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The Use of Geographic Information System Facilities to Estimate the Evapotranspiration in Iraq According to Thornthwaite Adjusted Formula.

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Abstract:
Iraq is facing water shortage problems due to various factors, globally (Global warming) and regionally (GAP project) and locally (improper water resources management projects). In this search the global warming influence on the annual mean value of temperature and yet on the annual mean value of the evapotranspiration for more than three decades has been studied. The climate of Iraq is influenced by its location between the subtropical aridity of the Arabian desert areas and the subtropical humidity of the Arabian Gulf. The relative ascension of temperature degrees in the recent decades was the main factor in relative humidity decrement which increase the evapotranspiration values, since that utilizing a temperature-based method as in this search is the best choice to obtain realistic results. The increment in the annual mean value for maximum, minimum, and air temperature for each decade comparing with the previous one is about (1-3) % which yield an increment in the Evapotranspiration values of the millenniums decade comparing with the eighties one of about (35- 60) % for some southern Iraqi administratives, while it is about (13-15) % in some northern ones.

Keyword: evapotranspiration, GIS, Global warming, Thornthwaite, and climatological data .

استخدام امكانيات نظم المعلومات الجغرافية لتخمين التبخر– نتح في العراق طبقاً لصيغة ثورنثويت المعدّلة

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الخلاصة
يواجه العراق اشكاليات ناتجة عن العجز المائي الحاصل بسبب عوامل عديدة، عالمية (الأحتباس الحراري) واقليمية مشروع ال (GPA) ومحلية (الادارة غير المناسبة للمشاريع الاروائية) .في هذا البحث تم دراسة تأثير ظاهرة الاحتباس الحراري على قيمة المعدل السنوي لدرجات الحرارة ومن ثم على قيمة المعدل السنوي للتبخر_ نتح ولاكثر من ثلاثة عقود. ان مناخ العراق يتاثر بموقعه بين الجفاف شبه الاستوائي لمنطقة الصحراء العربية والرطوبة شبه الاستوائية لمنطقة الخليج العربي. الارتفاع النسبي لدرجات الحرارة في العقود الاخيرة كان العامل الرئيسي لقلة الرطوبة النسبية وبالتالي زيادة التبخر– نتح، ومن هنا فاستعمال طريقة تعتمد على درجة الحرارة كما في هذا البحث هو الخيار الافضل لاستحصال نتائج واقعية. نسبة الزيادة في درجات الحرارة العظمى والصغرى والهواء لكل عقد عن سابقه كانت بحدود (1–3)% والتي ادت الى زيادة نسبة

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المعدل السنوي للتبخر – نتح في عقد الالفية الى حوالي (35–60)% عما هي عليه في عقد الثمانينات لبعض المحافظات الجنوبية في حين كانت (13–15)% لبعض المحافظات الشمالية.

Introduction:

The knowledge of the magnitude and variation of evaporative losses is required in water resources planning and management, design of reservoirs, assessment of irrigation efficiency of existing projects, evaluation of future drainage requirements, quantification of deep percolation losses under existing water management practices, water supply requirements of proposed irrigation projects, and preparation of river forecasts, to name but a few. Potential evapotranspiration, to gather with precipitation, are the inputs to most hydrological models. There exist a multitude of methods, for measurement and estimation of evaporation, which can be classified into five groups:

(i) water budget as in [1].
(ii) mass-transfer as in [2].
(iii) combination as in [3].
(iv) radiation as in [4].
(v) temperature-based as in [5] , and [6].

In this search a temperature-based method will be utilized (Thornthwaite method), [5] to estimate the evapotranspiration values all over Iraq. Thornthwaite method. A widely used method for estimating potential evapotranspiration was derived by Thornthwaite (1948) who correlated mean monthly temperature with evapotranspiration as determined from water balance for valleys where sufficient moisture water was available to maintain active transpiration. In order to clarify the existing method, the computational steps of Thornthwaite equation are explained.

