination of flood and drought forecasting, climate change impact assessments, reservoir management, water resources and water quantity. Hence, this integration will provide better understanding into the water resource management in Erbil basin.Using hydro metrological tools such as: First Investigate evapotranspiration, water loss, and availability of water. Second achieve hydrometeorological data to evaluate the rainfall variation analysis (monthly, seasonally, and annually).Third determining the basin's water surplus and deficit using multiple techniques. Forth determine runoff, recharge, and other water balance parameters, and fifth determine the climate category and the effect of climate change in the area based on climate factors.

1. Description of the study area

The study area is located in Erbil province in northern Iraq, with a total area of approximately 1400 km^2 (3.5% of Iraq). The territory of the city of Erbil is around 70 km^2 large inside the 1400 km^2 core basin of the Erbil plain. The region has an average elevation of 412 meters and is bounded on the north by latitude 36^{o}08'30''-36^{o}14'15''N and by longitude 43° 51'20''-44° 12'28''E on the east (Figure 1). Tectonically the basin is located in low folded zone, while the oldest exposure geologic formation is Bai-Hassan (Upper Bakhtiari) Formation (Pliocene)in western part of the basin, but most part of the basin are covered by quaternary these deposits are non-effected by Alpine orogeny, consist of clay, loam silt, sand,

and gravel. The Quaternary deposit is unconformable with underlying unit (vertically and horizontally appeared gravel (repeat) coarse, medium, and fine grain size) [5]. The age of quaternary deposits is Pleistocene to Holocene. These deposits were divided according to our field expert:

River Terrace

River terraces were produced by recent flood plain exposed along each side of valley, produced by variation in base level or by climate variation in area along valley. The age is Pleistocene; consist of rock fragment limestone, fragment, gravel (silica) and little amount of igneous and metamorphic rock fragments.

Flood Plain Deposit

The sediments originate as a result of river erosion during flood periods. They consist of clay, silt, sand, and gravel with some fine pebbles, and rock fragment. The age of this deposit is Holocene.

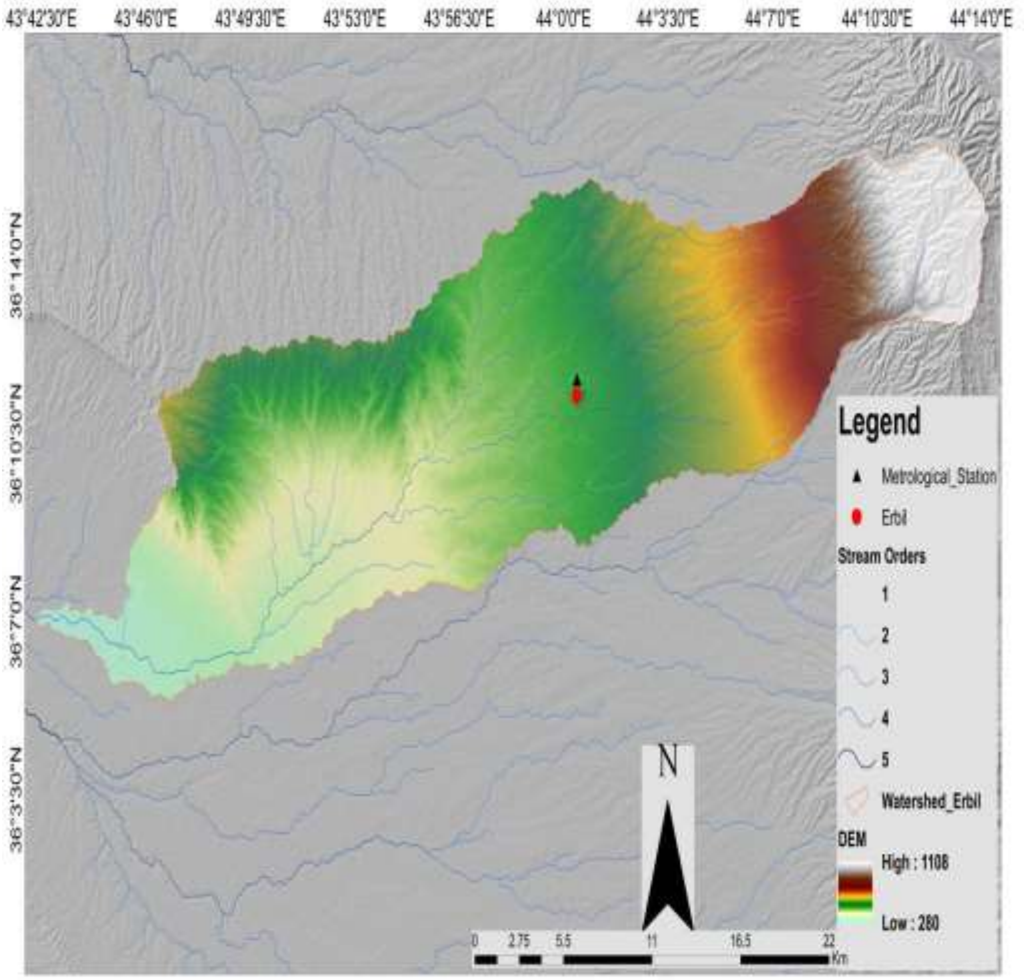

Figure 1: Erbil Central Sub-Basin Map.

2. Climate

Hydro-meteorological measurements aid in the planning, managing, creating, and building of water resources. They generate the data required for hydrologic and developing models.

The hydro-meteorological strategy for water balancing is frequently utilized when the production of a small basin, within which urbanization occupies a portion, is recognized.

Empirical methods were taken into consideration because such output isn't always available. As a consequence, probable water surplus and deficit periods are identified using the input parameters for this type of water balance. The factors in first set of these characteristics have to do with water availability, while the ones in the second group have to do with water loss [6]. The main air masses that influence the climate are the marine and continental three types of air masses: Polar air masses, tropical air currents on land, and tropical air masses at sea. The semi-arid climate of the study region is recognized for having annual precipitation totals of less than 500 mm [8] (Figure 1). Compared to the northern and northeastern zones of the research area, the air temperatures are greater, and a blizzard is uncommon. According to [9], the climate is continental and is characterized by scorching summers and chilly, wet winters. The steppe climatic region is known for having scorching summers and chilly, wet winters [10] [11] [12].

