ISSN: 0067-2904

Evaluation of Climate Change Indicators for Bagdad City Using Remote Sensing Technology

Yusra K. H. Moussa[1] *, Abdelwehab A. Alwehab[2]
[1] *Remote Sensing & GIS Department, College of Science, University of Baghdad, Baghdad, Iraq*
[2]*Centre for Urban & Regional Planning for Post Graduate Studies, University of Baghdad, Baghdad, Iraq*

Received: 23/8/2022 Accepted: 28/10/2022 Published: 30/8/2023

Abstract:
Climate change is a severe problem due to the continuous dynamic changes in urbanization in cities, and reaching it requires high-resolution spatial data represented by using remote sensing technology, as the data of the Space Science Network of NASA was relied on to measure the change in the climate of Baghdad city for a period of four decades 1981-2021, using the climate change equation referred to in the research and then tabulating the data in Excel. The results showed evident changes in the climatic rates, especially during the fourth time cycle; the high rates of temperature and low rates of relative humidity and precipitation indicate that the city's climate is heading towards drought, and similarities appeared between the rates of atmospheric pressure and wind speed at the height of 10 m in terms of stability and slope.

Keywords: Remote sensing, climate change, climate databases for NASA Power Network, Baghdad.

تقييم مؤشرات التغير المناخي لمدينة بغداد باستخدام تقنية الاستشعار عن بعد

يسرى كاظم حسون موسى[1] *, عبد الوهاب أحمد عبد الوهاب[2]
[1]قسم التحسس النائي ونظم المعلومات الجغرافية, كلية العلوم, جامعة بغداد, بغداد, العراق
[2]مركز التخطيط الحضري والاقليمي للد ارسات العليا, جامعة بغداد, بغداد, العراق

الخلاصة :
يعد تغير المناخ مشكلة خطيرة لأنه يتمتع بديناميكية مستمرة تتغير مع التحضر في المدن. فالتغيير ، يتطلب بالبحث الحصول على بيانات ذات دقة مكانية عالية باستخدام طرق الاستشعار عن بعد. الغرض من البحث هو تحديد مقدار التغير في المعدلات المناخية الشهرية والسنوية لمدينة بغداد لمدة أربعة عقود (1981–2021) باستخدام شبكة ناسا لعلوم الفضاء ومعادلة التغير المناخي المشار إليها ضمن البحث. ثم جدولة البيانات في برنامج Excel. وشهدت معدلات التغير انخفاضاً في الإشعاع الشمسي والرطوبة النسبية وزيادة في درجة الحرارة من 1.07–1.7٪، وهناك تذبذب في معدلات درجات الحرارة العظمى والصغرى. وظهرت أوجه تشابه بين الضغط الجوي وسرعة الرياح على ارتفاع 10 أمتار من حيث الثبات والانحدار ، بينما زادت سرعة الرياح

* Email: yosra.k@sc.uobaghdad.edu.iq

على ارتفاع 50 مترًا ، وشهد التساقط ارتفاعًا طفيفًا وانخفاضًا حادًا من 8%–85%. وأخيراً خلص البحث إلى أن تقنية الاستشعار عن بعد فعالة في قياس تغير المناخ

Introduction:

The world suffered from significant changes during the twentieth century and the first decades of the twenty-first century, especially at the level of cities, represented by the expansion of construction operations due to the spread of technology and the accompanying innovations and developments. In order to identify the concept of climate change, it is necessary to refer to the climate system, as it is a complex system represented by the interaction of the atmosphere with all its components and the earth's surface and natural and human phenomena, including weather and climate change statistics for any city in the world[1] [2]. The concept of climate change, according to the Intergovernmental Panel on Climate Change (IPCC), refers to any change in the climate over time, whether caused by natural variability or human activity, as stated in the Sixth Assessment Report 2021 to emphasize high confidence that any change in the climate is artificial. It is the primary driver of all climate change, especially the recent extreme phenomena observed during the past decade. The frequency of heat waves has almost doubled since the eighties until now [3]. The world's cities have witnessed apparent changes represented by a decrease in the percentage of ice cover to 40%, an increase in sea level by 17 cm, and an increase in average temperature by 0.74 C [4]. The reasons behind the changes were due to global warmings effects such as the increase in annual mean of maximum and minimum temperature, which in turn, decreased the average annual relative humidity [5], and increased average air temperature, which appeared a century or two ago as a result of human activity (industrial revolution) [6]. At the level of cities, climate change has local impacts and risks that negatively affect the city's environmental, material and social resources [7]. Since the climate is the average of atmospheric conditions, it is closely related to human life; it has occupied the interest of many researchers in astronomy, geology, city planning, and others. There are difficulties for researchers in obtaining accurate data, especially data periods for a long time, as it often appears to be missing data, which prompted researchers to rely on scientific techniques and remote sensing. That the research came to detect climate change in Baghdad city, which is a large urban area with diverse human activities [8], the previous studies of the city that dealt with the concept of climate change from different aspects would be addressed as follows:

Generally, Baghdad has had remarkable climate changes, especially in recent years, so it has become the focus of many researchers. In 2010, Salah analyzed the property of the spatial distribution of surface temperature for Baghdad city and its relationship to urban spatial information for the period 1961-2002; it was concluded that the influential role of remote sensing and GIS in analyzing surface temperature [9]. In 2016, Hassan et al. analyzed the climatic variables of Baghdad city for the period 1970-2013 by calculating the monthly averages of the data; the researchers concluded that there are anomalies in maximum temperatures [10]. Abdulla [11] studied the manifestations of climate change in Baghdad by reviewing the monthly temperatures; the research concluded that Iraq is affected by global climate change, which affects nature and crops, causing drought. Although previous research has made great strides, the representation of climate change and its accurate data was somewhat restricted, but the scientific techniques of remote sensing enabled studying and analyzing changes to all elements of the climate.

