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Evaluation to Some Aspects Causing the Crisis of Water Scarcity in Iraq

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ABSTRACT

Water as one of the natural resources plays a key role in shaping most components of the life; it's required more attention as an important resource in most countries in the world. Iraq's rivers have affected by the construction of dams and climate change, and this impaction may be expected to increase cumulatively. Therefore, the aim of this research is identifying and evaluation to essential aspects that caused the water scarcity crisis in Iraq, specialty Euphrates River basin as one of the vital rivers in Iraq. The area is selected to study is situated around main stream of Euphrates River start from Al Hindiyah Barrage until Al kifil town which considered as one of the most important regions that Euphrates River passes through. The monthly climatologically data was collected from GCMSM. A statistical analysis is used for analyzing the homogeneity of hydro-climate data and test the significant change- points to evaluate trends over time period. The evaluation is based on two sections; the first one deals with how climatic change as a natural property can affect water flow. Secondly; identify the impact of hydrological factor on fluctuation water intake through statistical analysis of data such as used Mann-Whitney with hypothesis testing the Null Hypothesis H0 and the Alternative Hypothesis H1 for the period before construction and after construction dams to recent year .The results are indicated that the arid continental climate of Iraq was conferred a fluctuation in rivers' discharges and the occurrence of consecutive dry years have allow for more fluctuation in some hydrological characteristics to the river regime. The climate change has caused a continuous rise in temperature with rate of 1-10 C ° annually and the effect of this rise has appeared since 1999.The amount of rainfall has also decreased sharply and at a noticeable way with peak decline in year 2000 in a time the rain occupies a first place in amount of recharge in Iraqi rivers at ratio of 42-49 % from total other recharge sources. Also from results, a direct correlation is appeared between rainfall and water consumption, as well as an inverse correlation with the temperature. The river's sources countries can increase the risk of this change and the impact of climate change will be clear in future years due to its cumulative effect.

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تقييم لبعض الجوانب المسببة لأزمة شحة المياه في العراق

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الملخص

تلعب المياه، باعتبارها أحد الموارد الطبيعية، دوراً رئيسياً في تشكيل معظم مكونات الحياة؛ فهو يتطلب المزيد من الاهتمام باعتباره موردًا مهمًا في معظم دول العالم. لقد تأثرت أنهار العراق ببناء السدود والتغير المناخي، ومن المتوقع أن يزداد هذا التأثير بشكل تراكمي. لذلك فإن الهدف من هذا البحث هو تحديد وتقييم الجوانب الأساسية التي تسببت في أزمة شح المياه في العراق، وخاصة حوض نهر الفرات باعتباره أحد الأنهار الحيوية في العراق. وتقع المنطقة المختارة للدراسة حول المجرى الرئيسي لنهر الفرات بدءاً من قناطر الهندية حتى بلدة الكفل والتي تعتبر من أهم المناطق التي يمر بها نهر الفرات. تم جمع البيانات المناخية الشهرية من GCMSM. يتم استخدام التحليل الإحصائي لتحليل تجانس البيانات المناخية المائية واختبار نقاط التغيير الهامة لتقييم الاتجاهات على مدى فترة زمنية. ويستند التقييم إلى قسمين؛ يتناول الأول كيفية تأثير التغير المناخي كخاصية طبيعية على تدفق المياه. ثانيًا؛ التعرف على تأثير العامل الهيدرولوجي على تقلب كمية المياه من خلال التحليل الإحصائي للبيانات مثل استخدام مان ويتني مع اختبار الفرضيات الفرضية الصفرية H0 والفرضية البديلة H1 للفترة قبل البناء وبعد بناء السدود إلى العام الحالي. وتمت الإشارة إلى النتائج أن المناخ القاري الجاف للعراق أعطى تقلبات في تصريفات الأنهار وحدوث سنوات جفاف متتالية سمح بمزيد من التقلب في بعض الخصائص الهيدرولوجية للنظام النهري. أدى التغير المناخي إلى ارتفاع مستمر في درجات الحرارة بمعدل 1-10 درجة مئوية سنوياً وظهر تأثير هذا الارتفاع منذ عام 1999. كما انخفضت كمية الأمطار بشكل حاد وملحوظ حيث بلغت ذروتها في عام 2000 في الوقت الذي تحتل فيه الأمطار المركز الأول من حيث كمية التغذية في الأنهار العراقية بنسبة 42-49% من إجمالي مصادر التغذية الأخرى. ومن النتائج أيضا ظهر وجود علاقة طردية بين هطول الأمطار واستهلاك المياه، فضلا عن وجود علاقة عكسية مع درجة الحرارة. ويمكن لدول منابع النهر أن تزيد من مخاطر هذا التغير وسيكون تأثير تغير المناخ واضحا في السنوات المقبلة بسبب تأثيره التراكمي.

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Introduction

Iraq has two Rivers Tigris and Euphrates. The two rivers start at Turkey and keep flowing through Syria, Iraq, and join to form Shatt al Arab in the south of Iraq and then pour into the Arab Gulf. The Tigris and Euphrates rivers are major water resources to the life of Iraq, but they sometimes threaten it because the disturbance of seasonal water flows. Different parts of these rivers are frequently flow very rapidly while most of time the water flows very smoothly (Al-Ansari, 2016). The level of water in these rivers are at lowest from September to December, and high level in spring season through months March, April, and May, also may cause a flood in this time. Otherwise, one season's flood may be ten or more times as great as that in another year (Nadia and Al-Khaqani, 2016; Al-Hathal *et al.*, 2012).

The two Rivers have experienced radical reductions in water flows in recent years due to Turkish hydro-engineering structures and regional droughts (Adamo *et al.,* 2018; De-Menocal *et al.,* 2000). Turkey and the Syrian have construction many dams at Euphrates River basin, these dams are caused a sharp decrease in downstream flow, the quantity of water entering Iraq fell by 25 % causing acute tension between the countries (Al-Azawi *et al.,*2013). Also, most of water resources in Iraq have suffered from serious an unconscionable management especially Euphrates River. The water crisis has serious sociological and economic effects and caused serious change in rivers system like develop more islands and sand bars and consequently reduce rivers capacity (UNEP, 2004).

In this context, this work is evaluated the Euphrates River in center of Iraq, which suffer from many problems which increased from last century. The majority of flow in Euphrates River comes from precipitation in Turkey which receives an average of 1000 mm of rainfall per year compare to 300 mm to150 mm in Syria and Iraq (Al-Azawi *et al.,* 2013; UNEP, 2004). The climate factors are varied with river direction between the region of river entering Iraq border upstream at Hassiba station and downstream region until reach Shatt Al Arab due to topographic variation (Klaphake *et al.,* 2005; Nasirian and Salehzadeh, 2019). The most notable natural hazard in Iraq and surrounding areas further to the arid climate are extreme temperature, low humidity, little precipitation and strong sand -dust wind (Medzini and Wolf, 2006) Since last decades, Iraq suffers from the hydrological drought events due to different climatic factors as results of global climate change (Klaphake *et al.,* 2005; Moneer, *et al.,* 2022).

There are other factors made water crisis escalate, lead Iraq entered into a water deficit that does not keep pace with its average needs estimated at 60-75 billion m3 (Klaphake *et al.,*2005; Wolman and Gerson, 1978). The first aspect is the drought, its accompanied with political and legal aspects, related to the fact that water sources collapse of Iraq has occurred outside its borders. Thus, the upstream countries control water quantity and build dams on it, ignoring the rules of the international rivers law (Medzini and Wolf, 2006). The second aspect is environmental pollution due to source countries dumping wastewater and the accompanying chemical fertilizers and pesticides (Al-Ansari, 2013; Abdulraheem, 2015). As for third aspect of water problem, it is the large population growth in Iraq, estimated at 4%, and this rapid increase will put a great pressure on the available water resources, which they cannot bear (WBG, 2020; Al-Barakat *et al.,* 2018).While for the fourth aspect represented by global climatic changes, and be the most dangerous natural factor that cause water crisis, even if they were originally caused by human causes (Zang and Liu, 2013; Al-Jawadi *et al.,* 2023). Evaporation has an impact as climatologically factor, which strongly related with temperature, strong winds, land use and other water resources (Sissakian *et al.,* 2013). It has great extent to help to determine the number of contaminants and sediment in water to reference the quality of the water resources. It has an effect on instability event and movement in the soil mass that deliver large input of fine grained sedimentary (Al-Ansari *et al.,* 2012).

