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The Climatic Quality Index Determination for Iraq Using Meteorological Stations Data

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Abstract:
The drought is a globally phenomenon, its influence will convert large parts of Middle East and North Africa (MENA) region into hot dry deserts under the expectations of the climate change scenarios. Climate limitations, soil erosion affected by weather properties such as unequally and limited rainfall; temperature changing and wind, unsuitable irrigation techniques, excessive grazing, agricultural expansion against to the natural habitats, extensively clearance of natural vegetation, and soil salinity had all contributed to land degradation, reduced water supplies, and limited agricultural production in Iraq. It is estimated that nearly 54.3 % of Iraq's area is threatened by desertification problems.

In this research, for Iraq the Climatic Quality Index (CQI) has been utilized to state the arid and semi-arid lands area variation during the interval (1980-2012) using the meteorological data of eleven stations. The results shows that at the end of eighties decade the arid lands covered only 73% of Iraq's area, and the arid lands covered 78% of Iraq's area in the nineties decade, while in the first decade of the second millennium the arid lands rapidly increased to cover 88% of Iraq's area. this search shows that the "Global Warming" was the reason beyond the temperature averages increments within last climate period which lead to arid regions rapidly extension in Iraq.

Keywords: aridity index, GIS, Global warming, Thornthwaite, and meteorological data .

تحديد معامل نوعية المناخ للعراق باستخدام بيانات المحطات الأنوائية

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الخلاصة
الجفاف عبارة عن ظاهرة عالمية، تاثيراته ستحول اجزاء كبيرة من منطقة الشرق الأوسط وشمال أفريقيا ال (MENA)الى صحاري حارة جافة وحسب توقعات سيناريوهات التغير المناخي. الاحوال المناخية القاسية، تعرية التربة بسبب بعض الخصائص الجوية كالامطارالمحدودة و غير المتساوية الانتشار; الحرارة والرياح، تقنيات الري غير الملائمة، الرعي الجائر، التمدد الزراعي على حساب المواطن الطبيعية، الاقصاءالشامل للنبات الطبيعي، وتملح التربة كلها ظروف اسهمت باضعاف التربة، تقليل الموارد المائية، وتحديد الانتاج الزراعي في العراق. من المتوقع ان 54,3% من مساحة العراق مهددة باشكاليات التصحر.

في هذا البحث، تم استخدام معامل نوعية المناخ (CQI) لتحديد التغاير في مساحة الاراضي الجافة وشبه الجافة داخل العراق وللفترة (1980–2012) بواسطة استعمال البيانات الانوائية لاحدى عشرة محطة. النتائج

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بينت بان الاراضي الجافة غطت 73% من مساحة العراق عند انتهاء عقد الثمانينات، والاراضي الجافة غطت 78% من مساحة العراق عند نهاية التسعينات، في حين تزايدت رقعة الاراضي الجافة بسرعة لتشمل 88% من مساحة العراق في نهاية العقد الاول من الالفية الثانية. هذا البحث بين بان "الاحتباس الحراري " كان السبب وراء تزايد معدلات درجات الحرارة خلال الدورة المناخية الاخيرة والتي افضت الى التمدد السريع للمناطق الجافة في العراق.

Introduction

In spite of the enormous progress on both levels science and applied technology, humanity still in confront with arid and semi-arid regions expanding. Arid and semi-arid lands extend to cover one third of earth. Climate is the main reason beyond arid environment aspects; it states the topography factor and controls the planet's aspects, animal's species, and soil composition as well [1]. In this research a number of Climate Quality indices have been proposed (Table-1); those indicators serve to clarify, locate or delimit the lands that suffer from a deficit of available water, a condition that can severely influence on the effective usage of the land soil for such efficiencies as agriculture or stock-farming, the climate quality index (CQI) is evaluated through the aridity index (AI), using the methodology developed by the applied meteorology foundation [2]. In the current study, climatological data of "11" meteorological stations were used to calculate the Aridity Index (AI) for Iraq as follow in equation (1):

$$AI = P/ET \quad \ldots \ldots \ldots (1)$$

where P; is the average annual precipitation and ET; is the average annual potential evapotranspiration.

Table 1- Classification of climate quality index (CQI) [1].