Study area:

Baghdad city is the capital of Iraq between two latitudes (33º 15'-33º 28'N) and longitudes (44º 15'- 44º 31'E), where it occupies an area of 890 km^2, it constitutes only 20% of the governorate's area of 4450 km^2 [12]. Baghdad city was chosen as the largest city in Iraq

regarding human activities. It witnessed irregular urban expansion at the expense of agricultural areas and the green belt and within residential neighborhoods. In addition to bypassing some buildings, government departments, public facilities, and organizations, more than 70% of the buildings were built residences between 2010-2020 [13].

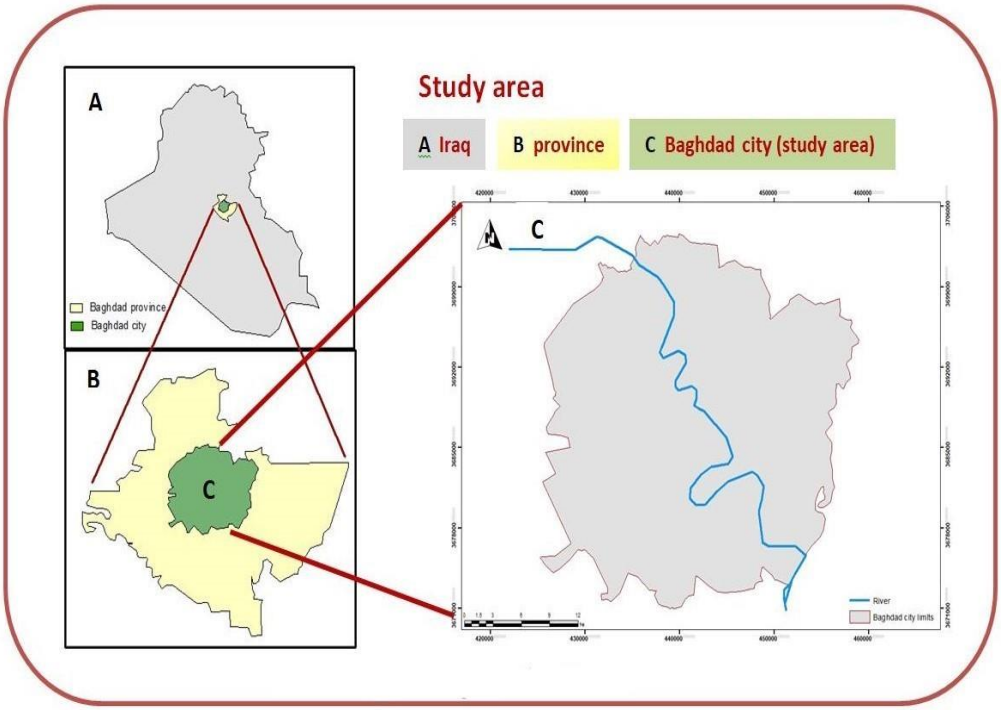

Figure 1: Baghdad city location [12]

-The city's climate:

Baghdad is located in the center of Iraq in an almost flat area; its height ranges between 31-39 m above sea level. It has semi-arid and semi-tropical, cold in winter and hot in summer [9]; the general climate of the city is characterized by the following:

1. A high seasonal temperature range between winter and summer, where the highest temperatures reach 36.73C^{o} during July and drop to 9.39C^{o} during January [14].
2. Very short transitional seasons. The cold winter season extends from December to the end of February, while the long hot summer season extends from late April until early October. [15]
3. Low rainfall and relative humidity and the strength of the solar radiation [16]

Data sources:

Accurate data is one of the most critical problems that researchers subject, especially if it is for long periods and within the field of atmospheric sciences, especially climatic studies, which is one of the scientific fields that have reduced the orientations of many researchers who suffer from obtaining climate data because some stations have stopped working. Studying for periods, especially during wars, appears as lost data [17]. The high efficiency of remote sensing technology provides researchers with scientific data that helps conduct in-depth studies in all scientific fields, where the launch of satellites and the emergence of the technical and digital revolution had a significant impact in facilitating access to climate data with accurate temporal and spatial coverage that can be adopted instead of stations the floor. At the same time, the NASA International Space Science Agency contributed to providing a database as one of its projects symbolized by the (POWER) database, which is an acronym (Prediction Of Worldwide Energy Resources); data cover a map of the world with spatial accuracy (5.0 latitude x 5.0

longitude) [18]. As part of the NASA Applied Training Program for Remote Sensing, it works to improve the ability of countries to obtain environmental data for Earth research within the scopes of renewable energy development, building energy efficiency and sustainability, and applications of agricultural climatology [19].
The system has been elected as "NASA/POWER CERES/MERRA2 Native Resolution Monthly and Annual"; Data include Dates Jan 01, 1981, through Dec 31, 2020. The station's coordinates for Baghdad station were entered (Latitude 33.18 and Longitude 44.28). File storage was in CSV format at an average height of (0.5 x 0.625) degree lat /extended region of (34.54 m). The data for 2021 was taken from Tutiempo.net climate Baghdad, altitude, and all climate elements. The data was tabulated, unified, and divided into four-time cycles (1981-1990), (1991-2000), (2001-2010), and (2011-2021), to see the extent of the climatic change in the city. In order to find out the amount of climate change, the climate change equation has been adopted:
(Amount of change = current cycle rate - previous cycle rate/previous cycle rate * 100) [20] [21]