In Iraq, despite of hypothesize that dam construction and water development projects have been a primary driver of change in annual water flow and hydrologic regime, but there is another important factor led to serious changes in water regime. Therefore, the aim of this study is evaluated main reasons causing water scarcity crisis, it is expected the impact of these factors will increase cumulatively, and the crisis of water scarcity will escalate with it. The objectives of research are identifying these reasons including; 1) Severe climate change and high evaporation caused degradation in river system besides drainage water effect; 2) the changes in Euphrates River hydrology due to upstream dams' operation; 3) and the construction of hydraulic structures in Iraq.

Study Site

After passed Iraqi- Syrian border, the Euphrates River is continuous in flowing crossing narrow valleys and desert lands until entering the Mesopotamian plain to reach Al Hindiyah Barrage where splits into two branches Al-Ḥillah channel and Al-Hindiya channel. The watershed is selected to study is situated around main stream of Euphrates River (Al Hindiyah channel) which extended from northern Al Hindiyah Barrage until Al kifil town. This area is considered as one of the most important regions that Euphrates River passes through (Figure 1). The river stream is only and most important resource of water to the agricultural lands and human uses. The massive lands use (e.g. built dikes and drainage networks) have severely affected river hydro-pattern from last century (Moneer *et al.*, 2022). The mean annual rainfall in the area is 98- 110 mm that occurs mainly in winter season between November and March The rainfall is unreliable with a large fluctuation from year to year (UN-ESCWA, 2013). The summer in this region is very hot and dry with day shade temperature frequently reached a maximum 48.0 ˚C in July and August. As well, a lot of environmental problems have risen as a result of installation a wide-open drainage network and a wide field drain spread in both sides of channel which designed to reduce salinization problems from thousands of hectares of agricultural lands (Al-Ansari *et al.*, 2012). In another way, the climate events have a significant affect in Physical and chemical properties of river water.

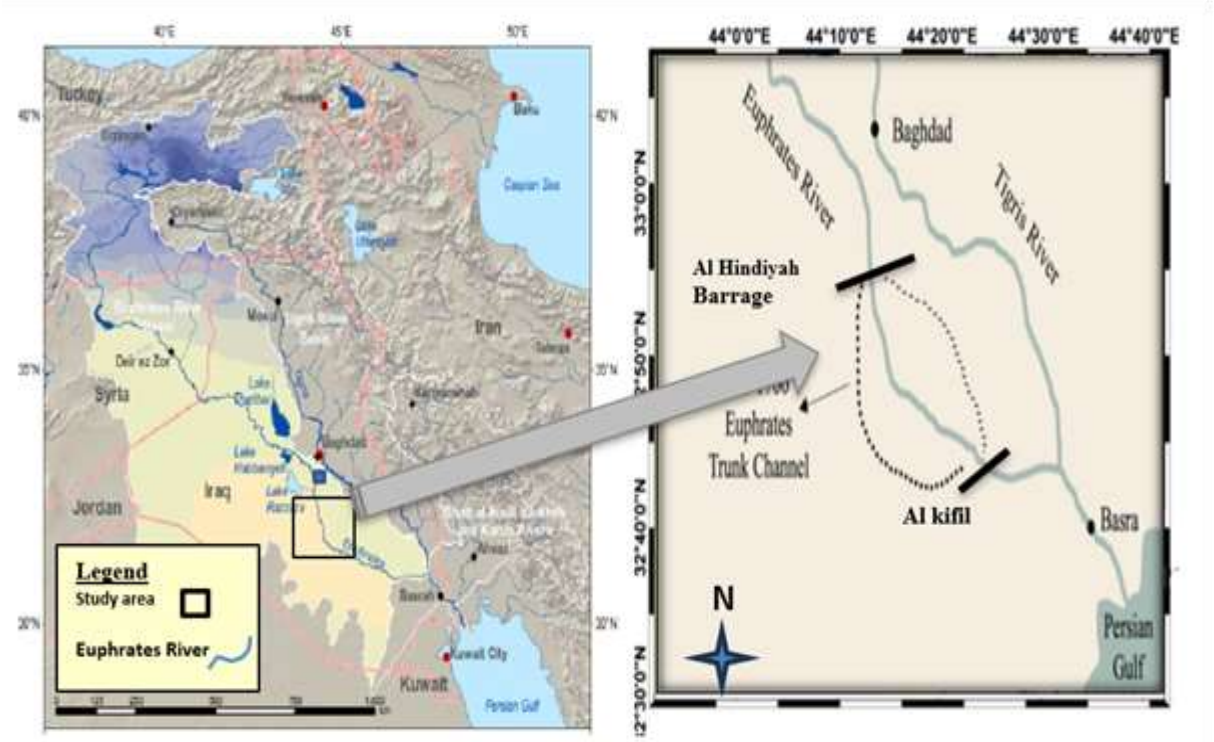

Fig. 1. Map of Iraq (left); the start and the end of study reach along Euphrates River (right)

Despite of maintains efforts to increase the capacity of river to carry water, but there is a necessity to evaluate main factors have an effect on river regime. This research will identify the change in the flow system of the Euphrates River and recognize the roles of dams versus climate on these observed changes. The climate with its multiple elements like the intensity of rain, change in temperature, and evaporation which are the most important factors directly affecting on water resources.

Methodology

Data Sources

The monthly climatologically parameters are collected from GCMSM (General Commission of Meteorological and Seismic Monitoring) to the cities surrounding river reach

for period between 1971 and 2022. The increase in temperature is recorded in the upstream region comparison the downstream river with a rate of 31% and 37.5%. The central part of river basin experienced severe changes in annual temperature (Al-Ansari *et al.,* 2012).

Data Analysis

A statistical analysis is used for analyzing the homogeneity of hydro-climate data and test the significant change- points to evaluate trends over time period. The probability of identifying change-points depends on how large variation is relative to the change (Al-Jawad *et al.,* 2019; Bozkurt and Sen, 2013; Villarini *et al.,* 2011). The position and significance of change-points were analyzed using a non-parametric test (Pettitt's test) that requires no assumption about data distributions and applied to detect a single change-point in continuous data (Salarijazi, 2012; Bosch and Hewlett, 1982). It uses the Mann-Whitney statistic for Hypothesis testing, the Null Hypothesis H0 and the Alternative Hypothesis H1for two samples (before and after the change-point) come from the same distribution. Choosing the change-point that maximizes the statistical approximate probability is good if p ≤0.5 (Pettitt, 1979). Homogeneity is calculated in Microsoft Excel using the XLSTAT tool, and analyzed over selected period of record between (1930 and 2022). The analysis is performed for flow rate Heet upstream station and AL Hindiyah downstream station, while the rainfall and temperature data are analyzed for Jarablus station in Syria, Al Hindiyah station in Iraq; and Annual fluctuation in temperature for three cities around river reach; for comparison the connection between observed changes in climate of Euphrates River basin. The correlation between rainfall and mean annual flow at two stations in Iraq (e.g. Heet and Al Hindiyah) are regressed against specific discharge (i.e. the flow divided by catchment area).

The potential Evapo-transpiration is another factor strongly related water resources and (Thornthwaite - Penman) method is more precisely defined the potential Evapo-transpiration [27,28]. This method is used to calculate ETp based on daily meteorological records of air temperature and hours sunshine for period (1987-2022). The potential Evapotranspiration is a theoretical monthly value based on 30 days/month and 12 hr sun shine / day as follows:

$$ETp = 16\left(\frac{10Ti}{I}\right)^{a}\left(\frac{N}{12}\right) \quad \ldots. (1)$$

$$J = \sum_{i=1}^{12}\left(\frac{Ti}{5}\right)^{1.514} \quad \ldots.. (2)$$

$$\alpha = 0.675*10^{-6}*J^{3} - 0.771*10^{-4}*J^{2} + 0.01792*J + 0.49239 \quad \ldots. (3)$$

Where; ETp is Potential evapotranspiration for each month (mm / month), Ti is mean monthly air temperature in C°, and N is average number of hours between sunrise and sunset in a month.