1. The annual value of the heat index I is calculated by summing monthly indices over a 12-month period. The monthly indices are obtained from the equations

$$i = (\frac{Ta}{5})^{1.51} \quad \ldots\ldots\ldots (1)$$

and

$$I = \sum_{j=1}^{12} i_j \quad \ldots\ldots\ldots \quad (2)$$

In which I is the annual heat index, I is the monthly heat index for the month j (which is zero when the mean monthly temperature is 0 °C or less), Ta is the mean monthly air temperature (°C) and j is the number of months (1–12).

2. The Thornthwaite general equation, Equation (4) calculate sun adjusted monthly values of potential evapotranspiration, ET (in mm), based on a standard month of 30 days, 12 h of sunlight

$$ET' = C(\frac{10Ta}{I})^{a} \quad \ldots\ldots\ldots.. (3)$$

In which C=16 (a constant) and ($a = 67.5\times10^{-8}I^3 - 77.1\times10^{-6}I^2 + 0.0179I + 0.492$) The value of the exponent a in the preceding equation varies from zero to 4.25 (e.g. JainandSinai,1985), the annual heat index varies from zero to 160, and ET' is zero for temperature below 0° C.

3. The unadjusted monthly evapotranspiration values ET are adjusted depending on the number of days N in a month ($28 \leq N \leq 31$) and the duration of average monthly or daily daylight d (in hours),which is a function of season and latitude.

$$ET = ET'(\frac{d}{12})(\frac{N}{30}) \quad \ldots\ldots\ldots\ldots. (4)$$

In which ET is the adjusted monthly potential evapotranspiration (mm), d is the duration of average monthly daylight (hr); and N is the number of days in a given month, 28–31(days), [7]

The study area:

Iraq is located in the eastern part of the MENA region (Middle East and North African) countries. It's total area is 438,320 km^2 with 924 km^2 as a water covered land. (MENA region) is considered to be arid or semi-arid as the average annual rainfall does not exceed 166 mm [8], and [9] with a high evapotranspiration rates. For this reason, the scarcity of water resources in this region, and particularly in the Middle East, represents an extremely important factor in the stability of the region and an integral element in its economic development and prosperity [10]. Due to the presence of Tigris and Euphrates rivers, Iraq was considered relatively rich in its water resources compared to its neighboring countries until the seventies. During the seventies Syria and Turkey started to construct dams on the Euphrates and Tigris Rivers which caused a major decrease in the flow of the Euphrates River [11] as well as deterioration of the quality of its water [12]. These facts highlighted a further concern over future water quotas and its alarming implications upon the national security and strategies. In addition to that Future predictions suggest more severe shortages to be expected both in surface and groundwater resources [13], and [14] the study of evapotranspiration rates (values and reasons) in Iraq districts for the latest climate cycle is important to guarantee or not these predications.