1. Solar radiation:

As shown in Table 1 and Figure 1, solar radiation data indicates an increase in the annual rate of solar radiation during the climatic cycles. There is a fluctuation between rising and falling monthly rates, but the highest rates were recorded during June. For the rate of climate change, there was a sharp decrease during the last period between the third and fourth cycles, compared to the previous periods and the percentages were (0.006 - 0.005 - 0.0003)%, respectively.

Table 1: Monthly and annual rates of solar radiation for Baghdad city and the four climatic cycles & Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1984-1990	222.91	280.17	353.312	419.3971	461.85	477.73	467.85	432.41	374.4743	302.56	237.26	205.24	352.931		
1991-2000	222.94	280.22	353.406	419.536	461.9	477.74	467.86	432.42	374.424	302.5	237.25	205.24	352.952	5.95017E-05	0.006
2001-2010	223.12	280.31	353.267	419.366	461.88	477.796	467.87	432.35	374.399	302.59	237.38	205.37	352.973	5.94982E-05	0.005
2011-2021	223.07	280.38	353.524	419.5872	462.04	477.8741	467.84	432.22	374.185	302.37	237.25	205.36	352.974	2.83308E-06	0.0003

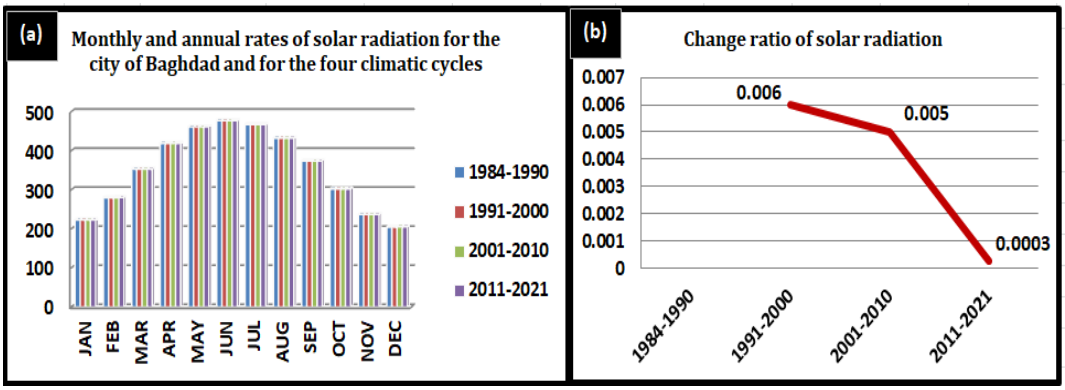

Figure 2: (a) Monthly and annual solar radiation rates for Baghdad city and the four climatic cycles **(b)** Change ratio.

2. Average air temp:

Table 2 and Figure 2 show the temperature rates during the four-time cycles. There is an apparent increase in the monthly and annual rates, especially during the fourth time cycle, where the annual rate reached 24.362C°. The highest percentage in the monthly rates was recorded during July, while the lowest percentages were during January and the percentages and quantity of time change between one cycle and another. The percentage of climate change gradually increased during the periods, and the percentages were (-0.1, 1.07, and 1.7) %, respectively.

Table 2: Monthly and annual rates of temperature for Baghdad city and the four climatic cycles & Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	9.166	11.42	16.1	23.6	30.1	34.232	37.1	36.2	32.81	25.8	17.12	11	23.71		
1991-2000	9.498	11.02	15.6	23.2	29.8	34.871	37	36.6	32.29	26	17.23	11.1	23.682	-0.001	-0.1
2001-2010	8.995	11.79	17.3	22.7	29.6	35.116	37.2	37.3	32.63	27.1	16.62	11	23.937	0.0107	1.07
2011-2021	9.899	12.22	17.2	23.3	30.2	35.1764	38.1	37.4	33.48	26.6	17.41	11.3	24.362	0.017	1.7