Results and Discussion

Climate Change

In view of impact the climate with its multiple elements like the temperature, rainfall, and evaporation as the most important factors directly affecting the Euphrates water feeding and as basic components effect on water resources, thus, details of analysis is representing as follows:

Temperature

The temperature has a direct effect on atmospheric pressure, and then on wind movement, rainfall and the amount of evaporation, whose rates rise with the rise of temperature (Addinsoft, 2019; Akanda, *et al.,* 2007). The temperature range above 45 C° in June, July and August to lower than 8 C◦ and sometimes below freezing from December through February. The study area classed as (arid – desert) hot region according to Koppen's climate classification and sub arid – moist according to climate classification.

According to the collected data from (Iraqi Meteorological Organization, 2022), the annual fluctuation in temperature during the period from 1971 to 2022 between stations in Syria and middle region of Iraq are presented in (Figure 2 A and B). The homogeneity test shows very clear rise in temperature and significant variation records between two riparian countries Iraq and Syria.

The Annual fluctuation of temperature in main (Karbala, Al Najaf, and Babylon) around study river reach is shown in (Figure 2 C) for period from 1971 to 2022.Between one decade and another there is arise between 2.0 and 3.1Cº. Thus, the average temperature in Iraq is increased with about 10 Cº from1971 until 2022, and this became clear after decade of the 1990. It has estimated that temperature will rise more than 3 degrees above its average during next twenty years, and this rise has serious environmental effects (Al-Azawi *et al.*, 2013).

From statistical analysis to the annual temperature values, the change-points at Jarablus station in 1993, which analyzed with the Null Hypothesis H_0=10.8, while Alternative Hypothesis H1=11.5; and give a good probability P<0.0001. In AL Hindiya station, the change -Point in 1994, with Null Hypothesis H_0= 177.3; and Alternative Hypothesis H1=137 with probability P= 0.026 as indicated in [Figure 2 A and B]. This value is seemed small but significant in statistics, because its below least 5% (or 0.05). Therefore, it's important to conclude that the data supports the Alternative Hypothesis; there is a relationship between the variables.

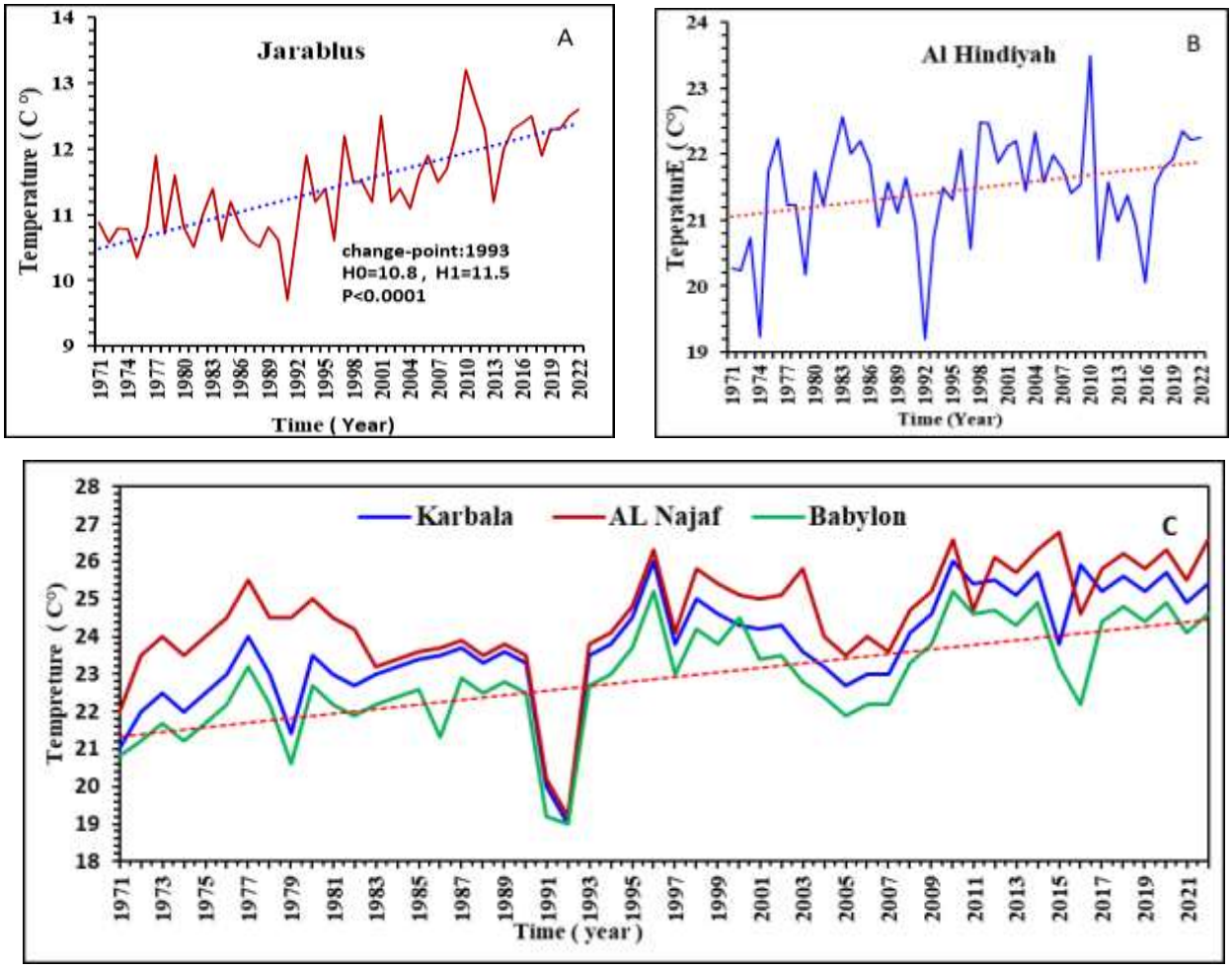

Fig. 2. The Isometric lines of annual temperatures for period between (1970 and 2022); A) Jarablus in Syria, and B) Al Hindiyah in Iraq; C) Annual fluctuation in temperature for three cities around river reach

Rainfall

Another effective element is the rainfall, it is not reliable into the region and records have shown large fluctuations from year to year. When rainfall is used as a base to classify the climate, two seasons can be noticed; dry season starting from April to September and wet season starting from October to May (IPCC, 2007). The characteristics of topographical area and climate behavior play important roles in this variation. According to the monthly data collected from (Iraqi Meteorological Organization, 2022) for period between 1970 to 2022 indicated the rainfall is sparse in Iraqi lowlands of Mesopotamian Plain, short duration high-intensity rainstorms account for the dominant contribution to low annual total