Class number	**Climatic zone**	**AI**	**CQI**
1	**Hyper-arid**	**<0.05**	**2**
2	**Arid**	**0.05-0.2**	**1.75**
3	**Semi-arid**	**0.2-0.5**	**1.5**
4	**Dry sub-humid**	**0.5-0.65**	**1.25**
5	**humid**	**>0.65**	**1**

In this research a temperature-based scheme will be utilized (Thornthwaite scheme), [3] to estimate the evapotranspiration values all over Iraq. It is a widely utilized one for estimating the potential evapotranspiration that derived by Thornthwaite (1948) who matched mean monthly temperatures with the evapotranspiration values as extracted from water balance for the valleys where sufficiently moisture water was there to keep active transpiration. In order to clarify the existing methodology, the computationally phases of the "Thornthwaite equation" explained:

A. The annually value for the heat index I was determined by calculating the monthly indices i over a 12-month interval. Those indices were determined from the equations:

$$i = \left(\frac{T_a}{5}\right)^{1.51} \ldots \quad (2)$$

and

$$I = \sum_{j=1}^{12} i_j \ldots \ldots \quad (3)$$

where I is the yearly heat index, i is the heat index for the month j (which is zero when the mean monthly temperature is 0 °C or less), the mean monthly air temperature is Ta in (°C) and the months (1–12) indicator is j.

B. The general formula of Thornthwaite, numbered as eq.5 determine adjusted values of potentially evapotranspiration for each month, ET in (mm) according to a month of 30 days long standardly, with sunlight 12 hours duration, from the unadjusted one ET' which illustrated in equation (4).

$$ET' = C(\frac{10T_a}{I})^a \dots\dots \quad (4)$$

where C is equal to 16 (constant) and (a = $67.5\times10^{-8}I^3-77.1\times10^{-6}I^2 + 0.0179I + 0.492$) The exponent a value in the previous equation has a range from (0 _ 4.25) as in (Jain and Sinai,1985), the annual heat index has a range from (0 _ 160), and $ET'$is zero for any temperature degrees under 0°C.

C. The non-adjusted monthly evapotranspiration numbers ET' were adjusted by adopting the number of days N in each month ($28 \leq N \leq 31$) and the daylight duration of the day or the month d (in hours),which is a function for the height and season.

$$ET = ET'\left(\frac{d}{12}\right)\left(\frac{N}{30}\right) \dots \quad (5)$$

where ET is the adjusted potential evapotranspiration in (mm) for each month, d is the average daylight interval for a month in (hrs); and N is the days number for a in a specific month, 28–31(days), [4]

The study area

Iraq locates in the east of the (MENA) region countries. The total area of it is 438,320 km^2 with 924 km^2 as a water covered landscapes [5]. (MENA) region is considered to be as an arid or semi-arid land since the average of annual rainfall does not exceed 166 mm [5, 6] with a high evapotranspiration rates. For that, the scarcity of water supplies in this area, and particularly in Middle East one, stands for a factor with an extremely importance for the stability of the area and an integral element in its economic growth and prosperity [7]. Because of the presence of Euphrates and Tigris rivers, Iraq was considered relatively rich with its water quantities comparing to some neighboring countries until the seventies. During the seventies decade Syria and Turkey began to construct dams on the two rivers which causing a major decrement in the flow rates of the Euphrates river [8] as well as deterioration in quality of the water [9]. Those facts highlighted a great concern on future water quotas and its worrying implications upon the nation security and strategies. Also the future expectations suggest more severely shortages both in the surface and groundwater supplies [10], the study of evapotranspiration rates (values and reasons) in Iraq districts for the latest climate period is important to guarantee or not these predications and to clarify the aridity orientation and area extension in Iraq administratives.