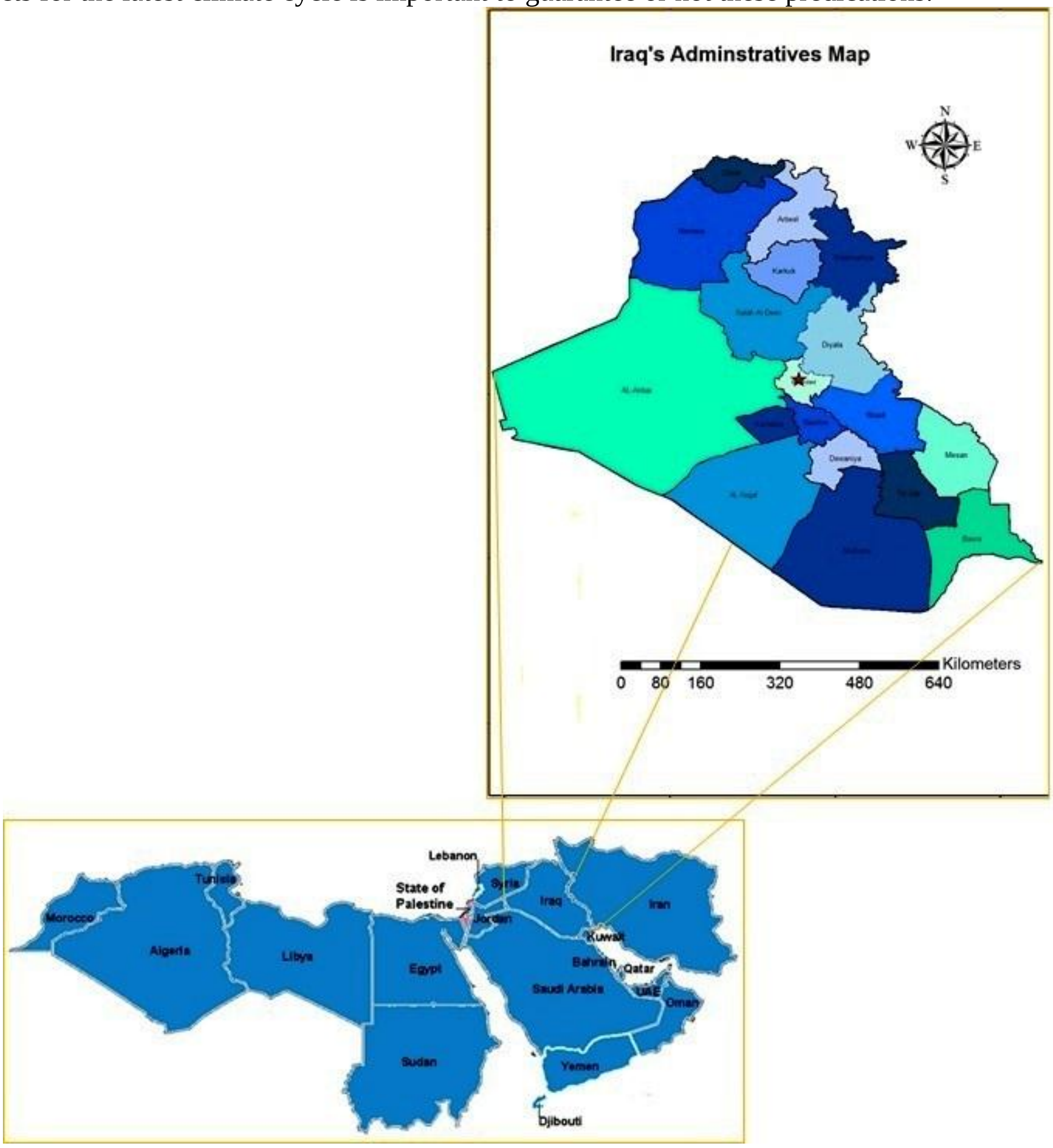

Figure 1- Iraq map location in the eastern part of MENA region with illustration to its administratives.

Methodology:

The meteorology scientists stated that long-range climate changes need an interval to happen and it should not be less 33 years (one climate cycle), so that in this research the interval should start from (1980) to (2012) because eighties decade had few climatological variations from previous ones (i.e. the noticeable variations begin in the eighties decade). In this research the utilize climatological data (monthly mean maximum and minimum temperatures of 11 meteorological stations that has been selected to be well distributed all over Iraq area) has been supplied by (Iraqi Meteorological Organization and Seismology). Every month values for each 11 years (almost a decade) has been summed and divided using simple arithmetic mean, after that the mean monthly air temperature was calculated; then after these values entered within Thornthwaite eq.(1) to get the monthly non-adjusted evapotranspiration values.

Later the annual mean values of the non-adjusted evapotranspiration has been calculated for each decade (seventies, eighties, and millenniums). The final processes was the determination of the annual mean values of the adjusted evapotranspiration using Thornthwaite eq.(4).

Table-1 illustrates the position of each station and its annual mean value of the non-adjusted evapotranspiration for nearly three decades.

Table 1- the position of the meteorological stations with its annual mean value of the non-adjusted evapotranspiration for nearly three decades .