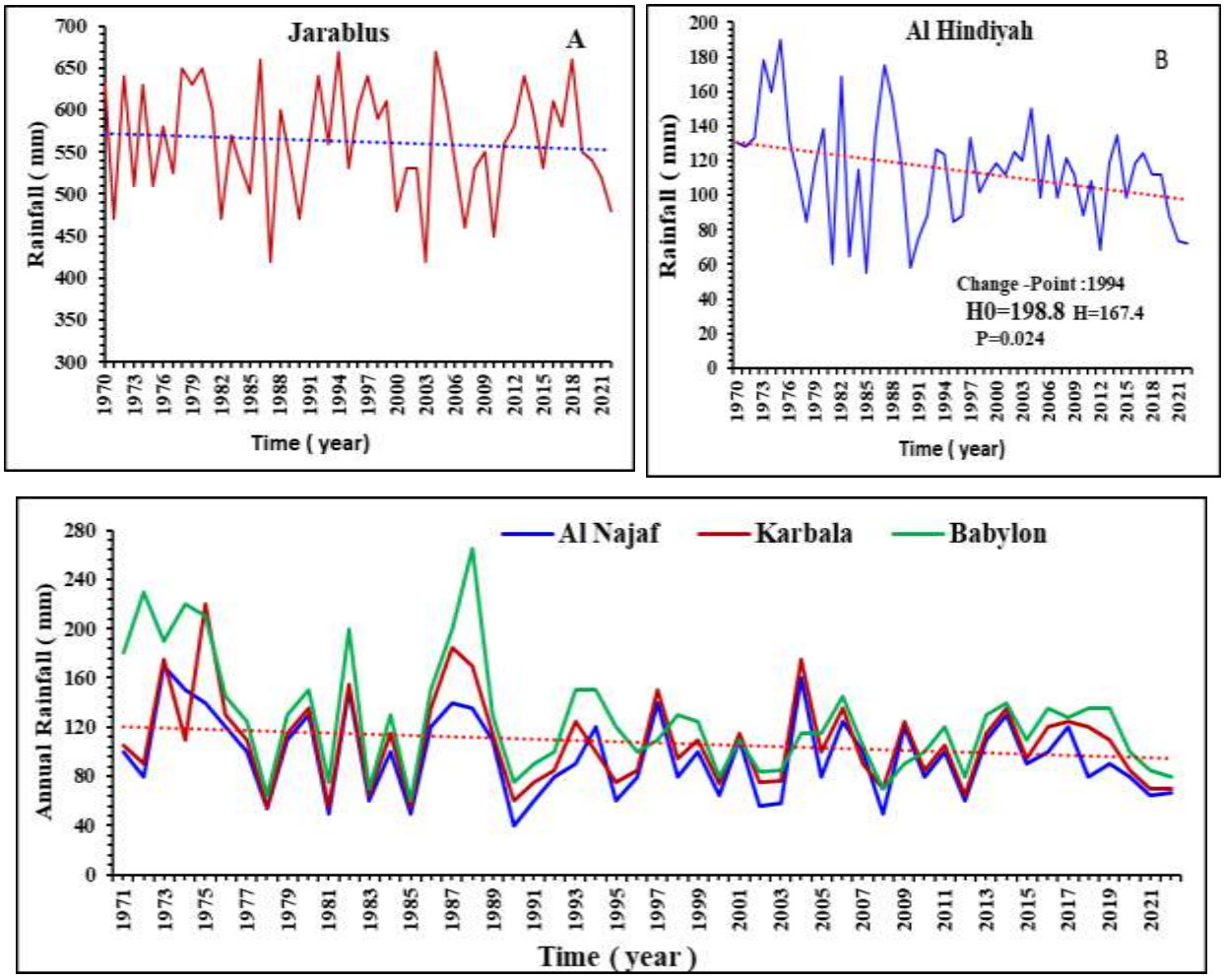

Fig. 3. The isometric lines of annual rainfall for period between (1970 and 2022); A) Jarablus in Syrian, and B) Al -Hindiyah in Iraq, C) Annual fluctuation of rainfall for some station around study river reach.

rainfall (Al Ansary, 2012). The rainfall in [Figure 3] shows noticeably reduction and variation from year to year with an irregular distribution in time and space

The extreme yearly variability in the wet and dry periods between 43 and 167 mm /year on the rain gauge measure and a mount can drop to minimum value as 42.82 mm in dry water years. The records in (Figure 3 A and B) are indicated that decreasing in amount of rainfall records downstream regions of river at a rate of 33% ranging between 100 and 150mm/year with overall average annual rainfall of order 107.51 mm per year with around 73% occur during November, December, January, and February. The intensive rainfalls storms take place during December to March while no rain cover the rest period of year (IPCC, 2007). The annual rainfall is detected for Jarablus station in (Figure 3 A), and also a significant decrease in rainfall is detected in Al Hinidiyah station (Figure 3 B). It is noted that the amount of rain in AL Hindiyah station is less than quantity in upstream Jarablus by more than 400 mm.

From statistical analysis to the rainfall over the period of record from1970 to 2022, the significant change-point at Jarablus station in 1993 with the Null Hypothesis H0=17.5; and alternative Hypothesis H1=18.5 with approximate probability for a two-sided test is calculated P<0.0001. The change –points at AL Hindiya station in1994 with the Null Hypothesis H0=198.8; and Alternative Hypothesis H1=167.4. While the approximate probability is good for P=0.024 (Figure 3 A and B). Therefore, the p-value is less than .05, thus the data supports the Alternative Hypothesis, there is a relationship between the variables.

When reviewing (Figure 3 C), it noticed the amount of change in rainfall during the period 1971-2022 in three main cities around Euphrates River reach indicates that during decade of 1980 s was less than the amount of fell during the decade of the 1970 s. While its slight decreases in the 1990 s than in 1980 with amount of 10.8**,** 4.9, and 10.1 mm, for main cities respectively**.** As for the decade of 2000 the amount of rain in all stations decreased by an amount 5.1-85.7 mm and as a percentage value between 4.1 -39.3 %than 1990s.

The characteristics of topographical area and climate change play important roles in this variation for example**;** at a day at Babylon city with about 42 mm of rainfall occurred, even though the total annual rainfall in the same year was 105 mm compared with other stations. There is an increase with about 0.5- 31.8 %, and these varieties of rainfall events can produce a great surface runoff resulting erosion.

In general, it is noted that the trend is toward a decline in the amount of rain, especially during the decade of the 2000 s due to growing effects of global warming and climate change. Consequently, limited rainfall may expect to deteriorate of Euphrates water discharge downstream in terms of increasing salinity and decreasing nutrients because of high evaporation process, leading to decline renewal water rates with rainwater and runoff (Al -Qatrani, 2012; UNDP, 2009). While high intensity rainfall has a great influence on groundwater replenishment and on leaching of soluble salts from soil profiles the shallow groundwater and then to the river waterway.

Evapotranspiration and Aridity Index

The results of potential Evapotranspiration ETp and Aridity Index are calculated based on daily Meteorological records between1987 to 2022, and the values are illustrated in (Figure 4). The mean annual values of Evapo-transpiration are ranged between 1303-1713 mm/year for main cities around studied river reach stations. Rainfall is exceeded Evapotranspiration range between December and March as between 6 and 12 mm/month depend on the amount of moisture available.

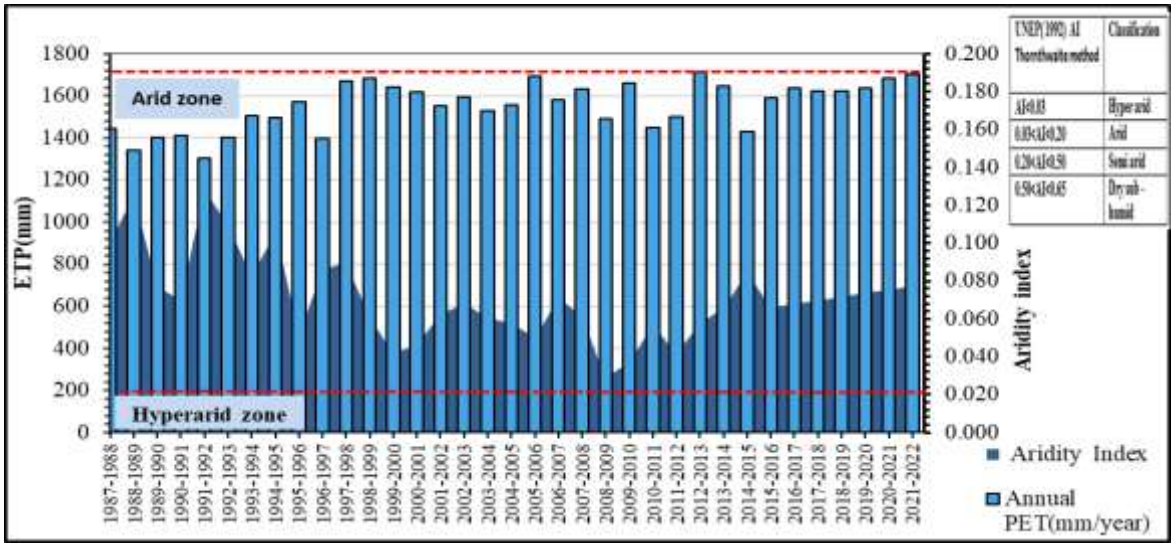

Fig. 4. The Aridity Index of climate zone classification in Iraq, and average annual ETPFor period (1987-2022); the dashed line represents the average Aridity index of study river basin

In area around river reach the evaporation rates are higher with hot summer months June, July, and August. The mean annual Evapo-transpiration values are between 300 to 450 mm per month and average annual value about 2416 mm per year. For example, its extent to average 2170 mm as max. value in Lake Abu Dibiss that feeding by Euphrates River. While the evaporation rates is raised at Al Hindiya station with about average value 3286 mm. it has a significant impact on increase water losses by evaporation. The average monthly evaporation rates are ranged with about 375 mm in July, unlike winter months which record with average valuen52 mm**.** Aridity index is significant factor for tracking the effect of climate change on local water resources (Holthaus, 2014; UNDP, 2009). Aridity is a function of rainfall, the potential Evapotranspiration rate**,** temperature**,** winds and humidity factors. Whether climate is moist or dry is dependent upon both the amount of rain and temperature and whether or not the rainfall is greater or less than the amount of water needed to offset evaporation and plant transpiration. The fluctuation values of aridity index values range between 0.028 and 0.128 as shown in (Figure 4).