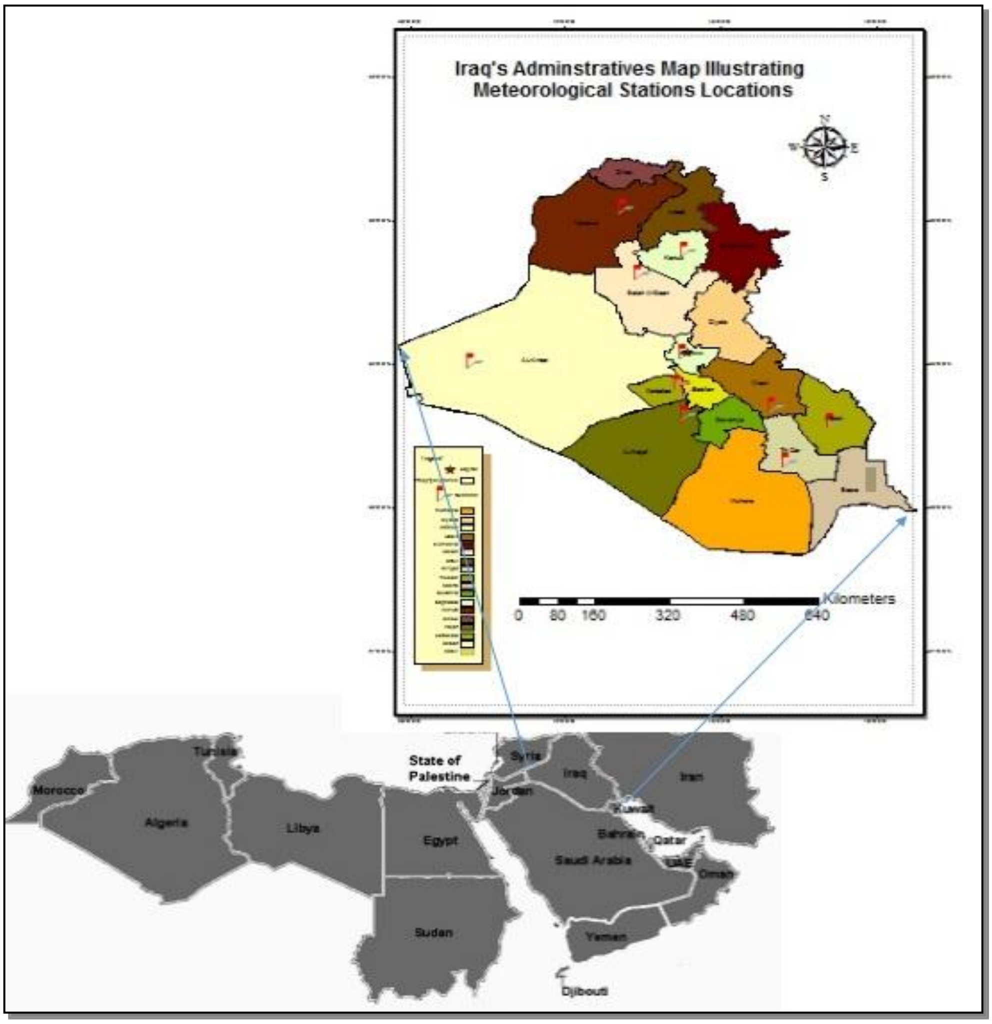

Figure 1- Iraq administrative map location in the eastern part of MENA region with illustration to the utilized meteorological stations.

Methodology

In this research the utilized 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) for 33 years (one climate period). 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 the 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 millennium 1st decade). The final processes was the determination of the annual mean values of the adjusted evapotranspiration using the Thornthwaite eq. (5).

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.

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 variation (%)	2000's-90's ET variation (%)	2000's-80's ET variation (%)
Baghdad	8.045	971.38	1037.25	1223.29	6.780	17.936	25.933
Karkuk	8.265	1016.15	1067.53	1148.82	5.056	7.6148	13.056
Musil	8.127	771.33	794.89	891.01	3.055	12.091	15.516
Najaf	8.41	1263.53	1382.60	1656.78	9.423	19.830	31.122
Emara	8.15	1334.57	1525.24	1807.83	14.286	18.528	35.461
Nasiriya	8.186	1336.53	1552.24	1886.07	16.139	21.506	41.116
Hai	8.206	1378.65	1542.71	2210.94	11.90	43.315	60.370
Beji	8.312	980.49	1056.63	1181.55	7.765	11.822	20.505
Karbala	8.287	1195.36	1322.27	1458.52	10.616	10.304	22.014
Hilla	8.287	1075.30	1187.99	1198.59	10.479	0.892	11.465
Rutba	8.761	762.71	815.71	863.74	6.948	5.888	13.246

In Figure-2(i) the annual adjusted evapotranspiration values of the eleven stations for three decades are demonstrated and in Figure-2(ii) the annual adjusted evapotranspiration contour values of Iraq for three decades are demonstrated by using the Inverse Distance Weighted interpolation technique (the utilized software was Arc GIS 9.3).

