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The Urban Expansion Impact on Climate Change for the City of Baghdad

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Abstract

The urbanization and climate change phenomena are global problems whose negative effects have been exacerbated in cities, and they are a reason for the formation of global warming and urban heat islands. The research came to shed light on the urban expansion of Baghdad for four decades which extended between (1981-2021) using the ArcMap Gis10.7 technique, then evaluating the impact of this expansion on the city's climate. The climate data were taken from Baghdad station by remote sensing technique for the same period. To clarify and analyse the relationship between the expansion and climatic data, Microsoft Excel was used. The results indicated a strong relationship between them, as urbanization rates increased, especially during the fourth cycle, to (85%), affecting all climatic elements, causing a rise in temperatures to 24362C as well as specific and relative humidity rates. While atmospheric pressure rates decreased to 100.64 kPa and that affected the wind speed, in addition to a clear fluctuation in rainfall and solar radiation rates.

Keywords: urban expansion, climate change, global warming, urban heat island.

أثر التوسع العمراني على التغير المناخي لمدينة بغداد

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الخلاصة

يشكل كل من ظاهرتي التحضر وتغير المناخ مشاكل عالمية تفاقمت آثارها السلبية في المدن ، وهما السبب في تشكيل ظاهرة الاحتباس الحراري والجزر الحرارية الحضرية. جاء البحث لإلقاء الضوء على التوسع الحضري لبغداد لمدة أربعة عقود امتدت بين (1981–2021) باستخدام تقنية ArcMap Gis10.7 ، ثم تقييم تأثير هذا التوسع على مناخ المدينة. تم أخذ بيانات المناخ من محطة بغداد بواسطة تقنية الاستشعار عن بُعد لنفس الفترة، ولتوضيح وتحليل العلاقة بين التوسع والبيانات المناخية استخدام Microsoft Excel. أشارت النتائج إلى وجود علاقة قوية بينهما، فأن زيادة معدلات التحضر خاصة خلال الدورة الرابعة إلى (85 ٪) ، أثر على جميع العناصر المناخية، مما تسبب في ارتفاع درجات الحرارة إلى 24362 درجة وكذلك معدلات

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الرطوبة النسبية. في حين انخفضت معدلات الضغط الجوي إلى 100.64 كيلو باسكال. مما أثر ذلك على سرعة الرياح ، بالإضافة إلى تقلبات واضحة في معدلات هطول الأمطار ومعدلات الإشعاع الشمسي.

1. Introduction

The city constitutes an area of intertwined and complex economic, social, political and administrative relations as a result of urban life patterns that have imposed themselves widely in all countries of the world, This area is negatively affected by urban expansion represented by a change of cities' size at the expense of agricultural lands and open spaces. As a result, the city is going to connect directly with climate change. According to UN-Habitat, cities contribute 70 percent of global greenhouse gas emissions, while the rest of the world contributes 2 percent. Thus urban areas are responsible for climate change [1].

The United Nations 2009 World Urbanization Prospects report indicates that more than 50% of the world's population currently lives in urban areas, and by 2050 this proportion is expected to reach 70% [United Nations, 2009]. Therefore, there is a need to pay more attention to the effects of urban heat islands on future climate change [2].

The urbanization is a non-positive example of human modification of land uses, as it causes a radical change in the surface properties and in turn affects the thermal and radiative air properties [3]. The process of urbanization associated with changes in the surface creates a modification in the climate elements, both the earth surface and the contacted layer of air with it which represents the lowest part of the atmosphere layers. The air characteristics are affected by the nature of urban system. As a result of this modification or change in the atmosphere, a new local climate arises for the city that is more thermodynamic and warmer than the surrounding areas, and disturbances occur between the local and regional climate of the city. Thus, what is known as the urban heat island is created [4], and thus the heat islands phenomenon is a feature of major cities with diverse human activities, whether industrial, residential, commercial and others uses.