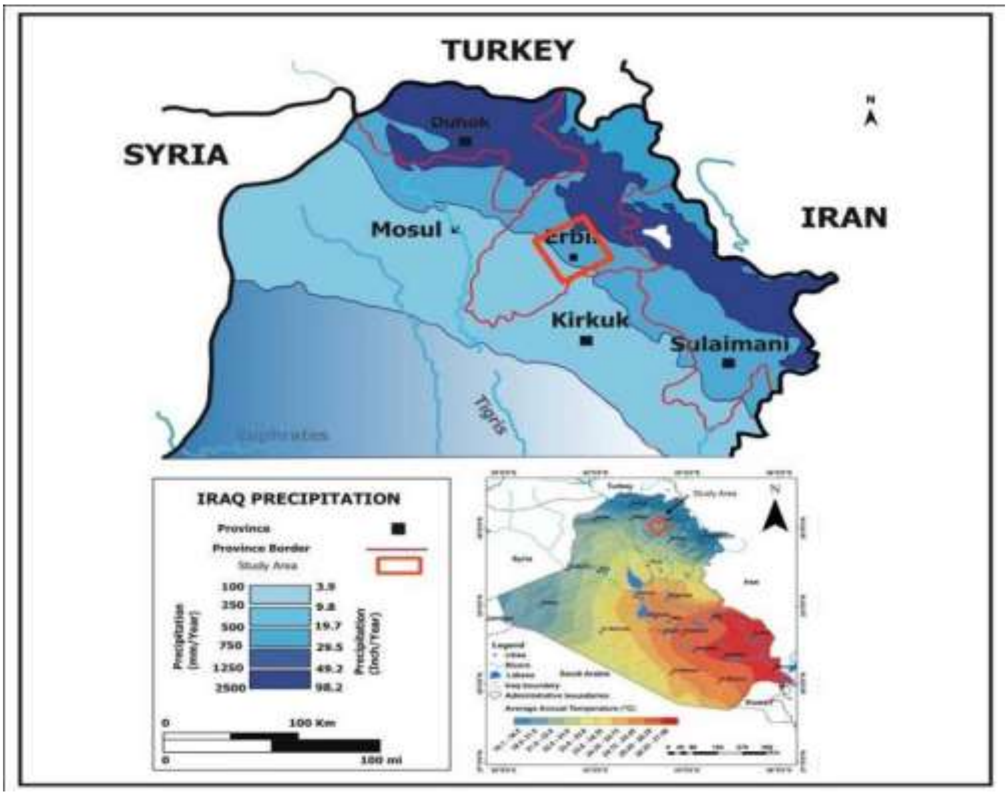

Figure 2: Shows rainfall in the city of Erbil according to spatial distribution [13]

The impacts of global warming in Erbil have been documented. His key conclusions and assumptions for this study included declining detrimental impacts on plants and soil, increased precipitation per year, boosting the monthly average temperature and altering the present precipitation trends (especially in low-rainfall areas), accelerating evaporation and evapotranspiration.

Meteorological data from the Erbil station were utilized to assess the hydroclimatic state of the Erbil basin since this station, located at latitude 36°.12' N and longitude 44° 02' E, provides a reliable source of information, and elevation 420m above nasty sea level, is used for analyzing and studying weather information between 1980 and 2021. Precipitation, surface temperature, sunshine duration, relative humidity, evaporation, and other climatic variables were used in the current study, which launched in Erbil and was eventually covered by the installation of a meteorological station.

3. Materials and Methods

3.1. Water Availability Elements

The primary factors of water availability are rainfall and relative humidity, together with resources to battle climate change and surplus water.

3.1.1. Precipitation

Data that have been reported indicate [8] the yearly precipitation varies from year to year, and this is also true for the monthly and daily precipitations. From 1980 to 2021, the year 2018 had the highest annual precipitation with 733.6 mm, the lowest with 229 mm, and the average was 416 mm (Table 1 and Figure 2) **.** The whole period has four cycles. First cycle started from 1980 to 1990 the highest in 1988 was 626.9 mm, and lowest in 1983 was 302 mm. Second cycle is from 1991 to 2000 the highest was 751mm in 1992, while the lowest in 1999 was 232mm. Third cycle was from 2001 to 2010, highest was 487mm in 2003, while lowest was 229 in 2008. Fourth cycle was from 2011 to 2021, the highest was 789 mm in 2019, while lowest was 198 mm in 2021. March 2019 saw 220 mm of precipitation, which is the highest monthly total between 1980 and 2021. Maximum average monthly rainfall for the period from 1980 to 2021 is 70.4 mm in March in the study area **(**table 1,2 and figure 3, 4). Minimum average rainfall measured in July and August (no rainfall). Throughout the year, November, December, January, February, March, and April are the wettest months, which together account for 98% of the year's total precipitation. But the almost dry months are June, July, August, and September. According to rainfall data from 1980-2021, there is significant shortage in rainfall especially from 1999 to 2021 (Figure3, and Table 1).

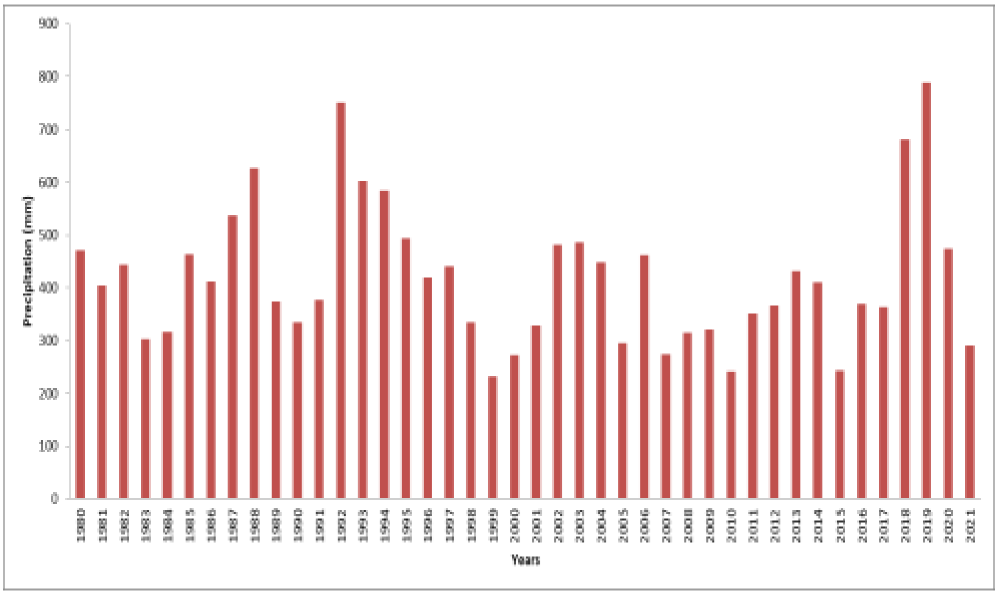

Figure 3: Annual precipitation in Erbil 1980 to 2021

Table1: Mean yearly precipitation in Erbilfrom1980 to 2021

Years	Precipitation (mm)	Years	Precipitation (mm)
1980	471.5	2001	328.7
1981	404.4	2002	481.4
1982	444.1	2003	487.3
1983	302	2004	448.5
1984	315.9	2005	295.2
1985	463.9	2006	462.4
1986	412	2007	273.5
1987	536.9	2008	229
1988	626.901	2009	321.2
1989	373.302	2010	241.2
1990	335	2011	351.7
1991	376.501	2012	366.4
1992	751.74	2013	431.8
1993	601.7	2014	410.1
1994	583.4	2015	243.7
1995	494.4	2016	369.9
1996	418.89	2017	363.9
1997	441.6	2018	681.5
1998	333.9	2019	789.1
1999	232.5	2020	474.4
2000	272.3	2021	198
AV			416