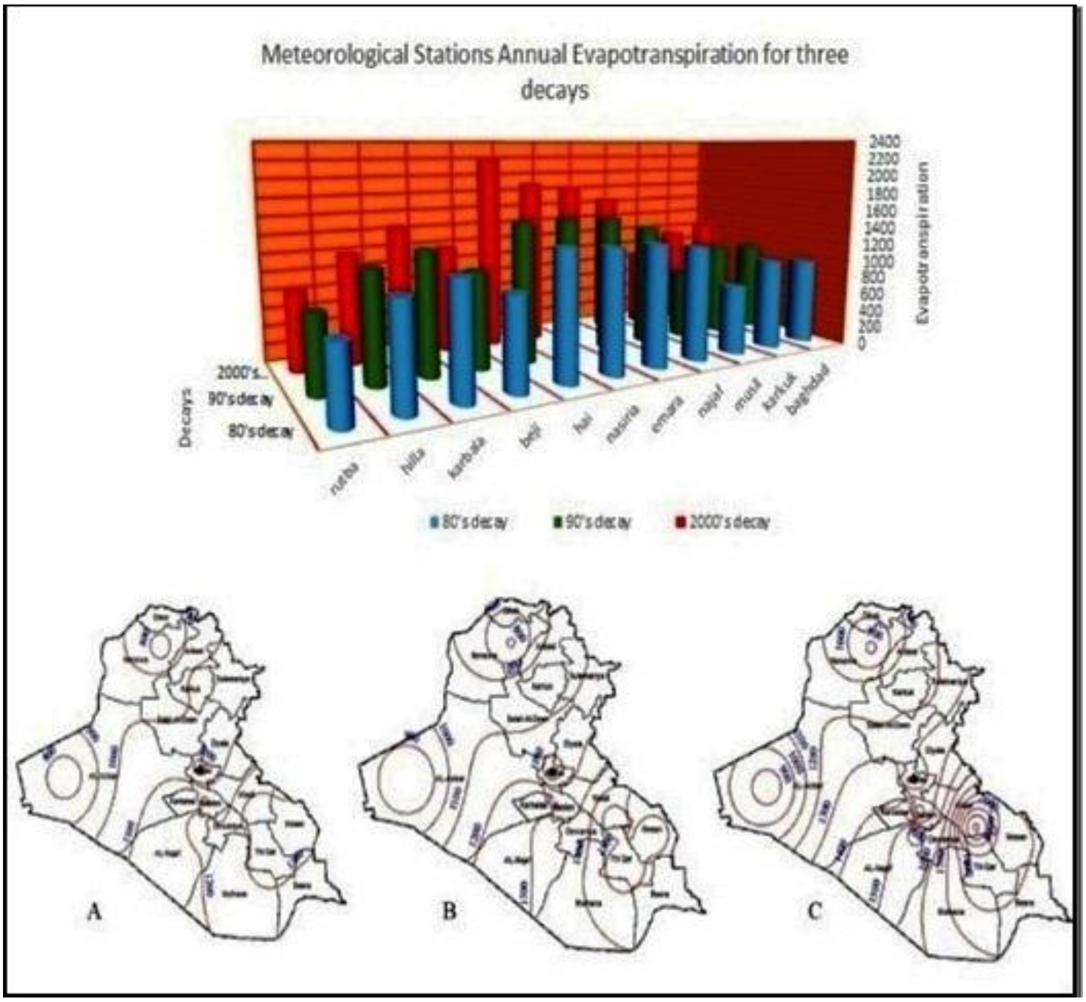

Figure 2- i. the annual adjusted evapotranspiration values of the eleven stations for three decades are demonstrated**. ii**. the annual adjusted evapotranspiration contour values of Iraq for three decades(A-eighties, B-nineties, and C- millennium 1st decade) are demonstrated.

Table-3 illustrates the annual mean value of the precipitation for nearly three decades of each station and the percentage variation in the precipitation annual values for each decade to the previous one and each decade aridity index (AI).

Table 3- the annual mean value of the precipitation for three decades and the percentage variation in the precipitation annual values for each decade to the previous one and each decade aridity index (AI)

Meteo. station	80's precip. (mm)	90's precip. (mm)	2000's precip. (mm)	90's-80's precip. variation %	2000's-90's precip. variation %	2000's-80's precip. variation %	80's AI	90's AI	2000's AI
baghdad	120.92	105.6	97.69	-12.669	-7.490	-19.211	0.124	0.101	0.079
karkuk	371.11	390	259	5.090	-33.589	-30.209	0.365	0.365	0.225
musil	386	356	290	-7.772	-18.539	-24.870	0.500	0.447	0.325
najaf	114	101	78	-11.403	-22.772	-31.578	0.090	0.073	0.047
emara	149	197	155	32.214	-21.319	4.026	0.111	0.129	0.085
nasiria	132	128	104	-3.030	-18.75	-21.212	0.098	0.082	0.055
hai	135	119	95	-11.851	-20.168	-29.629	0.097	0.077	0.042
beji	199	178	174	-10.552	-2.247	-12.562	0.202	0.168	0.147
karbala	104	90	82	-13.461	-8.888	-21.153	0.087	0.068	0.056
hilla	107	95	83	-11.214	-12.631	-22.429	0.099	0.079	0.069
rutba	117	132	86	12.820	-34.848	-26.495	0.153	0.161	0.099

then the annual precipitation values of the eleven stations for three decades are calculated. In Figure -3(i) these values are demonstrated and in Figure -3(ii) the annual precipitation contour values of Iraq for three decades are demonstrated by using the Inverse Distance Weighted interpolation technique (the utilized software was Arc GIS 9.3)