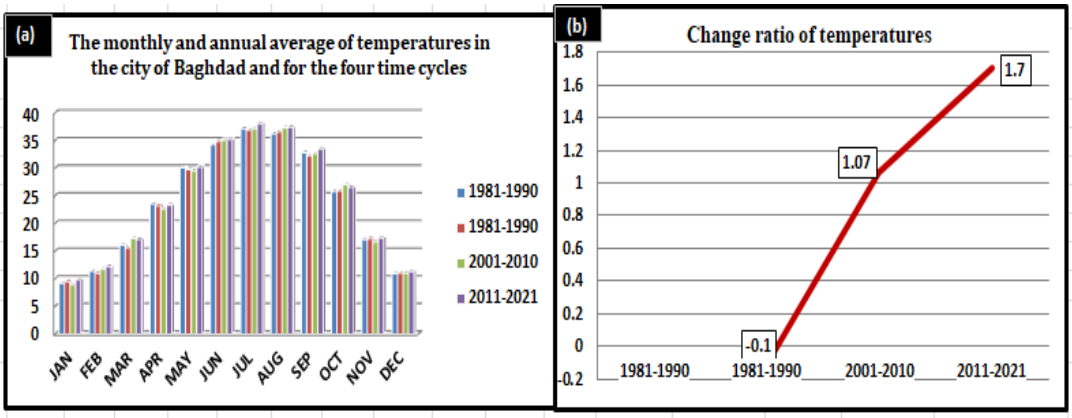

Figure 3: (a) Monthly and annual rates of temperature for Baghdad city and the four climatic cycles **(b)** Change ratio

a. Minimum temperatures:

Table 3 and Figure 3 show the minimum temperature for the four-time cycles, where the monthly and annual rates increased, especially during the fourth time cycle, the annual rate reached 12.5 degrees Celsius, and July recorded the highest monthly rates, while the lowest rates were during January. There was a fluctuation between one cycle and another as the rate of climate change between the first and second cycles reached 1.7%; the percentage dropped to 0.8% between the second and third cycles and then rose to 7.7% between the third and fourth cycles.

Table 3: Monthly and annual rates of minimum temperature for Baghdad city and the four climatic cycles & Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	-1.456	-0.013	2.385	9.345	16.05	22.23	25.123	23.79	20.44	12.978	5.351	-0.13	11.3		
1991-2000	-1.448	-1.276	3.11	9.159	15.75	22.35	25.525	24.93	19.87	14.296	5.293	0.822	11.5	0.017	1.7
2001-2010	-2.106	0.367	4.404	9.025	15.49	22.53	25.457	25.75	20.38	13.931	4.808	-0.83	11.6	0.008	0.8
2011-2021	-0.845	0.5118	5.145	10.05	17.89	22.93	26.438	26.27	21.42	14.1364	6.0127	1.205	12.5	0.077	7.7

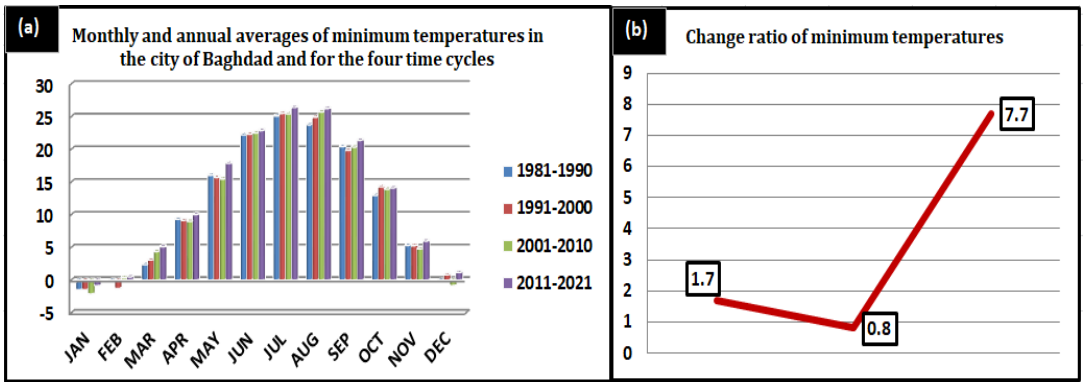

Figure 4: (a) Monthly and annual rates of minimum temperature for Baghdad city and the four climatic cycles **(b)** Change ratio **(b)Change ratio**

b. Maximum temperature:

Regarding the maximum temperature for the four-time cycles, there were fluctuations in the monthly and annual rates, and the highest percentage in the monthly rates was recorded during July and August. The lowest rates were during January, as well as the percentages of the time change. There was a fluctuation between one cycle and another, as the percentage of climate change between the first and second cycles amounted to 0.05% and rose to 0.9% between the second and third cycles, then decreased to -1% between the third and fourth cycles, Table 4 and Figure 4**.**

Table 4: Monthly and annual rates of maximum temperature for Baghdad city and the four climatic cycles & Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	21.27	25.4	30.9	39	44.7	47.82	49.33	48.6	46	40.62	31.49	23.15	37.34		
1991-2000	21.38	24.4	31.2	39.8	45	47.85	48.7	49.3	45.9	40.28	31.16	23.5	37.36	0.0005	0.05
2001-2010	21.44	25.4	32.9	38.5	44.5	48.14	49.39	49.6	46.8	41.23	31.23	23.72	37.73	0.009	0.9
2011-2021	21.49	25.4	30.9	38	44.6	47.75	49.87	49.3	46.2	40.57	31.2	22.93	37.33	-0.01	-1