Thus, urban expansion is a serious problem that cities suffer in general, as it represents the amount of the expanding area for the city, whether the extension is vertical and horizontal, and whether it is regular or irregular (which is represented by expansion and exploitation of lands without planning) [5]. The city of Baghdad suffers from the urban area increase in compare with the open and agricultural lands [6].This will lead to an increase in the greenhouse gases emission (resulting from burning fossil fuels used in electricity generation, production, transportation, industrialization, home heating, urban landfills, cement production, etc.), which leads to disruption of the radiation balance, thus increasing the surface temperature and Air temperature. So, the urbanization that turns vegetation cover into urban land will hinder the absorption of carbon dioxide which has a significant impact on the greenhouse gas emissions increase and weather changes [7].

We will address some of the previous studies of the city that dealt with the concept of urban expansion from different aspects, as follows:
Generally, Baghdad has remarkable changes in its temperature and climate especially in the recent years. For this reason, many researchers focus in urban expansion for this city such as in 2010,Salah [8] has analysed the spatial distribution property of surface temperature for Baghdad and its relationship with urban spatial information for the period 1961-2002 and he concluded that there is an effective integration between remote sensing and GIS to analyse the effect of expansion on surface temperature , while in 2020,Tawfeek et al. [9] have studied

the effect of the surface changes of the city of Baghdad for 2008, 2013 and 2019 on the recorded temperatures average in meteorological stations to detect the change of unbuilt lands in the city and they found that the highest rate of urbanization was in 2019, which clearly affected the local climate and change the site to be a heat island. In 2021, another study by Repeva [10] dealt with the concept of slums in the city of Baghdad, encroaching on agricultural lands, on state buildings and converting them to residential use. The researcher suggested future solutions represented in encouraging vertical expansion instead of horizontal in an attempt to maintain the green belt surrounding the city.

Although, the previous researches made great strides, but the representation of urban sprawl and its impact on climate change was somewhat restricted, as it is limited in the temperature changes. Finally, the availability of data from scientific sites and government institutions supported by scientific techniques are enabled us to study the impact of urban expansion on all elements of the climate.

2. Study area:

The city of Baghdad is located in central Iraq, as shown in Figure 1, between latitudes (33º 15′ -33º 28′N) and longitudes (44º 15′- 44º31′E), with an area of (89,000) hectares [11], this matter encouraged the horizontal expansion at the expense of agricultural lands and made our study on climatic changes free from topographic influences [12]. Therefore, the researches focus only on the effect of urbanization on the climate.

The city of Baghdad is a large urban area with diverse human activities, especially after 2003, when the number of vehicles entering the streets of Baghdad increased, and the number of installed generators increased as a result of the great shortage of central electric power generation [13], which were all accompanied by floods on agricultural lands and led to convert large areas of these lands to residential uses. This issue affects the prevalent communities through the demand increase for cooling in the summer, the use of air conditioners, air pollution, greenhouse gas emissions, and urban heat island phenomenon within the city which drive to increase in the solar radiation absorption, and converting it to the thermal energy [14], then the temperature of the surrounding environment increases and making these areas warmer than the surrounding rural areas [15]. In hot and sunny summer days, the temperature of the exposed surfaces in urban areas ranges between 27-50 degrees Celsius, where the temperature is close to the air temperature and they are warmer than the shaded or humid surfaces represented in agricultural areas [16].