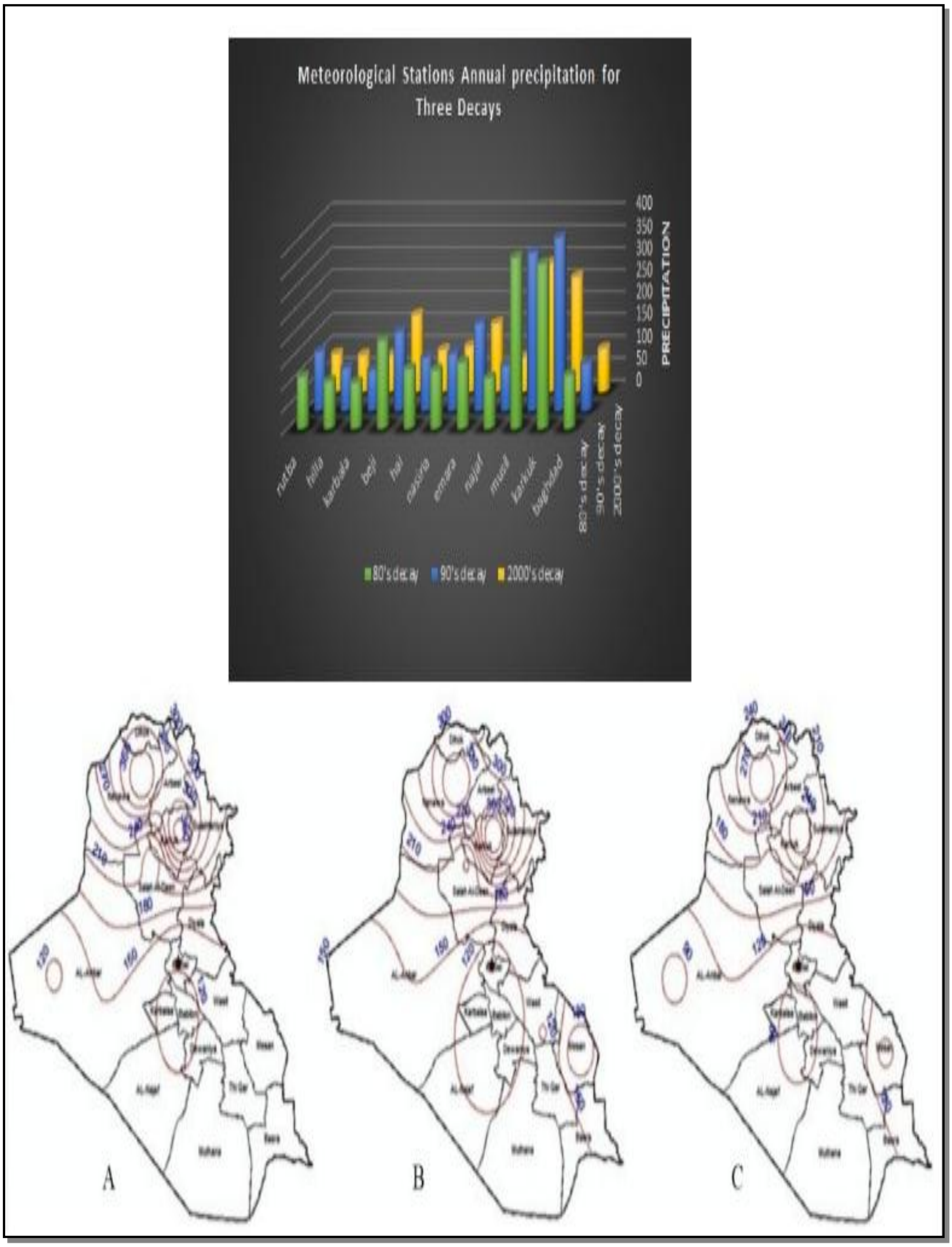

Figure 3-i)the annual precipitation values of the eleven stations for three decades are demonstrated
ii) the annual precipitation contour values of Iraq for three decades (A- eighties, B-nineties, and C- millennium 1st decade) are demonstrated.