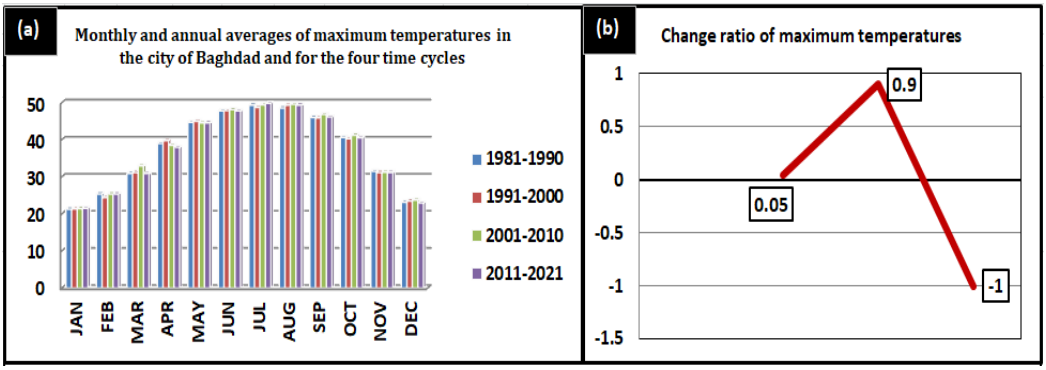

Figure 5: (a) Monthly and annual rates of maximum temperature for Baghdad city and the four climatic cycles **(b)** Change ratio

3. Atmospheric pressure:

Regarding the annual and monthly atmospheric pressure rates, the annual rate decreases gradually for the first, second, and third time cycles, and the decrease was by 0.01 between one cycle and another. The rate of climate change witnessed stability and then a sharp decline, as the percentages were recorded (-0.009, -0.009, and -0.019)%, respectively. The monthly rates were deficient during July, and the highest was during January and December, Table 5 and Figure 5.

Table 5: Monthly and annual rates of Atmospheric pressure for Baghdad city and the four climatic cycles & Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	101.58	101.31	101	100.7	100	99.9	99.53	99.67	100.25	100.88	101.36	101.58	100.68		
1991-2000	101.5	101.3	101.1	100.7	100	99.86	99.47	99.7	100.2	100.9	101.35	101.63	100.67	-9.93246E-05	-0.009
2001-2010	101.57	101.33	101	100.7	100	99.83	99.51	99.67	100.25	100.84	101.36	101.55	100.66	-9.93345E-05	-0.009
2011-2021	101.5	101.3	101	100.7	100	99.8	99.5	99.6	100.2	100.8	101.3	101.6	100.64	-0.000198689	-0.019

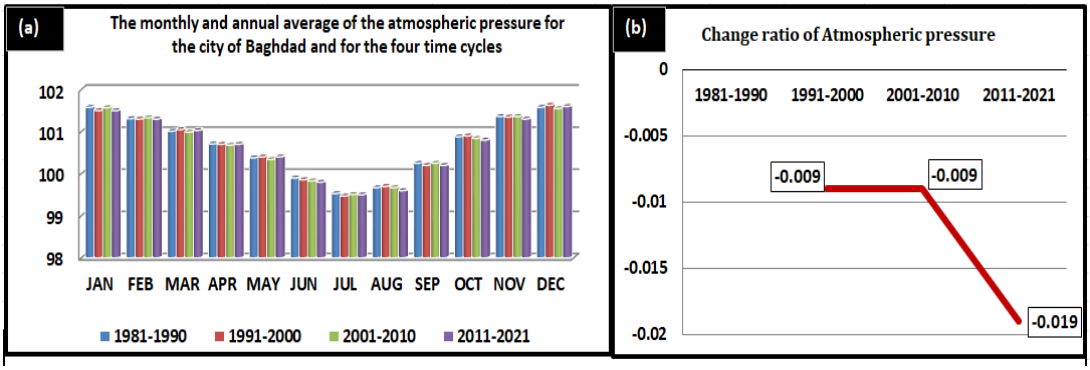

Figure 6:(a) Monthly and annual rates of Atmospheric pressure for Baghdad city and the four climatic cycles **(b)** Change ratio

4. Wind: It has been taken at two levels:

a) Velocity at the height of 10 meters:

The annual rates of wind speed at the height of 10 m explicitly agreed with the atmospheric pressure rates in terms of stability and fluctuation. The annual rates gradually decreased during the first, second, and third time cycles, and the decrease was by 0.01, so finding that the rate of climate change has taken apparent stability as it recorded 0.2% during these periods, as shown in Table 6 and Figure 6. Then the percentage of change decreased sharply, reaching 0.5 -% between the third and fourth cycles due to the annual rate of the fourth period recording a sharp decrease of 3.48. The monthly rates were very high during July, while the lowest was during January and November.

Table 6: Monthly and annual average wind speed at 10 m for Baghdad city and the four time cycles &Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	2.971	3.248	3.335	3.359	3.694	4.55	4.356	4.124	3.375	3.176	3.096	3.01	3.52		
1991-2000	2.954	3.201	3.222	3.368	3.595	4.338	4.792	4.281	3.593	3.051	2.946	2.879	3.51	-0.002	-0.2
2001-2010	3.03	3.086	3.216	3.282	3.477	4.544	4.627	4.061	3.638	3.136	2.954	2.953	3.5	-0.002	-0.2
2011-2021	2.97	3.01	3.37	3.28	3.53	4.57	4.62	4.13	3.55	3.007	2.85	2.97	3.48	-0.005	-0.5