Table 2: Mean monthly precipitation (mm) in Erbil from 1980 to 2021

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Mean	20.6 7	38.5 9	69.50	67.19	62.00	70.40	45.59	14.5 6	1.3 2	0.0 7	0.03	2.89
Max	89.6 0	132. 9	187.8 0	174.4 0	189.0 0	220.1 0	123.5 0	74.6 0	9.1 0	1.3 0	1.00	32.6 0
Min	0.20	0.00	8.90	1.60	8.20	6.40	0.30	1.30	0.0 0	0.0 0	0.00	0.00

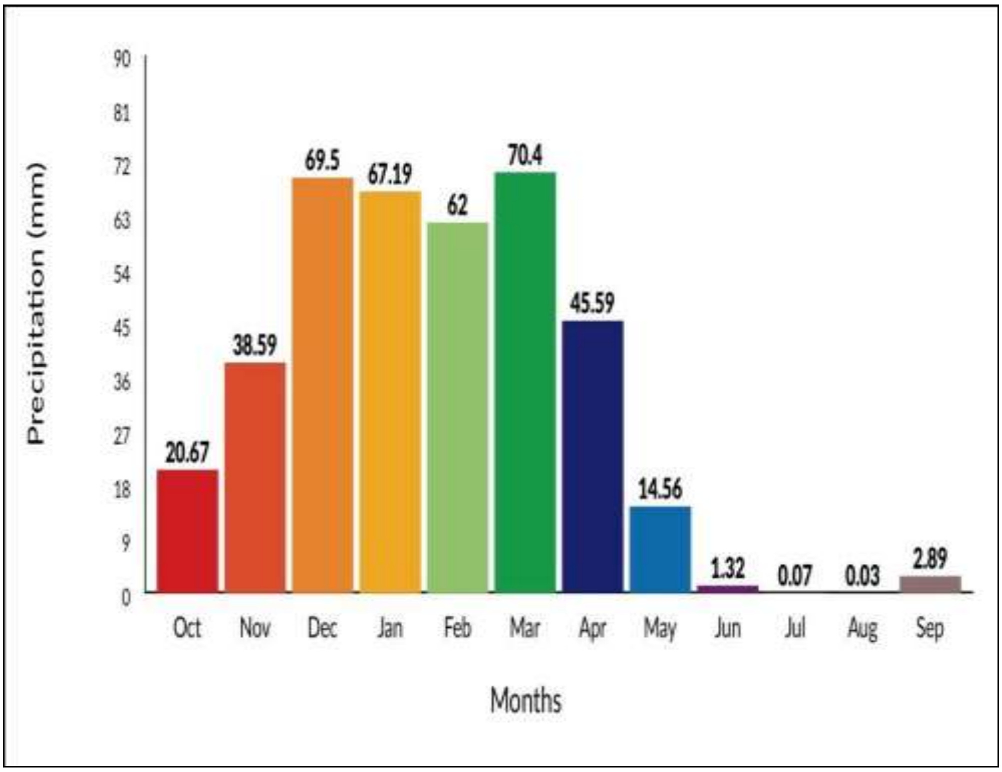

Figure 4: The average monthly precipitation of Erbil for the period between 1980 and 2021

3.1.2. Relative Humidity

The picture is not complete after a vapor pressure value has been established until that worth is contrasted with the fullness vapor pressure at the air's temperature. Result of relative humidity is defined as the difference between the vapor pressure (e) and the saturation vapor pressure (es(t)) at the corresponding temperature (h) [14].

H=100 e/es(t) ……………………………………………………………………………… (1)

Keeping in mind the concept of dew point temperature provided previously, we obtain

H=100 es(td)/es(t) ………………………………………………………………………… (2)

And never es(td) can be greater than es(t). For an interpretation see (Table3,Figure5) When h = 100%,

Condensation results upon reaching saturation.

Some exposed surfaces frequently warm up to a temperature that differs from the air. An equal relative humidity for such surfaces is defined as:

H=100 e/es(ts)=100 es(td)/es(ts)

Where ts is the current surface temperature. For instance, a surface that is colder than the air (ts t) would facilitate soaking more readily than the surrounding air. This explains why dew can occasionally develop on plant leaves even the relative humidity in the air has not reached 100%. Similar expressions might be defined by taking into account the saturation pressure for ice.

Hygrometers are tools that measure relative humidity directly. Instead of using digital hygrometers, analogu hygrometers employ the variation in length that human hair especially that of a blond woman, experiences with a change in relative humidity which typically based on some change in the electric properties of some material as a function of the relative humidity of the air.

Table 3: Mean monthly relative humidity (%) in Erbil for the years 1980 to 2021.

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Mean	45.00	59.72	67.98	71.68	67.48	60.04	53.63	39.93	29.85	27.20	28.96	33.49
Max	63.00	73.60	82.10	83.00	78.90	74.40	71.30	55.60	39.10	34.30	35.10	53.00
Min	34.50	45.20	53.80	59.50	50.00	35.00	26.00	23.00	22.00	22.00	24.60	24.50