In Figure-4 the AI for each meteorological station is illustrated.

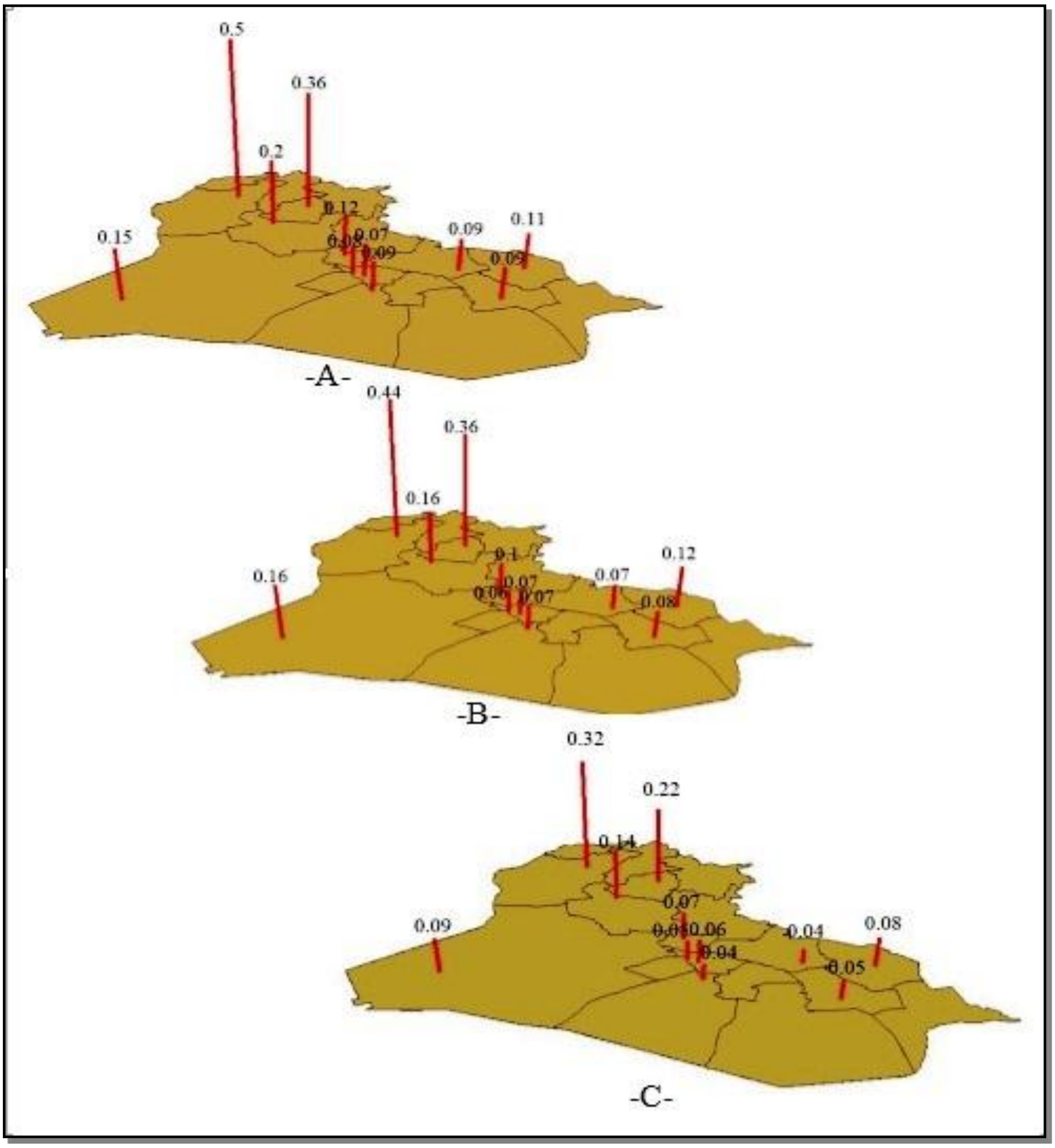

Figure 4- the AI of each meteorological station illustrated for three decades(A-eighties, B-nineties, and C-millennium 1st decade)

In Figure -5 the Climate Quality Index values of Iraq for three decades are demonstrated by using the Inverse Distance Weighted interpolation technique, then according to CQI values the arid regions (CQI=1.75) and semi-arid ones (CQI=1.5) are determined.