Thus, depend on the classification of (UNDP, 2009) the calculated Aridity Index AI is 0.0714. It is classified as arid region which have low Humidity. The evaporation from free water surfaces is up to 12 mm / day (IPCC, 2007), while an average annual evaporation is about 1500-2000 mm depend on maximum temperature and humidity.

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Hydrological Condition

Sources of Discharge

Due to a large area of the Euphrates basin in Iraq, it has been variety in water feeding sources, and the rainfall is the first source of feeding (Al-Ansari and Knutsson, 2011). As for the percentages of water supplied to the river that 82 % comes from Turkey, 9 % from Syria, 8.97 % comes from the seasonal desert valleys in Iraq, and 0.3 % comes from Saudi Arabia (Al-Ansari, *et al.,* 2014a). It is noted that Iraq is contributed by very few and fluctuating proportions of their imports due to their exposure to seepage and evaporation because of its arid climate. The feeding is concentrated during the winter and spring seasons ranging between 6.41 and 3.49 %. Despite the high percentage of rain feeding, the discharges during this period are unstable and fluctuated according to the fluctuation of rain falling on the whole river basin.

The second source of feeding water is the melted snow in mountain of Turkey, and its nutrition concentrated in the spring. It begins with melting in the months of April and May because of rising temperatures addition to the rainy season. It occupies the second place in the nutrition ratios as ranged between 26.2 and 41.1 % of the total expenditures. This period is more stable than the previous period because it's relied on the melting of snow accumulated on the heights after the high temperatures, addition to the falling rains, so it will build and maintain more nutrition and stability.

As for the third source is the groundwater which is related the amounts of rain and melted snow that seep into the ground, and the groundwater recharge of rivers occurs in the summer due to the interruption of other sources of nutrition (Al-Ansari, *et al.,* 2014b). It occupies the last rank in the nutrition ratios, which ranged between 14 and 27.4%. The previous ratios on the sources of nutrition for the three types of rivers gave a very clear view to the size of contribution of each source despite their overlap with each other. However, one should not lose sight of the annual variation of these ratios in relation to their rates depending on the characteristics of the water year, whether it is dry, medium or humid (UNDP, 2009). The Hydrograph of the mean

monthly flow at AL Hindiyah Barrage site is separated as before and after 1973 as shown in (Figure 5).

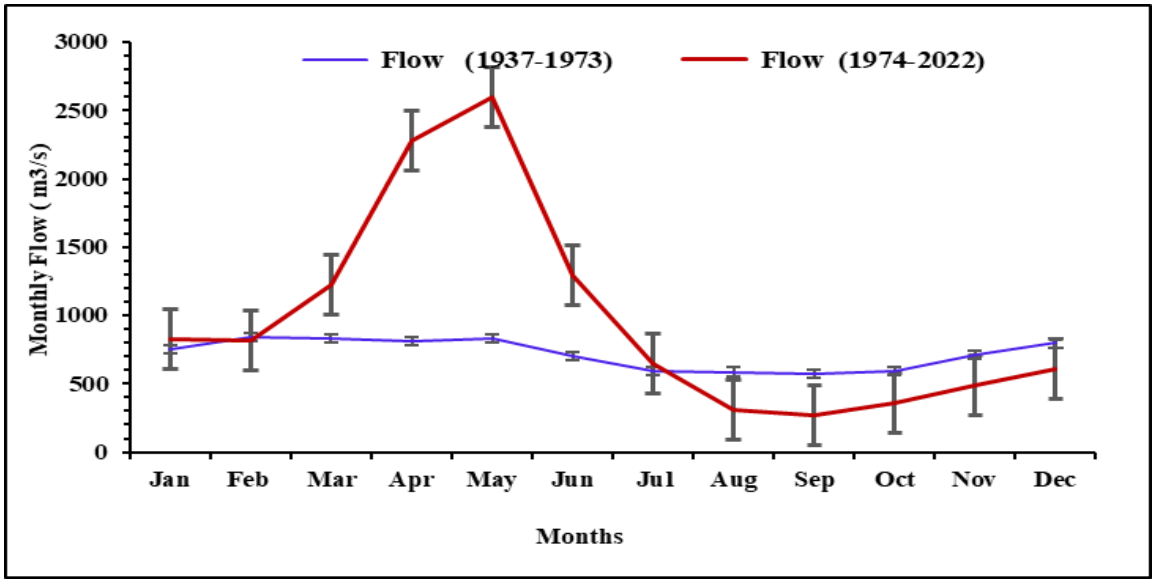

Fig. 5. Hydrograph of the mean monthly flow at AL Hindiyah Barrage as before and after 1973

Flow Conditions

From documents are issued by the (Ministry of Water Resources / General Directorate of Water Resources Management**)**, the variation in rate of flow data at station Jarablus in Syria and three main stations in Iraq (e.g. Hussiaba, Heet and Al Hindiyah) for period 1930-2022 are represented in (Figure 6**)**. It is noted the discharges at Husaiba site has decreased very clearly since 1970, and reached their lowest level in the 2000 s with about 517 m^3 / sec, which is lower than the general average of 819.5 m3 /sec by37 %. The average annual discharge of the Euphrates River at Heet is 1000 m ^{3}/s and changed widely from less 200 m^3/s to more than 2000 m^3/s through the period of records depending on the volume and timing of rainfall in upstream countries.

The data analysis shows fluctuation changes in monthly and annually discharges records in period between 1930 and 1989, there is a sharp fell to 98.85 m ^{3}/sec in 1974. There is a sudden increase in annual average discharge in flood season as 1272.3 m ^{3}/sec and 888.44 m ^{3}/s recorded in 1969 and 1988 respectively. then a significant increase during the main rainy season, where the average monthly discharge is dropped from 595.10 m ^{3}/s for the period 1930-1989 to about 257.13 m 3/s for the period 1990-2014. As well as, the case downstream Al-Hindiya Barrage site with the exception of slight rise in the eighties. Then, it returned to decline and reached its lowest level in the two thousand decade reaching 213 m^3 /s, which is lower than the general average of 515 m ^{3} /sec by 58.6%.

In general, the flow data of river regime during a period 1970 to 1990 considered, as there was limited in water regulation of the runoff-generating area in Turkey. The natural flow regime has represented with a high-flow season from October to April and a low-flow season from June to September. This is a regular feature in hydrological of arid regions where no /or few tributary rivers discharge within the area. The discharge has increased during the flood season, because the high flow generated in upstream highlands and typical in 1970.

After 1990, the fluctuation in annual discharge data is continued with a significant fell trend in level of records compared to the last periods until the end of measurement years. The impact of the dry years in 2000 and 2001 is more pronounced, with release rates approximately 1/3 rd of the normal water release rates. Under the current water management regime, droughts form a major natural hazard that affect water supplies in the basin, as witnessed in recent

decades in Iraq. While the decline in outcome from Al Hindiyah discharge rate in period 1990-2022 year is because construction and operation of the Keban dam in Turkey and the Tabqa dam in Syria led to a shift the Euphrates flow regime. The increased regulation of the naturally flow regime of the Euphrates resulted in less powerful seasonal flow variation with higher dry season flows and lower wet season flows.