Meteorological station	Longitude (decimal deg.)	Latitude (decimal deg.)	80's ET' (mm)	90's ET' (mm)	2000's ET' (mm)
Baghdad	44.352558	33.273364	1428.22	1525.064	1798.604
Karkuk	44.366656	35.410581	1454.272	1540.685	1644.143
Musil	43.154251	36.28746	1122.636	1156.939	1296.835
Najaf	44.370311	31.967195	1726.145	1912.319	2263.371
Emara	47.204974	31.810161	1936.939	2213.654	2623.803
Nasiriya	46.317051	31.001656	1931.253	2242.938	2725.308
Hai	46.076356	32.126716	1987.247	2223.73	3186.951
Beji	43.493128	34.931212	1395.327	1503.687	1681.444
Karbala	44.257927	32.619297	1706.215	1887.356	2081.832
Hilla	44.42611	32.483149	1534.844	1695.682	1710.815
Rutba	40.273563	33.056428	1030.312	1102.312	1167.22

While Table-2 illustrates the annual mean value of the adjusted evapotranspiration for nearly three decades of each station and the percentage increment in the ET annual values for each decade to the previous ones.

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Table 2- the annual mean value of the adjusted evapotranspiration for nearly three decades of each meteorological station and the percentage increment in the ET annual values.

Meteorological station	Daylight (hrs.)	80's ET (mm)	90's ET (mm)	2000's ET (mm)	90's-80's ET increment (%)	2000's-90's ET increment (%)	2000's-80's ET increment (%)
Baghdad	8.045	971.3866	1037.253	1223.299	6.780658	17.93641	25.93328
Karkuk	8.265	1016.154	1067.533	1148.824	5.056222	7.614847	13.05609
Musil	8.127	771.33	794.8981	891.0164	3.055515	12.0919	15.51689
Najaf	8.41	1263.538	1382.607	1656.787	9.42346	19.83065	31.12285
Emara	8.15	1334.579	1525.24	1807.839	14.28623	18.52817	35.46137
Nasiriya	8.186	1336.539	1552.243	1886.072	16.139	21.50623	41.11612
Hai	8.206	1378.65	1542.71	2210.944	11.90005	43.31559	60.37022
Beji	8.312	980.4962	1056.635	1181.551	7.765334	11.82206	20.50541
Karbala	8.287	1195.3688	1322.275	1458.5247	10.61649	10.30419	22.01462
Hilla	8.287	1075.306	1187.99	1198.592	10.47925	0.892432	11.4652
Rutba	8.761	762.7125	815.7107	863.7427	6.948647	5.888362	13.24617

In Figure-2 the Meteorological station positions are illustrated on Iraq's map and the annual adjusted evapotranspiration values of Iraq for three decades are demonstrated by using the Inverse Distance Weighted interpolation technique (the utilized software was Arc GIS 9.3)