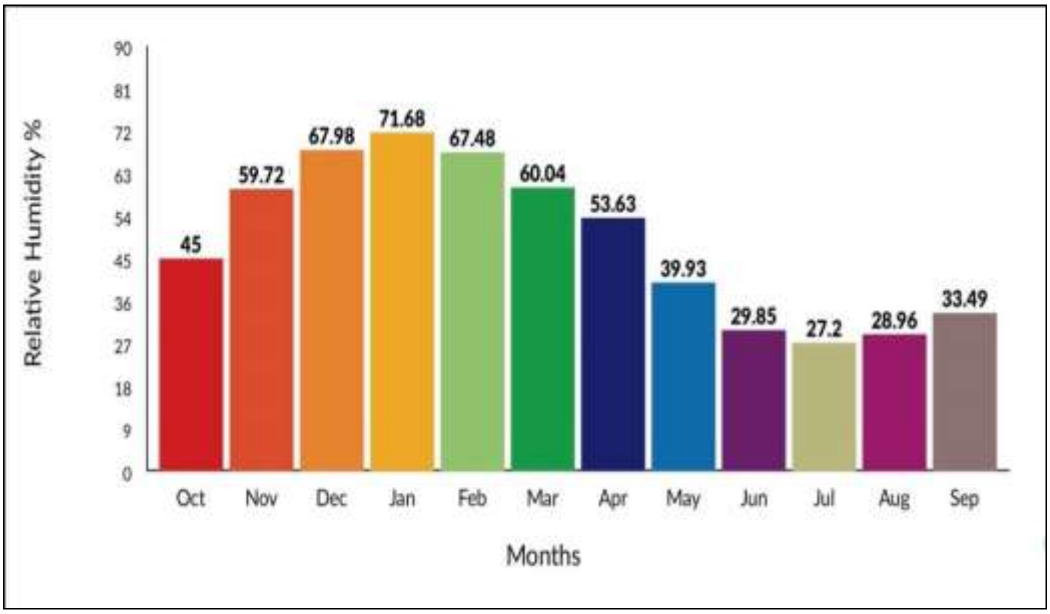

Figure 5: The Erbil average monthly relative humidity for the years 1980 to 2021.

3.2. Water Losses Elements

3.2.1. Temperature

The most important climatic factor is temperature aspect because it both directly and indirectly impacts all other weather and climate aspects and circumstances. The terrain, length of the sun's rays, latitude position, as well as additional land and plant characteristics, all have a direct impact on air temperature. The average monthly temperature for a year follows a pattern that is essentially constant from year to year. Between 1980 and 2021, the Erbil meteorological station's lowest average temperature was 5.95 °C until January 2008. 38.8 °C was the highest average temperature for the same period in August 2006. At the time, the average temperature was 22°C. The typical yearly temperature clearly shows that the climate is warming (i.e., the climate in the area is warming) (Figure 6). Figure 6 demonstrates a significant increase in the median annual temperature at the Erbil station from 1998 to 2021.

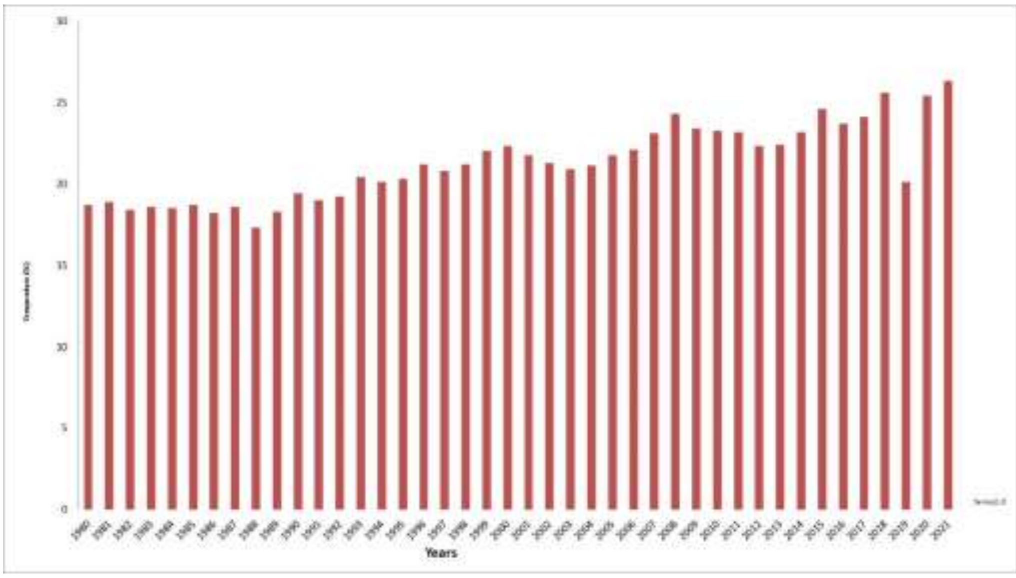

Figure 6: Average annual temperature for the period 1980 to 2021 in Erbil.

According to averages (mean, maximum, and minimum), January was indeed the coldest month, and July was the warmest (Table 4; Figure 6).

Table 4. Erbil's average monthly temperature from 1980 through 2021 (in degrees Celsius) (data was collected from Erbil meteorological station).

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Mean	24.36	15.88	10.52	8.97	10.76	14.97	19.59	26.54	32.09	35.02	34.70	30.04
Max	25.80	19.27	13.80	11.86	12.85	17.60	28.29	29.56	34.21	36.58	36.60	32.70
Min	22.35	12.55	6.00	5.950	8.55	11.20	15.72	24.45	30.70	33.10	32.50	27.31

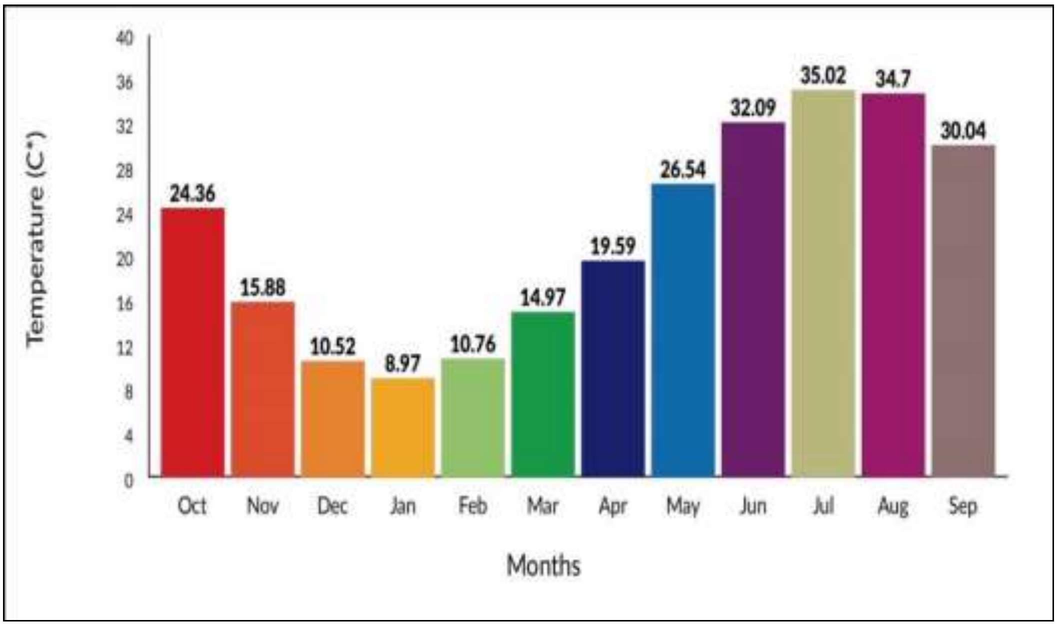

Figure 6: Average monthly temperature from 1980 to 2021 in Erbil.