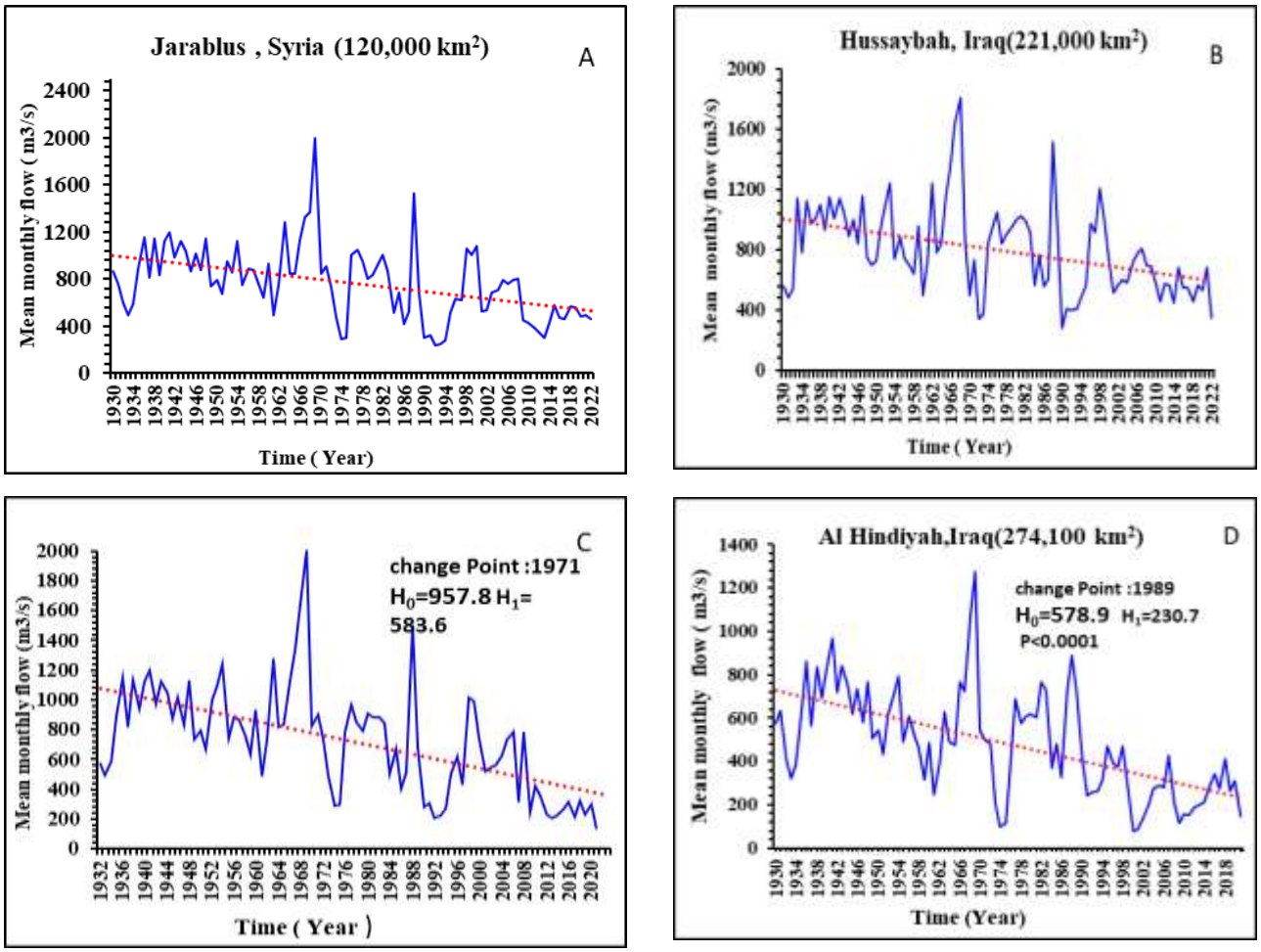

Fig. 6. Mean monthly flow in Euphrates River from 1930 to 2022 at stations: A) Jarablus in Syria, and three stations in Iraq B) Husiaba, C) Heet and; D) Al Hindiyah

Homogeneity tests as statistically significant change-point applied over the period from 1930 to 2022 for identified in Euphrates River flow at two stations Heet and Al Hindiyah. At Heet station statistically significant change-points in 1971 with Null Hypothesis H0=957.8 and Alternative Hypothesis H1= 583.6, The approximate probability is P < 0.001. The p-value is less than .05, the data supports Alternative Hypothesis. While at AL Hindiya station the change-point in 1989 with H0=578.9, H1=230.7 and probability <0.0001 as indicated in (Figure 6 C and D)

Effect of Hydraulic Structures

In this research, it is important to consider the effect of hydraulic structures, old Al Hindiyah Barrage and New Al Hindiyah Barrage are located upstream river reach. The function of new Barrage was controlled water level and distributed water as rotation system for every branch that located northern side barrage and the main stream of Euphrates River at another side. From last century, the sediment augmentation was threating the studied river reach n spite of efforts to maintain processes to remove excess of sedimentation. This issue has led to reduce the capacity of river width, depth and change the cross sections patterns of river. Besides, minimize the amount of the discharge and block water streams by fluvial sediment. The

sedimentation process increased the silting areas and many bars and islands appeared due to water scarcity and minimize rate of flow.

In 2009, a UNESCO report formed that the level of water in the Euphrates River have retraction by more than two- thirds and premonitory these vital lifelines could dry up completely by 2040. This problem threatens an environmental catastrophe in Iraq. Iraq also constructed a complex network of canals on the Euphrates River, diverting Euphrates water to the dam lakes such as Al -Habbaniyah lake and Al Tharthar lake, which store overflow flood water, but recently these lakes suffer from shortage of water. These structures have also suffered from a large accumulation of sediment which caused a serious flood in upstream tributaries were featured to concern that reservoirs have become a reason for trapping sediments (Al-Ansari, *et al.*, 2014c). The sediment augmentation was threated Euphrates River downstream Al Hindiyah Barrage in spite of efforts to maintain processes to remove excess of sedimentation. This issue has led to reduce the capacity of river, river depth and change the cross sections patterns of river. Besides, minimize the amount of the discharge and block water streams by fluvial sediment. The sedimentation process increased the bars and islands appeared due to water scarcity and minimum rate of flow.

The values in (Figure 7) is illustrated the relationship between Euphrates River flow rate and water storage at Al Hindiyah barrage comparison main dams in riparian countries with data separated as (pre-1971) and as (post-1971) periods. In particular, the year of 1974 marks in which Keban and Tabqa dams have operated for the upper Euphrates basin, and this alteration resulted in decreased flow and reduced flood peaks due to regulation. After 1990, Turkey construction many dams at Euphrates River (e.g. Ataturk Dam), these dams caused a sharp decrease in downstream flow, the quantity of water entering Iraq fell by 25 %.

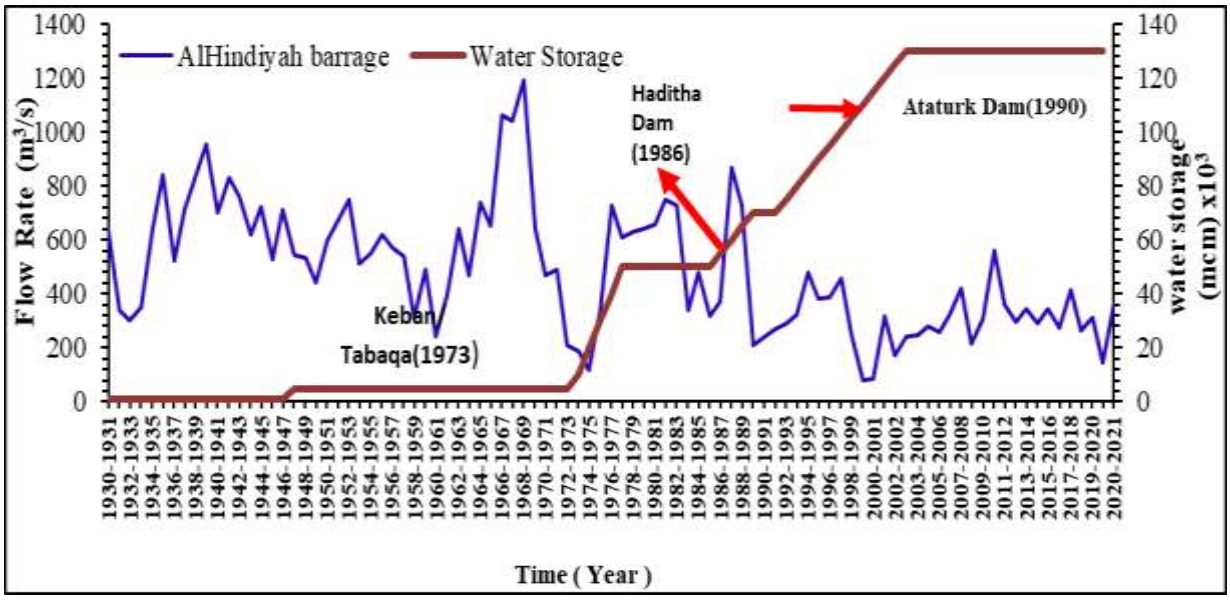

Fig. 7. Hydrological changes in Euphrates River flow from 1930 to 2022 and accumulated reservoir storage in the basin plotted with mean annual flow at Al- Hindiyah Barrage site