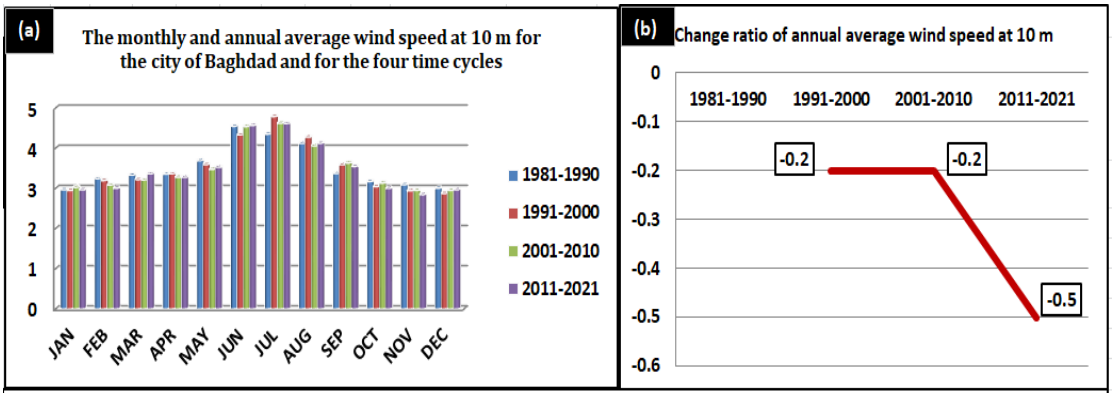

Figure 7: (a) Monthly and annual rates of wind speed at 10 m for Baghdad city and the four climatic cycles **(b)** Change ratio

b. Velocity at the height of 50 meters:

At the height of 50 m, the annual rates of wind speed recorded an apparent rise, especially during the fourth time cycle, as well as the rates of climate change, which rose slightly for the first periods, and then a sharp rise, where the percentages were recorded (0.01, 0.08, and 0.39)%. The monthly averages were very high during July, while the lowest rates were during January and November, which agreed with the monthly averages of wind speed at 10 m, Table 7 and Figure 7,

Table 7: Monthly and annual average wind speed at 50 m for Baghdad city and the four time cycles &Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	4.745	5.186	5.258	5.26	5.674	6.91	6.692	6.491	5.52	5.162	5.007	4.856	5.563		
1991-2000	4.753	5.149	5.119	5.305	5.567	6.634	7.234	6.706	5.822	5.016	4.812	4.656	5.564	0.0001	0.01
2001-2010	4.857	4.984	5.176	5.207	5.479	6.971	7.125	6.434	5.903	5.144	4.78	4.769	5.569	0.0008	0.08
2011-2021	4.84	4.98	5.45	5.273	5.55	7.006	7.136	6.58	5.79	4.986	4.642	4.859	5.591	0.0039	0.39

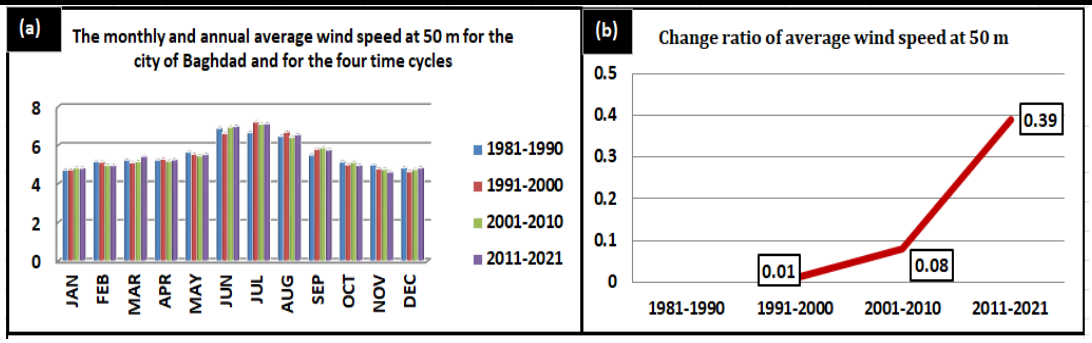

Figure 8: (a) Monthly and annual rates of wind speed at 50 m for Baghdad city and the four climatic cycles **(b)** Change ratio

5. Humidity

It includes two types:

a) Specific humidity:

The annual rates of specific humidity increase significantly over the four-time cycles, while climate change recorded the lowest percentage, 1.9%, between the second and third cycles, and the highest percentage, 5.3%, between the third and fourth cycles, as shown in Figure 8. The monthly rates fluctuated from one cycle to another and recorded the lowest rates in January and the highest in August, Table 8.

Table 8: Monthly and annual average specific humidity for Baghdad city and the four time cycles &Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	4.16	4.06	4.8	5.39	5.46	5.01	5.49	5.6	4.65	5.15	5.22	4.55	4.96		
1991-2000	4.32	4.14	4.6	5.5	5.65	5.38	5.9	5.99	5.16	5.3	5.26	4.68	5.15	0.038	3.8
2001-2010	4.24	4.73	5.2	6.14	5.95	5.09	5.93	5.84	5.25	5.32	4.88	4.54	5.25	0.019	1.9
2011-2021	4.2	4.5	5.2	6.01	6.4	5.9	6.2	6.5	5.6	5.6	5.6	4.7	5.53	0.053	5.3