3.2.2. Sun Shine Duration

The highest value was recorded in July while the monthly average lowest duration is 4.88 hours per day, there are 11.86 hours of sunlight every day. The average yearly sunshine duration was 8.2 hours/day from 1980 to 2021. (Table 5; Figure 7).

Table 5: Monthly sunshine mean (h/day) extent in Erbil from 1980 to 2021

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
P%= (h)	7.76	6.42	5.32	4.88	5.61	6.59	7.55	9.42	11.67	11.85	11.22	10.18

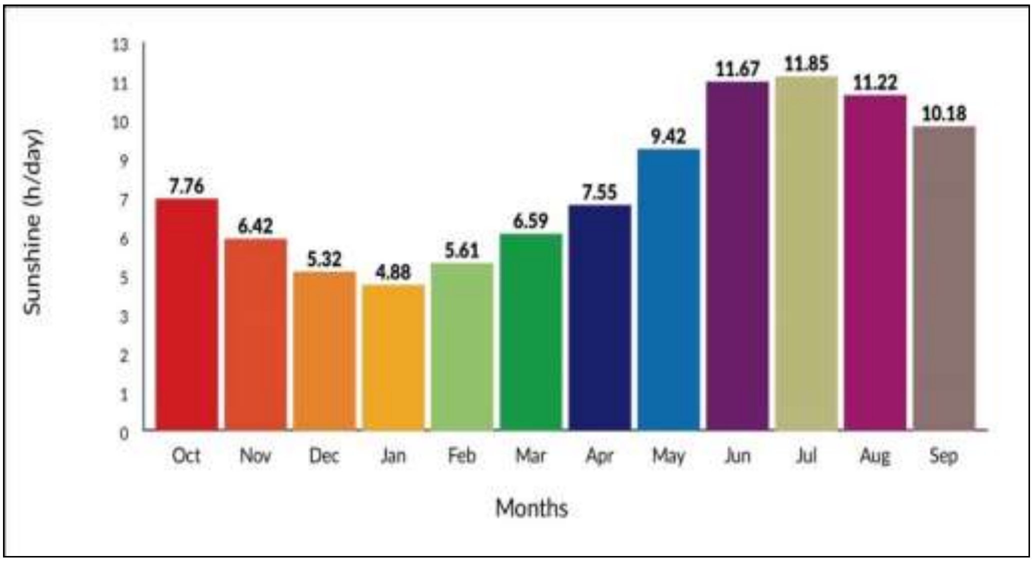

Figure 7: In Erbil, the average monthly sunlight duration ranged from 1980 to 2021

3.2.3. Wind Speed:

At the metrological station in Erbil, the daily average wind speed was 3.5 m/s. The average maximum and minimum worth for this limit in the research region is 0.1 m/s and 0.2 m/s, respectively, in the months of March and November. The average yearly wind speed at the Erbil station from 1980 to 2021 is shown in Table (6) and Figure 8.

Table 6: The average monthly wind speed at the Erbil weather station during 1980-2021

Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	1.75	1.38	1.47	1.76	1.95	2.10	2.18	1.97	1.98	1.66	1.69	1.46
Max	2.30	2.50	2.30	3.40	3.00	3.40	3.50	3.00	3.00	2.50	3.00	2.30
Min	0.10	0.20	0.20	0.20	0.10	0.20	0.20	0.20	0.10	0.10	0.10	0.10

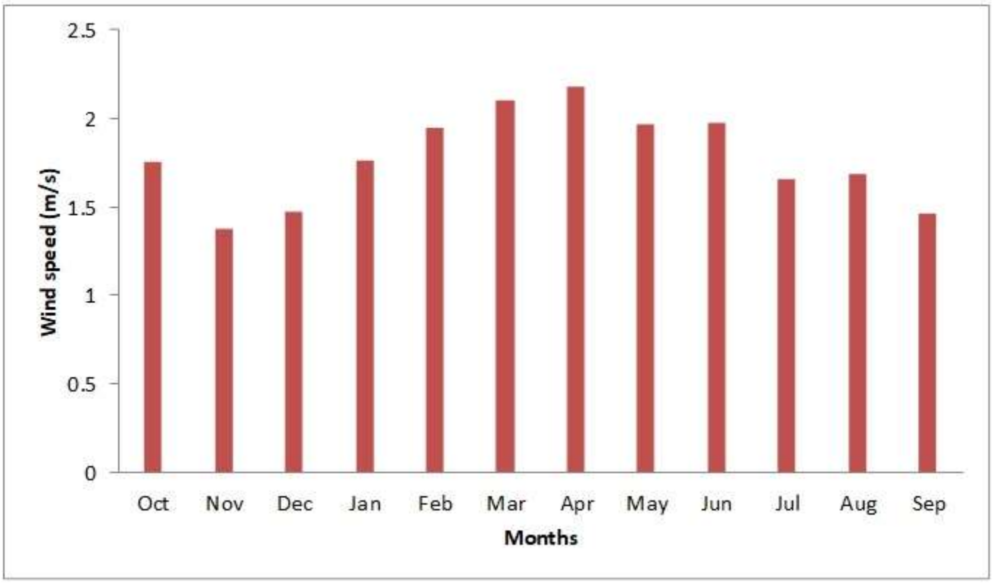

Figure 8: From 1980 through 2021, the average monthly wind speed at Erbil Station

3.3. EVAPORATION from class (A) pan

A technique for determining free water evaporation is to evaluate evaporation from a class (A) pan. Evaporation is determined by calculating using the change in water level in the pan. The pan coefficient, which typically has an annual average of approximately 0.7 but fluctuates from season to season owing to changes in heat storage, is the ratio of lake evaporation to pan evaporation. [15] Developed this formula to determine depending on pan evaporation and air temperature, daily free water evaporation:

$E_{fw} = 0.7 * (Tspan * Ta|^{288}) * [E_{pan} \underline{+} 0.064 * P * a_{pan} * (0.37 + 0.00255 * v_{pan})]$ ……. (3)

E_{fw}: Evaporation free water (mm/day)
T_{span}: The pan's water surface temperature (°C)
T_a: Temperature air (°C)
E_{pan}: evaporation pan (mm/day)
P: Pressure atmospheric (KPa)
a_{pan}: Part of the energy is exchanged through the sides of the pan.
v_{pan}: At a height of 15 cm above the pan, the average wind speed (km/day)
From 2001 to 2021, the Erbil meteorological station's Class-A pan calculations of the average monthly evaporation are published in (Table 7 and Figure 9).