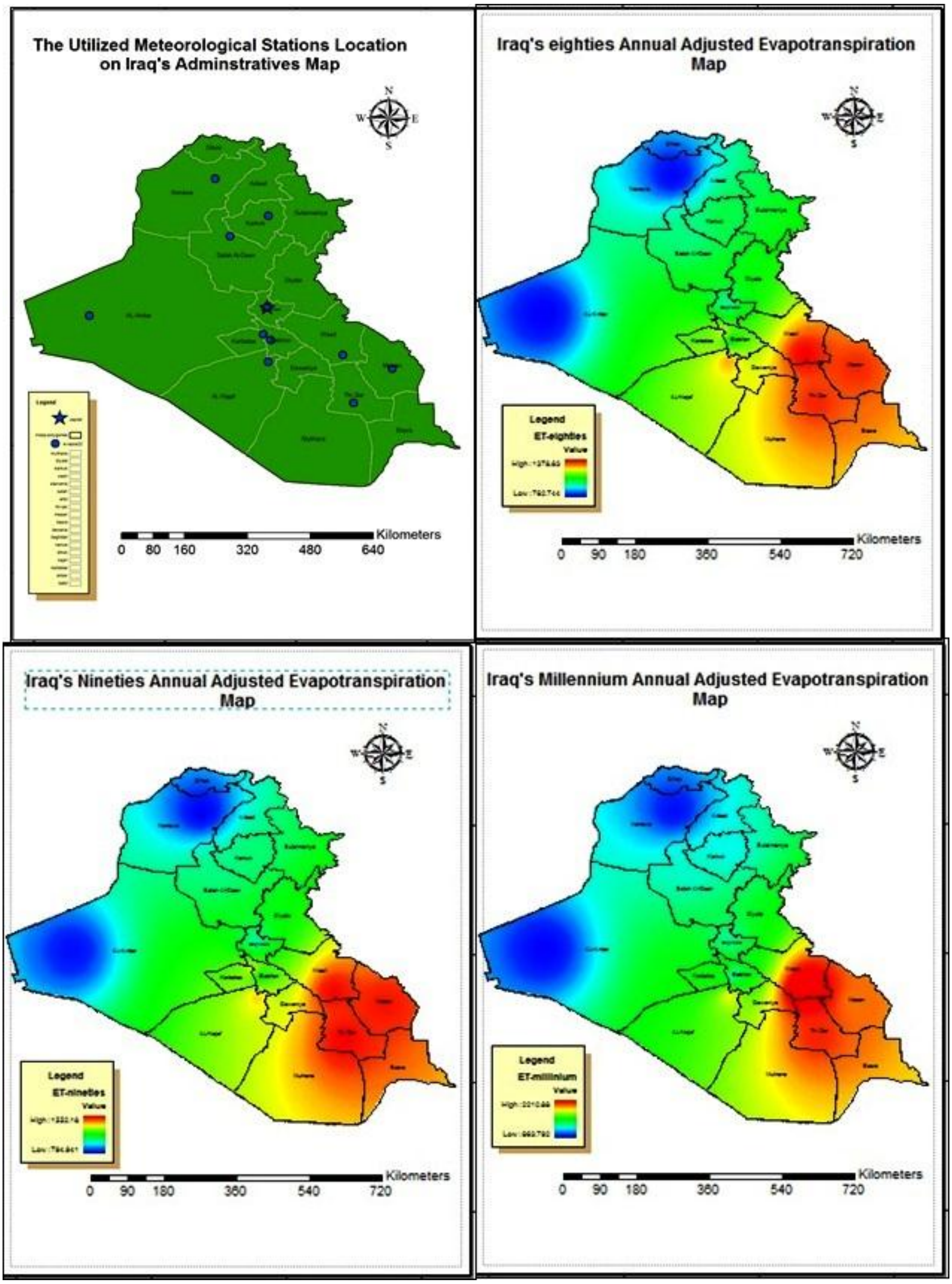

Figure 2- (A) the Meteorological stations location on Iraq's map, (B) Iraq's annual adjusted ET values for Eighties, (C) Iraq's annual adjusted ET values for Nineties, and (D) Iraq's annual adjusted ET values for Millennium.

Results and analyses:

The obtained potential evapotranspiration values referred to a serious situation that could be (with continuity) a disaster on many levels such as agricultural, social, economic, and healthy levels; since increment in the ET values of the millenniums decade comparing with the eighties one is about (35-60) % for some southern Iraqi administratives. Even northern administratives (by utilizing the aridity index) will face a "meteorological drought" if the annual Precipitation Rates maintains. yet arid lands will extend to cover all over Iraq's area in the recent future. As an explanatory example the area with ET rates less than (1000 mm/ year) was (143915.923 km^2) in the eighties. In the nineties it became (82516.93 km^2), and recently it shrank to (37381.533 km^2). As can be illustrated in the next Figure.