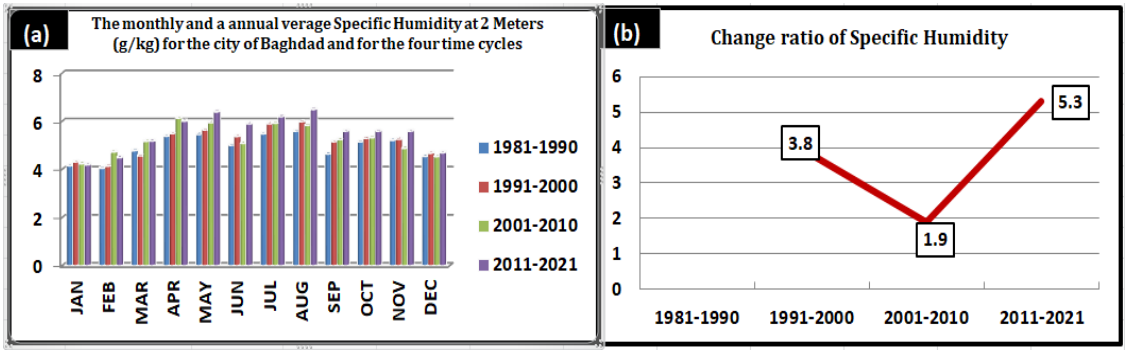

Figure 9: (a) Monthly and annual rates of specific humidity for Baghdad city and the four climatic cycles **(b)** Change ratio

b) Relative Humidity:

The annual rates of relative humidity are witnessing a rise in the four-time cycles, as shown in Table 9, while climate change is recording an apparent gradual decrease from 2.6-1.4-0.5%, as shown in Figure 9. The monthly rates fluctuated from one cycle to another and recorded the highest rates in January and the lowest in July.

Table 9: Monthly and annual average relative humidity for Baghdad city and the four time cycles &Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	60.3	51.6	45.3	32.9	22.9	16.5	15.3	16.5	16.6	27.5	45.6	58.4	34.11		
1991-2000	60.6	53.1	45	34.8	24.3	17.1	16.6	17.3	18.7	28	45.3	59.6	35.03	0.026	2.6
2001-2010	61.8	58.1	46.2	39.7	26.2	15	16.3	16	18.9	26.6	44.3	57.5	35.55	0.014	1.4
2011-2021	58.7	54.5	45.02	36.4	27.02	18.2	16.7	17.8	19.7	28.6	47.9	58.4	35.74	0.005	0.5

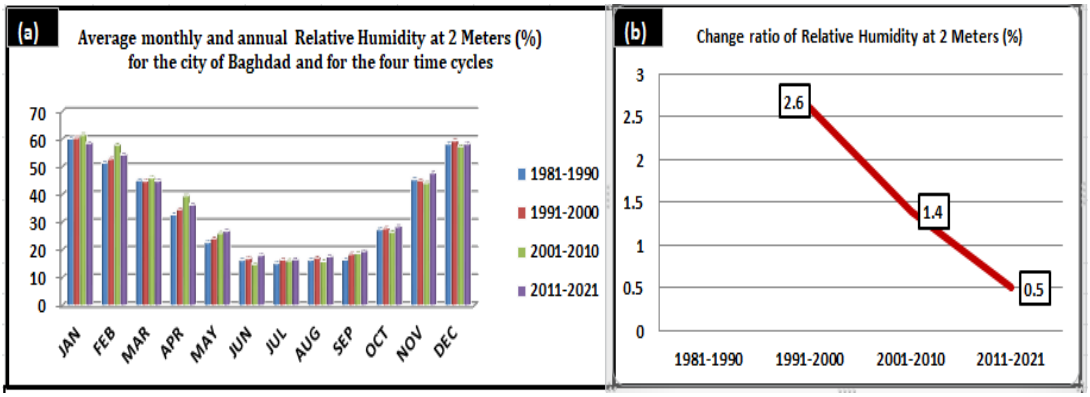

Figure 10: (a) Monthly and annual rates of relative humidity for Baghdad city and the four climatic cycles **(b)** Change ratio

6. Precipitation:

Table No. 10 and Figure 10 show the annual rates of precipitation and the rates of change occurring to them. Both rates increased slightly during the first three cycles and then decreased sharply during the fourth time, where the percentages of change were recorded (55, 85, and 8)

% respectively. The monthly rates fluctuated from one cycle to another and recorded the highest rates in February and the lowest rates during June, July, and August.

Table 10: Monthly and annual average precipitation for Baghdad city and the four time cycles &Change ratio [19]

Time cycles	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Rat	Amount of changes	Change ratio
1981-1990	0.415	0.523	0.494	0.283	0.07	0.007	0	0.001	0.001	0.238	0.467	0.422	0.243		
1991-2000	0.685	0.676	0.822	0.472	0.243	0.022	0.001	0.019	0.021	0.235	0.641	0.697	0.377	0.55	55
2001-2010	1.494	1.352	0.951	1.019	0.195	0.003	0.001	0.007	0.044	0.446	0.775	0.875	0.596	0.85	85
2011-2021	0.7709	2.2	0.954	0.474	0.209	0	0.0054	0	0.006	0.2673	0.974	0.657	0.543	-0.08	-8