Table 7: Mean monthly evaporation (mm) measurements with a Class-A pan in Erbil during period from 1980 to 2021

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Mean	6.40	3.16	1.87	1.70	2.48	4.01	5.78	9.39	12.76	13.60	12.89	9.72
Max	9.70	4.80	2.60	2.80	4.30	6.50	10.20	12.60	15.60	17.20	18.50	12.80
Min	4.40	2.20	1.20	1.10	1.70	2.20	4.10	7.20	10.30	10.60	9.60	8.10

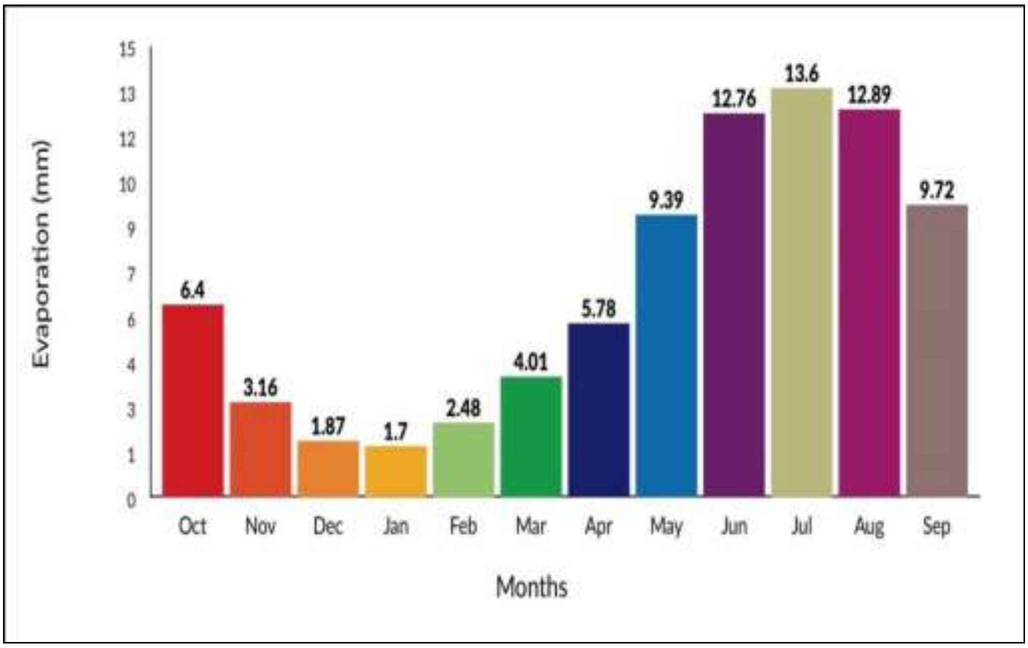

Figure 9: Evaporation class (A) pan average monthly in Erbil between 1980 to 2021

3.3. Climate Classification

One method was used to determine climate type for Erbil central sub-basin. The method is:

3.3.1. Al-Kubaisi

The yearly dryness treatment was used to analyze the climatic type using equations, which Al-Kubaisi (2004) [16] devised and is based on temperature and rainfall totals:

$$AI\text{-}1 = (1*P) / (11.525*t) \text{ (t is not equal to zero)} \quad (5)$$
$$AI\text{-}2 = 2\sqrt{P} / t \quad (6)$$

Where P is the amount of yearly precipitation (mm), t is the temperature (°C), and AI is aridity index.

As demonstrated in Table 8, while value (AI-2) reflects a modification of the latter categorization, value (AI-1) represents the classification of the dominant climate.

Table 8: Climate classification according to Al-Kubaisi (2004)

Type.1	Evaluation	Type.2	Evaluation
AI.1>1.0	Humid to moist	AI.2>4.5	**Humid**
		2.5 <AI.2< 4.0	**Humid to moist**
		1.85<AI.2<2.5	**Moist**
AI.1<1.0	Sub-arid to arid	1.5<AI.2<1.85	**Moist to sub arid**
		1.0 ≤ AI.2<1.5	**Sub arid**
		AI.2<1.0	**Arid**

4. Result and discussion

4.1. Climate factor

The annual average rainfall from 1980 to 2021 is 416 mm/year (Tables 1and 2, Figure 3), with a relative humidity of 47.49% (Table 3, Figure5). The pan evaporation annual is 1634.7 mm/year (Table7, Figure9), the mean temperature is 27.34°C, the annual evaporation is 27.34°C (Table4, Figure6), the average wind speed is 1.7 m/s (Table 6, Figure8), and the average amount of sunshine is 8.8 hours (Table5, Figure7).

4.2. Water Balance Method

There are other ways to compute water evenness, but the bulk of them rely on meteorological information that is already accessible. The actual and prospective evapotranspiration of the study region was computed using hydro-meteorological information from the metrological station in Erbil, and the computation was utilized to identify the times of water scarcity and abundance. The approach can forecast potential groundwater recharge when rainfall data is utilized to compute runoff, nonetheless, aquifer yield). Three distinct methods were chosen for determining evapotranspiration, there are water shortages and surpluses. The evaluation of evapotranspiration was done using Kharufa methods.

4.2.1. Evapotranspiration (ET)

Different techniques may be used to measure water balance, most of which are done based on weather information. The actual and prospective evapotranspiration of the study region was computed using hydro-meteorological information from the metrological station in Erbil, and the computation was utilized to identify the seasons of water excess and deficiency. The approach can forecast potential groundwater recharge when rainfall data is utilized to compute runoff, but not aquifer yield [18]. As a result, the water balancing technique is an ideal approach [19]. Three distinct methods were chosen for the current study find the basin's best suitable method for determining evapotranspiration, water deficit, and water surplus. The evaluation of evapotranspiration was done using Kharufa methods. For the examined region, potential evapotranspiration may be calculated using a variety of methods.

4.2.1.1. Kharrufa Method

To determine PET values Kharrufa (1985) created a straightforward formula. Many studies have used this approach in Iraq. This is done based on the correlation between temperature and sunlight length, and it is thought to be the most suitable approach for the climate in Iraq. (Hassan, 1998; [20]; Shwany, 2008; Dara, 2011; [21]; Qurtas 2013). The formula is as follows:

$$at^{m} = PET / \rho \quad (8)$$

Where:

t: Mean monthly temperature (°C**)**

ρ: The sum% of sun shine hours in each month to the sun Shine hours of one year.

M: Constant (1.31)

a: Constant (0.33)

Table 9 Demonstrates that over the different months, the PET values estimated using this approach are comparable to those computed using the Blany-Criddle method. However, they are not the same as those determined using the Thornthwaite approach. In the earlier approach, the formulae used two parameters. The former, in comparison, only included one climatic element in the calculation, which was the mean monthly temperature plus a relative latitude adjustment factor. Figure 9 shows the water surplus and deficit in the Erbil basin as determined using this approach.

Table 9: Using the Kharrufa approach, potential evapotranspiration values were computed in Erbil from 1980 to 2021.