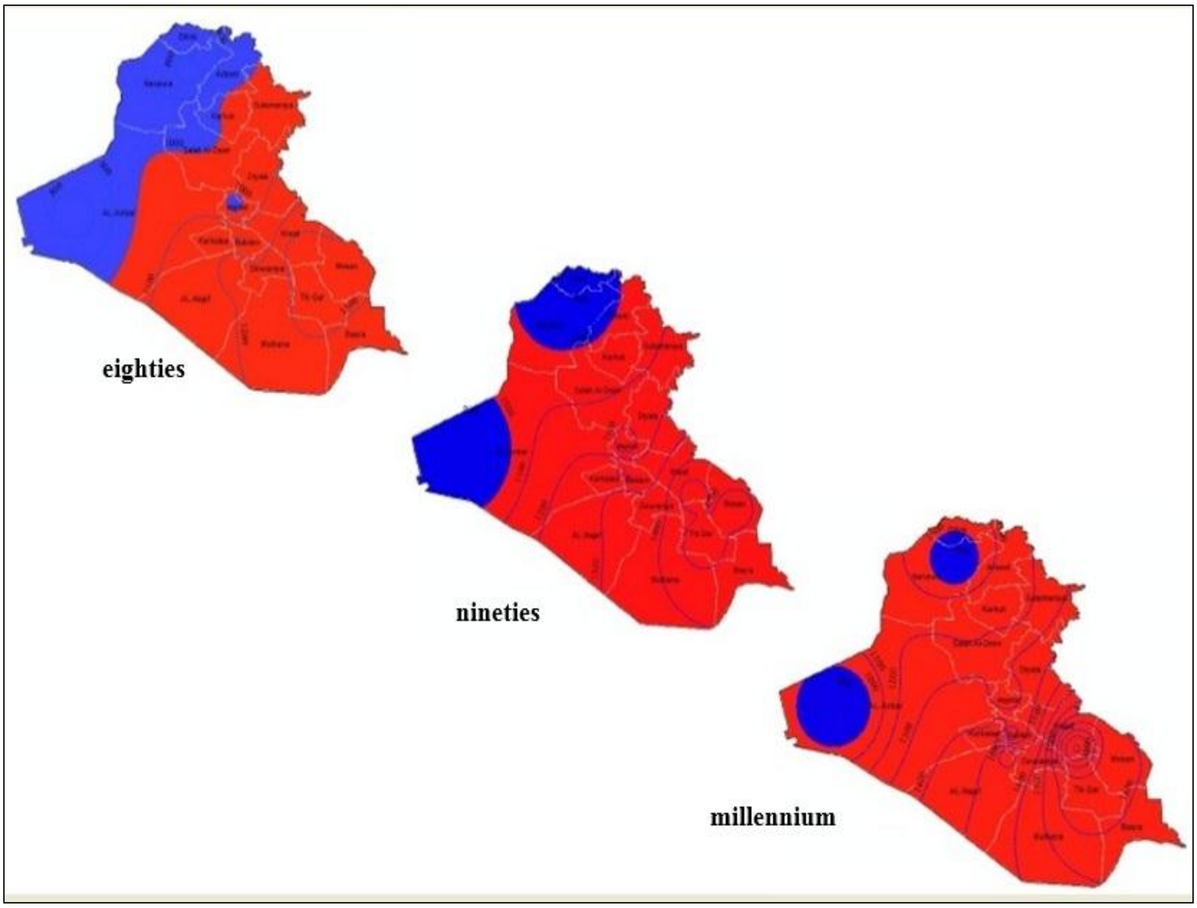

Figure 3- Iraqi lands with ET rates more than (1000 mm/ year) in red color; while the lands with ET rates less than (1000 mm/ year) in blue color for three decades.

Since Thornthwaite method is a temperature-based method ,so that the reason beyond these enormous increments in ET values over almost three decades is the increment in the annual mean values of air temperature (i.e. in the annual mean value of maximum and minimum temperature). This can be illustrated in the next figure.