The Impact of Climate Change on Flow Rate

The relationship between rainfall and specific discharge (i.e. the discharge divided by catchment area) is illustrated (Figure 8) for two stations Heet and Al Hindiyah with data into separated as natural flow (pre-1971) and regulated flow (post-1971) periods of time. In particular, the year of 1974 marks in which Keban and Tabqa dams were operated for the upper Euphrates basin, and this alteration has resulted in decrease flow and reduced flood peaks due to regulation. At both stations, the natural flow regime was described by a relatively relationship between flow and annual rain with regression R^2 = 0.677 and R^2= 0,637 for Heet and AL

Hindiyah stations respectively. The slope varied between 0.41 and 0.18 in two stations indicating that 41% and 24% of weighted basin area and recorded mean annual flow of 967 m^3 /s and 638 m^3 /s at the Heet and Al Hindiyah stations. While regulated flow at both stations had much lower regression factor R^2=0.432 and R^2= 0.413 for both stations respectively indicating a vast reduction in water transportation and utmost shift in the Euphrates River flow system.

The relation between rainfall and specific discharge in regulation period (post-1971) indicating a vast reduction in water quantity and utmost shift in the Euphrates River flow system. This clearly shows the impact of climate change on water scarcity, especially since rain occupied the first place in water nutrition ratios as well as its impact on other sources of feeding. Perhaps this relationship between rainfall and Specific discharge is due to human intrusion in amount of discharge. It was consistent with the climatic data that recorded a decrease in the amount of rain and an increase in temperature for the same period, and it has noted that most stations recorded the highest temperature increase after 1999.

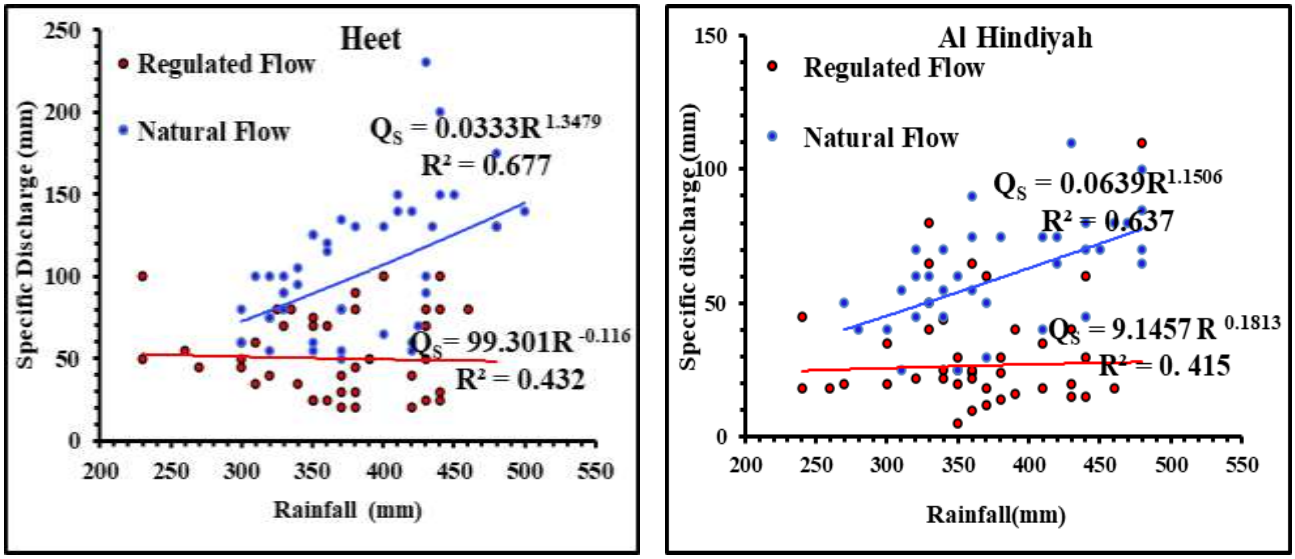

Fig. 8. Mean annual Euphrates River specific discharge at Heet and Hindiyah versus area weighted rainfall in the natural and regulated periods before and after 1971

The amount of rainfall also decreased in the same year, which reached its peak in the 2000s, especially in two years 2007 and 2008, and this clearly shows the impact of climate change on water scarcity, especially since rain occupied the first place in water nutrition ratios, as well as its impact on other sources of nutrition. It is not a requirement that all of mention correlations be medium to show the relationship of climate change with decline in water quantities, as the problem of water and water drainage has affected by several factors that contribute in different proportions to its emergence as mentioned previously.

Conclusion

Euphrates River is one of the main rivers in Iraq country and playing a vital role as a key of freshwater source. This river was affected negatively by climate change and an unconscionable management policy of riparian countries by constructed large water projects have caused serious variation in river regime and created a threat to the natural cycle. Therefore, this assessment is evaluation to the essential factors causing serious change in the river regime and water flow since 1970. Thus, the results of evaluation are outstanding to the following points:

1. The Iraqi water crisis has principal causes, and the climate change is one of the most important reasons**.** Also, the diversification in Iraqi hydrological and topographical conditions from upstream to downstream have assessed for more alteration in river regime.
2. The upstream countries have a significant effect on flowing water by causing serious reduction in downstream water flow since the early 1970 s with construction more Dams has affected river basin in downstream
3. There is a clear correlation between the decline in water revenue, the decrease rain for and the rise in temperatures in most of the stations in Iraq, and thus the impact on the decline in the rates of water supply from the various sources of feeding the river.
4. From statistical analysis to rainfall fluctuation the significant change-point in Jarablus in 1993 with the Null Hypothesis H0=17.5 and Alternative Hypothesis H1=18.5 with approximate probability for a two-sided test is calculated P<0.0001. The change –points at AL Hindiya station in 1994 with the Null Hypothesis H0=198.8 and Alternative Hypothesis H1=167.4**.** While the approximate probability is good for P=0.024.
5. Iraqi dams' operation has an effect on Euphrates River inflow, the Change-point at AL Hindiya station in 1989 with H0=578.9, and H1=230.7 and probability P<0.0001.

There are some recommendations must be taken with a strategic goal of the Iraqi governments, if the river has retained the vital role in the region**,** it should strengthen operational capacity and enhance the ability to monitor and regulate rainwater harvesting, hydrological tracking weather patterns and geographical mapping of groundwater levels. The Euphrates River basin is expected to experience change in weather due to the global El Nino phenomenon and proactive warning for multi-year forecasting to the future effect of drought and mitigating its risk on water resources**.**

References

Abdulraheem, Z.A., 2015. Allocating the Best Representative Water Quality Monitoring Station. University of Technology, Baghdad, Iraq, A thesis in Water Resources.

Adamo, N., Al-Ansari, N.A., Sissakian, V. Knutsson, S. and Laue, J., 2018. The Future of the Tigris and Euphrates Water Resources in View of Climate Change, (in press).

Addinsoft, N., 2019. The XLSTAT Statistical and Data Analysis Solution. USA, Boston. Doi: https://www.xlstat.com .