Month	T °C	P (h)	T^1.31	PET
Oct.	24.36	7.76	65.54	169.53
Nov.	15.88	6.42	37.42	80.07
Dec.	10.54	5.32	21.87	38.78
Jan.	8.98	4.88	17.73	28.84
Feb.	10.73	5.61	22.39	41.86
Mar.	14.97	6.59	34.63	76.07
Apr.	19.89	7.55	50.25	126.46
May.	26.55	9.42	73.37	230.38
Jun.	32.09	11.67	94.04	365.81
Jul.	35.03	11.86	105.4	417.03
Aug.	34.70	11.22	104.19	389.67
Sep.	30.05	10.19	86.29	293.09

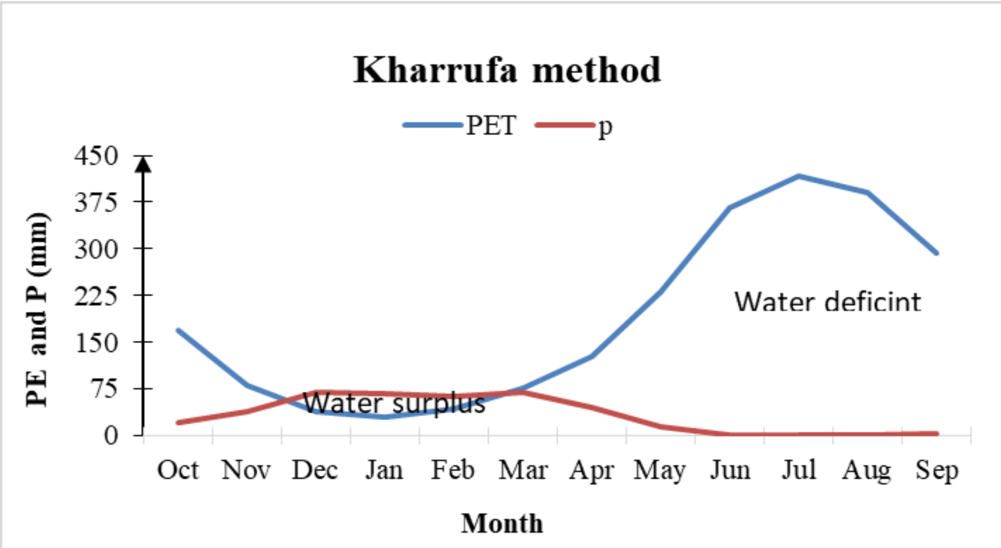

Figure 9: Mean monthly water surplus and water deficit calculated by Kharrufa method.

4.2.2. Water Deficit and Water Surplus

Over time, there is a surplus of water when precipitation exceeds potential evaporation, whereas the opposite is true when potential evaporation exceeds precipitation.

WS = P PE; P > PE

WD = PE P; P < PE

Where:

WS: Water Surplus

WD: Water Deficit

P: Rainfall

PE: Potential evapotranspiration

When there is more water available, real evaporation approaches its potential value, nonetheless, actual evapotranspiration (AET) equals precipitation when there is less water available (4).
P > EP then PE = AET
P < EP then P = AET

The water surplus includes total runoff (Rs), groundwater recharge (recharge), and soil moisture (irrigation). Because the groundwater table is so deep in the Erbil Sub Basin, there is no evaporation of groundwater. As a result, soil moisture is either consumed by plants or evaporates from the soil. The following is equation for the water balance:

$$P = Rs + I + AET \quad (9)$$

WS = I + Rs
WS = P AET
Where:
AET: Actual evapotranspiration
Rs: Surface runoff
I: Infiltration
Using the Kharrufa method, the average monthly potential evapotranspiration statistics were determined (Table 10). The average monthly water surplus and deficit as well as the average monthly actual evapotranspiration in the study region were then calculated using these data. Because PET surpasses precipitation and, consequently, soil moisture use, there is a visible water scarcity from the start of March to the end of November. Precipitation surpasses PET between the end of February and the end of December, allowing soil moisture to return to its maximum level and turning any additional water into groundwater recharge and surface runoff.

Table 10: Using data derived using the Kharrufa approach, compare the water surplus and shortfall**.**

Month	T °C	P (h)	T^1.31	PET
Oct.	24.36	7.76	65.54	169.53
Nov.	15.88	6.42	37.42	80.07
Dec.	10.54	5.32	21.87	38.78
Jan.	8.98	4.88	17.73	28.84
Feb.	10.73	5.61	22.39	41.86
Mar.	14.97	6.59	34.63	76.07
Apr.	19.89	7.55	50.25	126.46
May.	26.55	9.42	73.37	230.38
Jun.	32.09	11.67	94.04	365.81
Jul.	35.03	11.86	105.4	417.03
Aug.	34.70	11.22	104.19	389.67
Sep.	30.05	10.19	86.29	293.09

4.2.2.1. Surface Runoff

The Soil Conservation System (SCS) [22] approach uses rainfall data to compute surface runoff. The empirical rainfall-runoff connection is as follows:

$$Q = (P - 0.2\,S)^2 / P + 0.8\,S \quad (10)$$

Where:
Q: Runoff (mm) of depth
P: Monthly Rainfall (mm)
S: Retention including the initial abstraction [S=1000/CN – 10]
CN: Curve number.

This strategy is applied when comprehensive information on vegetation and soil cover is obtainable. Different records of rainfall and runoff, as well as numerous combinations of soil and cover, were used to create the approach (Table 11; Figure 10), demonstrate how the SCS technique was used with four different soil classifications (hydrologic soil groups).

Table 11: Groups of soils depending on infiltration rates for hydrology [22].

Group type	Infiltration rate cm/h	Runoff rate	Soil Description
A	≥ 0.76	Low	Sands or gravels
B	0.38 – 0.76	Moderate - Fine	Silt loam and loam
C	0.13 – 0.38	Fine - High	Sandy clay loam
D	0.0 – 0.13	High	Clay loam, silty clay loam, sandy clay, silty clay and clay

The mixed-type soils of the Erbil Central sub-basin include grains that range in size from fine clay to coarse sand (23;24), and wheat provides the rainy season's foliage cover, with straight row cultivation being employed to remediate the soil, In light of the categorization suggested by this technique, the soil is categorized as class A (Table 14). The number for this soil condition is thus 65. As indicated in Table 12, the mean monthly precipitation values (records) for the Erbil meteorological station were used to estimate (Rs) values from the standard graphs in Figure 10.