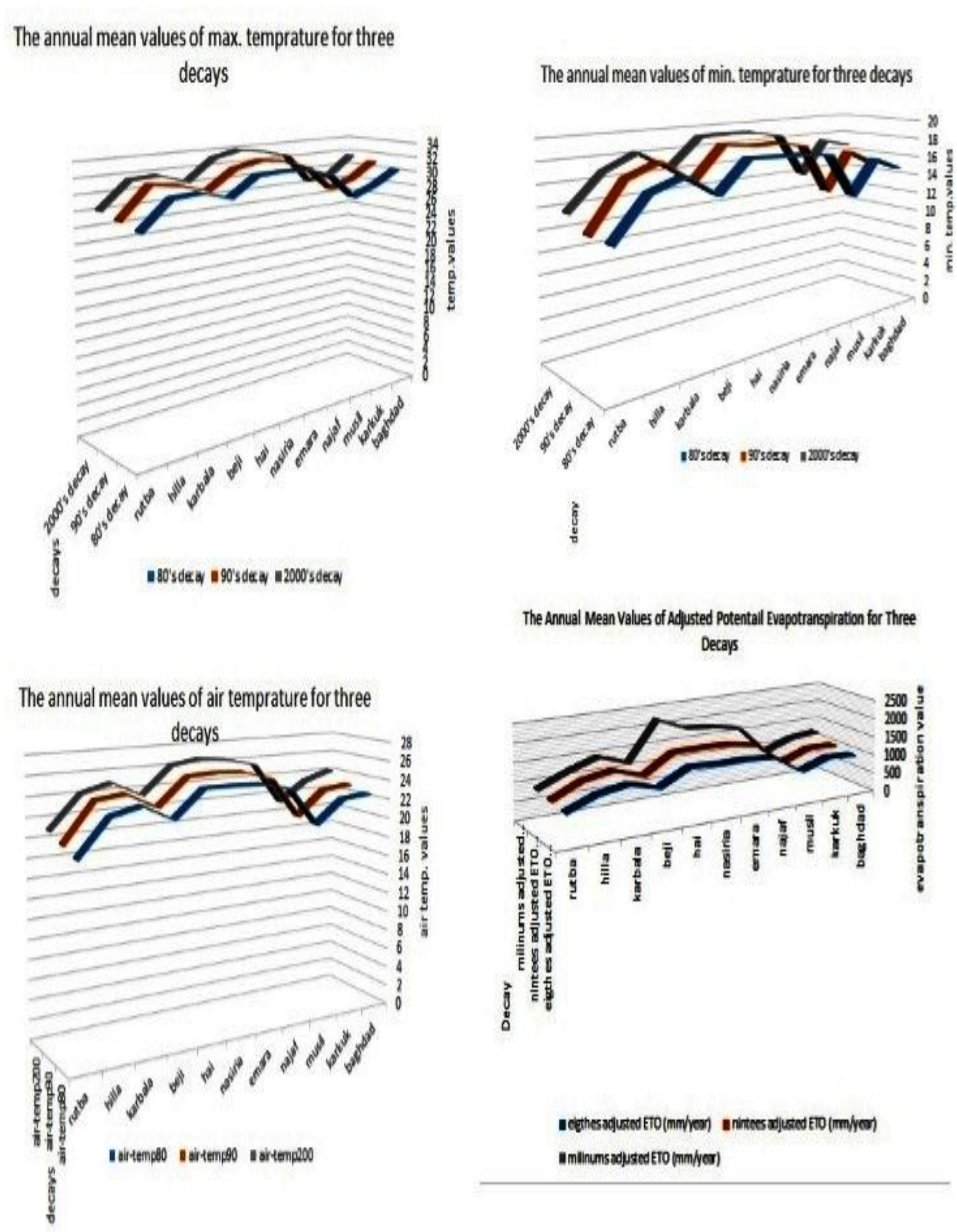

Figure 4- (A) the annual mean values for three decades chart of maximum temperature, (B) the annual mean values for three decades chart of minimum temperature, (C) the annual mean values for three decades chartof air temperature, and (D) the annual mean values for three decades chart of adjusted ET.

The obtained potential evapotranspiration values also illustrates that ET rates increases in significant direction from north-west to south-east, the reason beyond that is the high relative humidity rates in the north-west part of Iraq because of its geographic location near the Mediterranean sea that decreases weather minimum and maximum annual mean temperatures (i.e. decreases air mean temperature).

Conclusions:

As mentioned in the methodology section, this research submit to a dreadful fact that since the beginnings of eighties the ET rates all over Iraq are in a rapidly ascension , which have negative influence on many vital levels. since evapotranspiration depend on many factors such as relative humidity, global sun radiation value, wind speed, air temperature, and rainfall values. This research shows that by using Figure-4 the main reason beyond this ascension, which is the temperature increasing within last climate cycle because of the "Global Warming", The percentage increment in the annual mean value of maximum, minimum, and air temperature for each decade comparing with the previous one is about (1-3) %.

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