Akanda, A., Freeman, S., and Placht, M., 2007. The Tigris-Euphrates River Basin: Mediating a Path Towards Regional Water Stability. Al Nakhlah, the Fletcher School Journal for Issues Related to Southwest Asia and Islamic Civilization, Spring Vol: pp. 1-12 http://www.fao.org/nr/water/aquastat/basins/euphrates-tigris/index

Al -Qatrani, F.S., 2012. Environmental and Economic Impacts of Drought in Iraq. University of Szczecin. University of Basra (Iraq) nr 29 Climate Change, Economy and Society - Interactions in the Baltic 5-1. DOI: http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.ekon-element-.

Al-Ansari, N., 2013. Management of Water Resources in Iraq: Perspectives and Prognoses. Engineering 05 (08), pp. 667–684.

Al-Ansari, N., 2016. Hydropolitics of the Tigris and Euphrates Basins. Engineering 08 (03), pp. 140–172. https://doi.org/10.4236/eng.2016.83015

Al-Ansari, N., Knutsson, S., Ali, Ammar, 2012. Restoring the Garden of Eden, Iraq. Journal of Earth Sciences and Geotechnical Engineering 2 (1), pp. 53–88.

Al-Ansari, N.A. and Knutsson, S., 2011. Toward Prudent Management of Water Resources in Iraq, J. Advanced Science and Engineering Research, Vol. 1, pp. 53-67.

Al-Ansari, N.A., Abdellatif, M., Ali, S. and Knutsson, S., 2014b. Long Term Effect of Climate Change on Rainfall in Northwest Iraq, Accepted Central European Journal of Engineering.

Al-Ansari, N.A., Abdellatif, M., Ezeelden, M., Ali, S. and Knutsson, S., 2014a Climate Change and Future Long-Term Trends of Rainfall at North-eastern Part of Iraq, J. Civil Engineering and Architecture, Vol. 8, No. 6, pp. 790-805. DOI: https://doi.org/10.4236/eng.2013.58080

Al-Ansari, N.A., Ali, A., and Knutsson, S., 2014c. Present Conditions and Future Challenges of Water Resources Problems in Iraq. J. Water Resources and Protection 6 (12), pp. 1066-1098.

Al-Azawi, F.W, Ali, S.M., Qutaiba, A.S., and Hussan, M. ,2013, Fluctuating Rainfall as One of the Important Cause for Desertification in Iraq. Journal of Environment and Earth Science, 3, pp. 25-33.

Al-Barakat, R., Lakshmi, V., Tucker, C., 2018. Using Satellite Remote Sensing to Study the Impact of Climate and Anthropogenic Changes in the Mesopotamian Marshlands, Iraq. Remote Sens. 10 (10). https://doi.org/10.3390/rs10101524

Al-Hathal, A., Youssef, M., and Hamdan, O., 2012. The General Trend and Change in the Ratios of Seasonal Rainfall Amounts in Iraq, research accepted for publication in the Fifth International Scientific Conference (Education and Education in Building Human and Intellectual Development, College of Education ibn Rushd for Human Sciences, for the duration.

Al-Jawad, J. Y., Alsafar, H. M., Bertram, D. and Kalin, R. M. A., 2019. Comprehensive Optimum Integrated Water Resources Management Approach for Multidisciplinary Water Resources Management Problems. J. Environ. Manage 239, pp. 211–224. https://doi.org/10.1016/j.jenvman.2019.03.045 .

Al-Jawadi, A.S., Al-Abbasi, M.W., and Al Jubouri, K.K., 2023. Sustainability of the Tigris River Between Environmental Conditions and Oppressive Quarrying in Northern Iraq, IOP Conf. Series: Earth and Environmental Science 1202 (2023) 012017, pp. 1-9, https://doi:10.1088/1755-1315/1202/1/012017.

Bosch, J.M., Hewlett, J.D., 1982. A Reviewing of Catchment Experiment to Determine the Effect of Vegetation Changes of Water Yield and Evapotranspiration. J. Hydrol. 55, pp. 3-23.

Bozkurt, D. Sen, O., 2013. Climate Change Impacts in the Euphrates-Tigris Basin Based on Different Model and Scenario Simulations, Journal of Hydrology, 480, pp. 149-161.

De-Menocal, P., Ortiz, J., Guilderson, T. and Sarnthein, M., 2000. Coherent high- and lowlatitude climate variability during the Holocene warm period. Science 288, 2198–2202, http://www.eoearth.org/view/article

Holthaus, E., 2014. Is Climate Change Destabilizing Iraq. Slate, Future Tense. http://www.slate.com/articles/technology/future_tense/2014/06

IPCC, (Intergovernmental Panel on Climate Change) 2007. Climate Change Impacts, Adaptation and Vulnerability. Cambridge University Press, Genev. https://www.ipcc.ch/.../publications_ipcc_fourth_assessment_report

Iraqi Meteorological Organization, 2022. The Iraqi General Meteorological Authority, Atlas of Iraq's Climate for the Period (1930-2022) Baghdad.

Klaphake, A., Kramer, A. Scheumann, W., 2005.Cooperation on Turkey' S Trans Boundary Waters. The German Federal Ministry for Environment, Nature Conservation and Nuclear Safety.

Medzini, A., Wolf, A., 2006. The Euphrates River Watershed: Integration, Coordination, or Separation? In: Finger, M., Tamiotti, L., Allouche, J. (Eds.), The Multi-Governance of Water Four Case Studies, pp. 103–146. State University of New York Press.

Moneer, B., Seker, D. Z., and Ahmed, K. A., 2022. Drought Monitoring Based on Predicted SPI Using Fuzzy Controller System. Iraqi National Journal of Earth Science (INJES), 22(2), pp. 140-152.

Nadia, R. and Al-Khaqani, M., 2016.Study and Analysis of Drought in the Central and Southern Regions of Iraq Using the Standard Rain Index, MSc. Thesis (unpublished), Department of Geography, College of Education for Buildings, University of Kufa.

Nasirian, H., Salehzadeh, A., 2019. Effect of Seasonality on the Population Density of Wetland Aquatic Insects: A Case Study of the Hawr Al Azim and Shadegan Wetlands, Iran. Veterinary World. 12(4), pp. 584–592. https://doi.org/10.14202/vetworld.2019.584-592.

Pettitt, A.N., 1979. A Non-Parametric Approach to the Change-Point Problem. Appl. Stat. 28 (2), pp. 126–135.

Salarijazi, M., 2012. Trend and Change-Point Detection for the Annual Stream-Flow Series of the Karun River at the Ahvaz Hydrometric Station. Afr. J. Agric. Res. 7 (32), pp. 4540-4552.

Sissakian, V., Al-Ansari, N., Knutsson S., 2013. Sand and Dust Storm Events in Iraq. Natural Science Vol. 5, No. 10, pp. 1084-1094. http://file.scirp.org/pdf/NS_2013101014315787.pdf.

UNDP, 2009. UNDP Helps Drought-Stricken Iraq Combat Effects of Climate Change. http://www.undp.org/content/undp/en/home/presscenter/articles/2009/12/16/u

UNEP, (The United Nations Environment Programmer International Environmental), 2004. Integrate Watershed Management - Ecohydrology and Phytotechnology Manual Technology Centre Oroshimo-cho, Kusatsu-City, Shiga 525-0001. www.unep.org/ietc/Procurement/tabid/104300/Default

UN-ESCWA, BGR, 2013. United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe. Inventory of Shared Water Resources in Western Asia, Beirut. https://doi.org/10.18356/48e4072c-eng

Villarini, G., Smith, J., Serinaldi, F., Ntelekos, A., 2011. Analyses of Seasonal and Annual Maximum Daily Discharge Records for Central Europe. J. Hydrol. 399 (3–4), pp. 299-312. https://doi.org/10.1016/j.jhydrol.2011.01.007.

Wolman, M.G. and Gerson, R., 1978.Relative Scales of Time and Effectiveness of Climate in Watershed geomorphology. Earth Surf. Processes 3, pp. 189-208: http://onlinelibrary.wiley.com/doi/10.1002/esp.3290.

World Bank Group (WBG), 2020. Climate Change Knowledge Portal.

Zang, C., Liu, J., 2013. Trend Analysis for the Flows of Green and Blue Water in the Heihe River Basin, Northwestern China. J. Hydrol. 502, pp. 27–36. https://doi.org/10.1016/j.jhydrol.2013.08.022