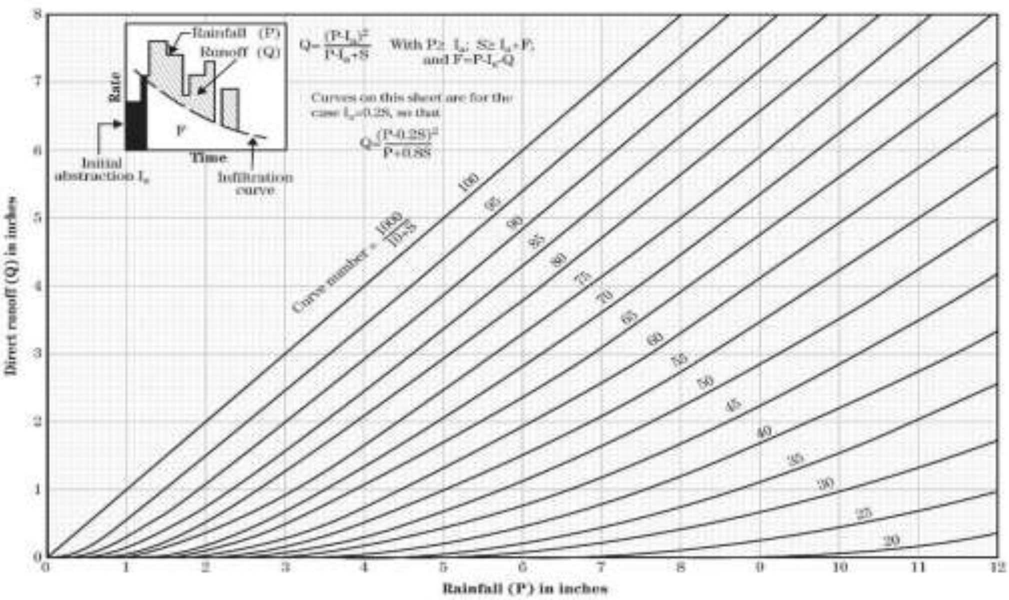

Figure 10: Nomograph for the link between rainfall and surface runoff (after Evans, 1971)

Table 12: The value of the surface flow was calculated by the soil preservation system

Month	Monthly Pm (mm)	Rs (mm)
Oct	20.67	0
Nov	38.59	0
Dec	69.52	9.91
Jan	67.2	8.89
Feb	62.02	6.39
Mar	70.39	10.16
Apr	45.58	2.54
May	14.57	0
Jun	1.32	0
Jul	0.07	0
Aug	0.047	0
Sep	2.89	0
Total	392.867	37.85

4.2.2.2. Recharge

The relation below was used to determine the recharge values:

WS = Re + Rs

Re = WS – Rs

Re = 89.22 – 37.85 = 51.37 (mm)

Re % = 100 x (Re / P)

= 100 x 51.37 / 392.86 = 13.07 %

and Rs % = Rs / P x 100

= 37.85 / 392.86 x 100 = 9.6 %

Therefore:

WS % = Rs % + Re % = 13.07% + 9.6 % = 22.67 %

Where:

WS: Water surplus

Rs: Surface runoff

Re: Recharge

There are several factors that affect the number of recharge operations, including:

- Topography of the area.
- Type of soil and rocks.
- Porosity and permeability of the beds.
- Transmissivity
- Outcrops area of the formations

The majority of the study area is both urban and agricultural, and it is reliant on water wells. Additional sources of recharge in the region include human activity during water consumption and liquid wastewater penetration into the aquifer. Using the hydrometer's findings, one may estimate feeding in the research region by doing things like:

Groundwater Recharge = Recharge x Area

Where:

Area of the sub-basin = 354.7 km^2

Recharge = Water surplus – Surface runoff = 51.37 (mm)

Groundwater recharge = (354700000) m^2 x (51.37) m= 18220939000 mm^3 =18220939 m^3

4.3Climate classification

4.3.1. Al-Kubaisi, 2004 Classification:

By applying the two equations 5 and 6, the value of (AI-1) and (AI-2) becomes as follows:

AI- 1 = (1.0 * 416) / (11.525 * 21.95) = 1.66

This score indicates that the region's predominant climate is wet when compared to the climatic type in Table 17.

AI- 2 = 2√398.1 = 2* 20.39/21.95 = 1.85

This number indicates that the predominant climate in the region is wet to sub-arid when compared to the climate type in Table 13.

According to Alkubasis2004, the climate of Erbil sub-basin is moist to sub-arid based on value of (AI-1) and (AI-2).

Table 13: Al-categorization Kubaisi's of the climate from 2004 [23]

Type.1	Evaluation	Type.2	Evaluation
AI.1>1.0	Humid to moist	AI.2>4.5	**Humid**
		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**

According to Alkubaisi et al., 2019, [25] the area has a moist to sub-arid climate, whereas the current study categorizes the climate as moist to humid, and this shows the reality of climate change in the region. We can notify a significant change in climate type according to[25] and current study that is effect of climate change.

5. Conclusions:

1. The metrological data were useful to assess climate change especially precipitation, relative humidity, temperature, and evaporation. In this study, there are significant shortages in precipitation and relative humidity whereas there are significant decrease in temperature and evaporation. The results of this study revealed that the climate parameters have changed dramatically during the past forty (40) years.
2. The rainfall variation is observed during the past 40 years (Figure 3) in which from 1980-2010 annual rainfall precipitation was 653mm/year, but during period 2011 to 2021 was about 425 mm/year we have significant shortage in precipitation about 228mm/year. This indicates that the Erbil basin is remarkably affected by climate change.
3. Figure 6 shows the average annual temperature in Erbil station it can be categorized to four stages. First stage from 1980 to 1990, the average annual temperature is18.5C° which shows less variation in temperature value. Second stage from 1991-2000 average annual temperature is 20.6 C°. Third stage from 2001 to 2010, the average annual temperature is 22.29 °C, while fourth stage from 2011 to 2021 average annual temperature is 23.07 °C. It has been observed that the temperature value increased during the classified categories. More importantly, 4.57°C has been raised since 1980 compared to temperature value in 2021.
4. According to the current study, 89.2 percent of the total precipitation (416 mm) is made up of water excess that is used to refresh the water supply.
5. The water surplus is split between groundwater recharge (51.37 mm), which accounts for 13.07% of the total rainfall, and surface runoff (89.22 mm), which accounts for 13.07% of the

total rainfall. The adjusted potential evapotranspiration, or (1953.95mm), is represented as the water deficit.

6. By contrasting the current study with earlier research, a significant change in climatic type was found. According to Alkubaisi et al., (2019), the area has a moist to sub-arid climate, whereas the current study and AlKubaisi categorize the climate as moist to humid which indicated the impact of climate change during the past few decades.

7. Outcomes of this study have provided a significant source for water resource management in central Erbil basin especially for those projects that use high quantity of water. Furthermore, this study will provide information about water incomes to the basin which the government could rely make strategic plans for the basin such as building ponds and small dams.

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