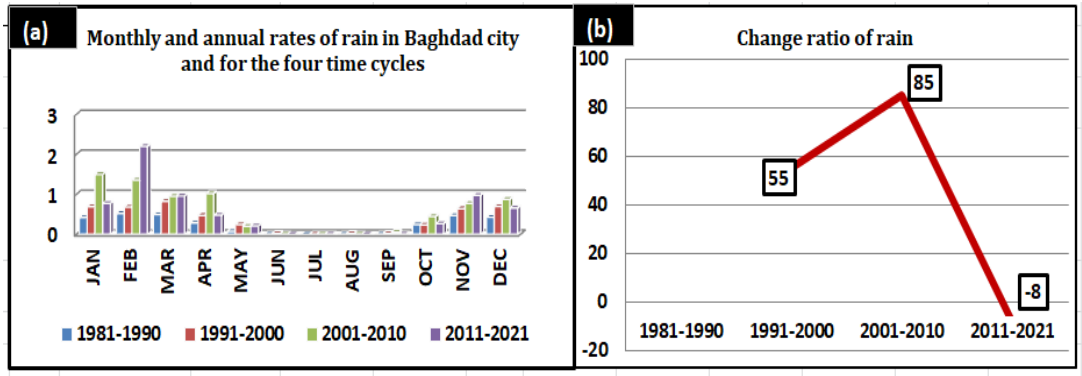

Figure 11: (a) Monthly and annual rates of precipitation for Baghdad city and the four climatic cycles **(b)** Change ratio

Conclusions:

As one of the major cities, Baghdad has seen climatic changes during the past four decades, 1981-2021, primarily caused by human activity.

1. The annual and monthly rates witnessed the highest rates of climate change during the fourth period.

2. The increasing temperature rise and the corresponding decrease in the precipitation rates index indicate the increasing drought in the city. There is a gradual increase in the time change of temperature index from -0.1, 1.07, and 1.7 % for the periods between climatic cycles. At the same time, the precipitation index witnessed a fluctuation of 55, 85, and 8%.

3. The climate change index of solar radiation witnessed a gradual decrease in the time intervals between climatic cycles, where the percentages were 0.006, 0.005, and 0.0003%, respectively.

References:

[1] M. F. Abdulateef and . H. A. S. Al-Alwan, "Climate change risk assessment in Baghdad: examining population vulnerability," *IOP Conference Series: Materials Science and Engineering*, 2021.

[2] H. L. Treut, S. Richard, etc., "Historical Overview of Climate Change Science," *Cambridge University Press, Cambridge.*

[3] IPCC, "Climate Change 2021: Physical Science Basis, AR6," Summary for Policymakers, 2021.

[4] J. Berthold and M. H. Wetterwik, "Examining the Ecocity:- From Definition to Implementation," *Bachelor of Science Thesis*, 2013.

[5] L. A. Jawad, "The Climatic Quality Index Determination for Iraq Using Meteorological Stations Data," *Iraqi Journal of Science,* vol. 57, no. 4, pp. 3005-3016, 2016.

[6] M. N. A. Mazrouei and F. . A.-J. Al-Rubaie, "Globale warming (An Empirical Study of Iraq)," *AL-Mostansiriyah journal for arab and international studies,* no. 35, pp. 119-131, 2011.

[7] IPCC, "Annex II: Glossary," *In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* pp. 113-130, 2014.

[8] M. A. Hassan and . O. A. Ibrahim, "Determine the Radon Gas Level Using the GIS Technique for Baghdad city," *Iraqi Journal of Science,* vol. 59, no. 1, pp. 218-226, 2018.

[9] S. A. H. Saleh, "IMPACT OF URBAN EXPANSION ON SURFACE TEMPERATURE IN BAGHDAD, IRAQ USING REMOTE SENSING AND GIS TECHNIQUES," *Journal of Al-Nahrain University,* vol. 13, pp. 48-59, 2010.

[10] A. S.Hassan and S. A. Matar, "The variation of daily maximum and minimum temperatures in the summer in the city of Baghdad," *Al-Mustansiriyah Journal of Science,* 2016.

[11] H. J. Abdulla, "Manifestations of Climate Change in Baghdad Area," *Al-Mustansiriyah Journal of Science,* vol. 30, no. N:2521-3520 (online).

[12] M. o. Baghdad, "Department of Engineering Designs (Urban Planning Division, GIS Division).".

[13] A. Repeva, "Informal settlements in Baghdad city," Vols. 263, 2021, no. E3S Web Conf., 2021.

[14] M. o. S. a. T. Climate Department, "unpublished data," 2005.

[15] S. F. H. Al-Hiti, "The Development of the Residential Function of the Greater Baghdad City," *Master's Thesis submitted to the College of Arts, University of Baghdad,* 1973.

[16] G. Gideon, Desert Planning [Journal], London, 1982.

[17] Hesham-badawy@du.edu.eg, "Evaluation of the efficiency of the global climate database (POWER) in monitoring surface temperature data in Egypt."

[18] https://power.larc.nasa.gov/data-access-viewer/. [Online].

[19] NASA POWER, "Understanding and Obtaining NASA Data Products Through POWER," National Aeronautics and Space Administration. [Online]. [Accessed 15 June 2021].

[20] O. G. A. H. Al-Yasiri, "Climate change and its impact on the elements and climatic phenomena at Baghdad Station," *Uruk Journal of Human Sciences,* pp. 2397-2408, 2019.

[21] A. H. Zini, Ways, and measures of agricultural statistics, Baghdad, 1973, p. 78.