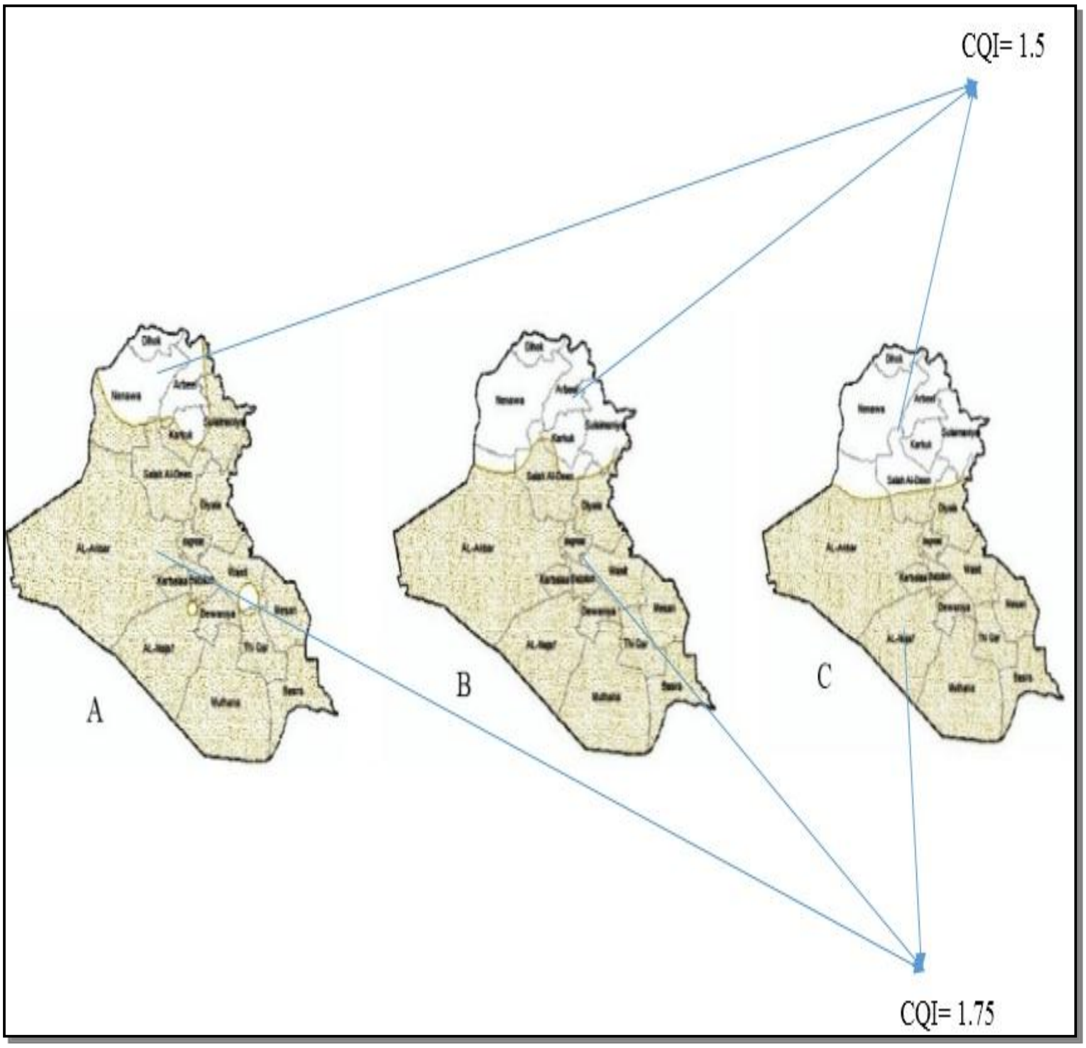

Figure 5- the Climate Quality Index values of Iraq for three decades (A- millennium 1st decade, B- nineties, C- eighties) are demonstrated, then arid regions (CQI=1.75) and semi-arid ones (CQI=1.5) are illustrated.

Results and Analysis

The obtained CQI values of the recent climate cycle refer to a serious drought situation that Iraq has been encountered with, it could be (with continuity) a disaster on many levels such as agricultural, social, economic, and healthy levels; the increment in ET values of the millenniums 1st decade comparing with the eighties one is about (35- 60) % for some Iraqi administratives; while the decrement in precipitation values of the millenniums decade comparing with the eighties one is about (-29 _ -31) % for other administratives. The changes in evapotranspiration and precipitation were The reason beyond arid lands extending in Iraq. the global warming effects on MENA region was the cause beyond these changes (i.e. the increment of the annual mean value of maximum and minimum temperatures that decrease the annual mean value of relative humidity). This can be illustrated in Table-4.

Table 4- the annual mean value of the maximum and minimum temperature degrees for three decades and the percentage variation in the temperature annual values for each decade to the previous one.

Meteo. Station	Eighties max. (deg.)	Nineties max. (deg.)	Millennium 1st max. (deg.)	Eighties min. (deg.)	Nineties min. (deg.)	Millennim 1st min. (deg.)	90's-80's max. variat. %	2000's-90's max. variat. %	90's-80's min. variat. %	2000's-90's min. variat. %
Baghdad	30.25	30.94	31.49	14.81	15.04	16.69	2.28099	1.777634	1.5530	10.9707
karkuk	28.46	28.89	29.01	16.04	16.48	17.4	1.51082	0.415369	2.7431	5.58252
Musil	27.27	27.92	28.55	12.6	12.58	13.97	2.38357	2.256447	-0.1587	11.0492
Najaf	30.56	31.13	32.46	17.15	17.69	18.45	1.86518	4.272406	3.1486	4.29621
Emara	31.75	32.46	33.34	17.5	18.3	19.06	2.23622	2.711029	4.5714	4.15300
nasiria	31.88	32.87	33.87	17.6	18.29	19.21	3.10539	3.042288	3.9204	5.03007
Hai	31.76	32.16	33.12	17.8	18.71	19.11	1.25944	2.985075	5.1123	2.13789
beji	29.38	29.77	30.42	14.88	15.55	16.36	1.32743	2.183406	4.5026	5.20900
karbala	30.48	30.85	31.61	16.92	17.76	18.19	1.21391	2.463533	4.9645	2.42117
hilla	30.28	31.39	31.46	15.91	16.6	16.79	3.66578	0.223001	4.3368	1.14457
rutba	26.94	27.6	28.2	12.24	12.3	13.58	2.44988	2.173913	0.4901	10.4065

For Iraq the aridity situation can be explained as follow:

- till the end of eighties decade the arid lands covered 73% of Iraq's area.
- In the nineties decade the arid lands covered 78% of Iraq's area.
- In the first millennium decade the arid lands covered 88% of Iraq's area.

Next Figure -6 illustrate the arid districts area that had been added to one of the eighties.

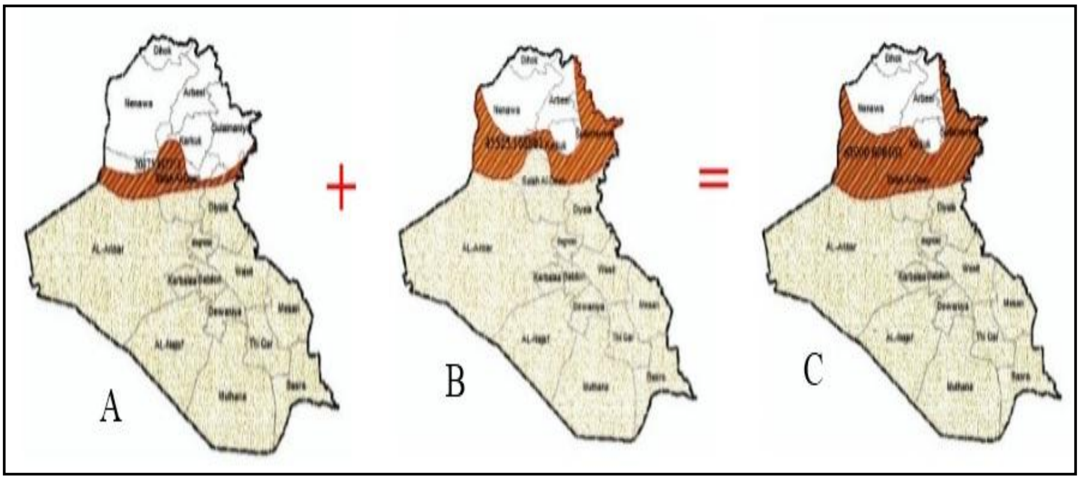

Figure 6-

- **A.** the arid districts area that had been added in the nineties.
- **B.** the arid districts area that had been added in the millennium 1st decade.
- **C.** the overall arid districts area that had been added in the recent climate cycle.

As can be seen the arid districts area that had been added in the nineties was 20375.43 km^2; while the arid districts area that had been added in the millennium 1st decade was 45525.16 km^2 and the overall area was 65900.6 km^2.

Conclusions:

This research submit to a dreadful fact that arid regions are in a rapidly extension in Iraq , which had negative influence on many vital levels. In addition to that this search shows the reason beyond this extension, which is the temperature increments 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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