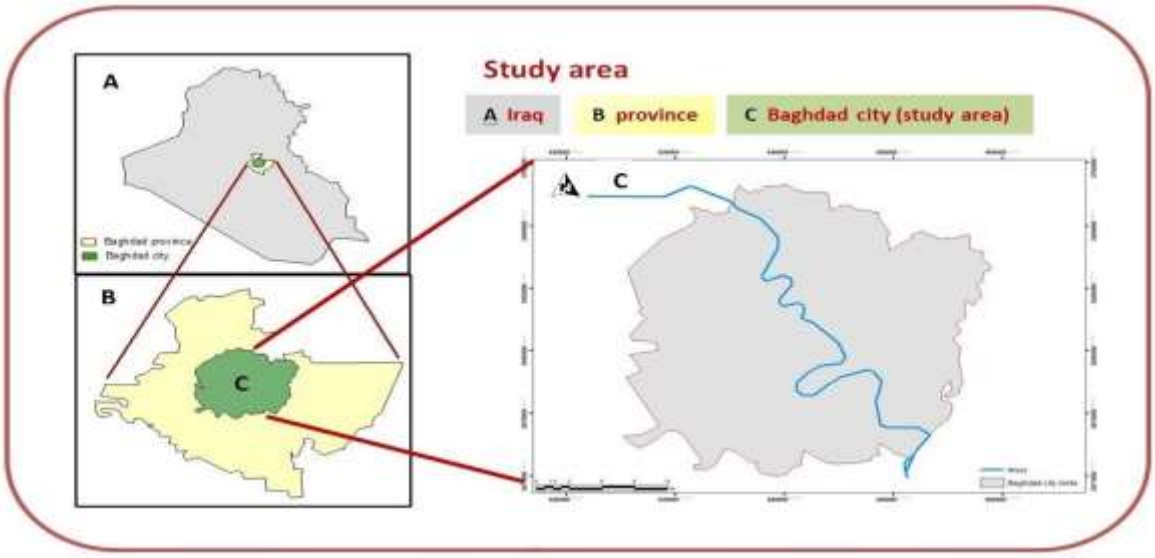

Figure 1: Baghdad city location [17]

3. Data source:

3.1. Urban expansion:

The planning approach for the city of Baghdad emphasizes the necessity of imposing the green belt as a mean to control its growth and preserve its vital area, but the irregular urban sprawl at the expense of green spaces dominated most of them, as this expansion was monitored for four periods using Arc.Gis.10.7 software. The rates of expansion are as follows:

3.1.1. Period (1981-1990): during this period, the area of the green cover reached (55976.8) hectares, equivalent to (62.90%) of the city area, while the urban expansion covered approximately (33023.2) hectares, equivalent to (37.10%) of the total area of the city, as clarified in Figure 2.

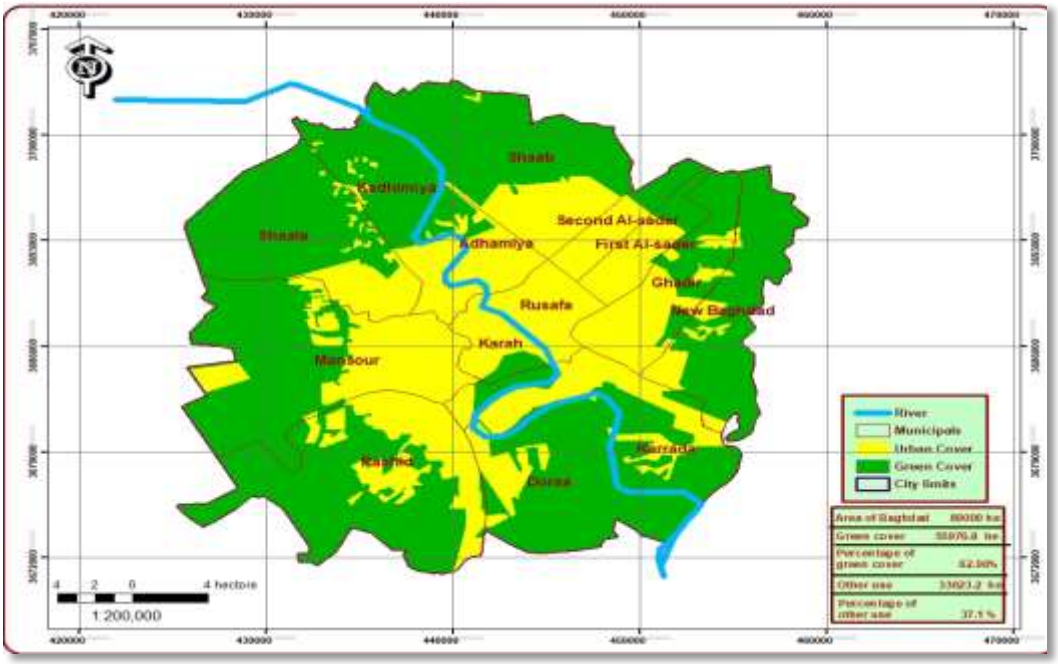

Figure 2: Baghdad and its sectors, the green usage and urban cover for the period (1981-1990) [18].

3.1.2. Period (1991-2000): during this period, the area of the green cover reached (46191.2) hectares, equivalent to (51.90%) of the city area, while the urban expansion covered approximately (42808.8) hectares, equivalent to (48.10%) of the total area of the city, as seen in Figure 3.

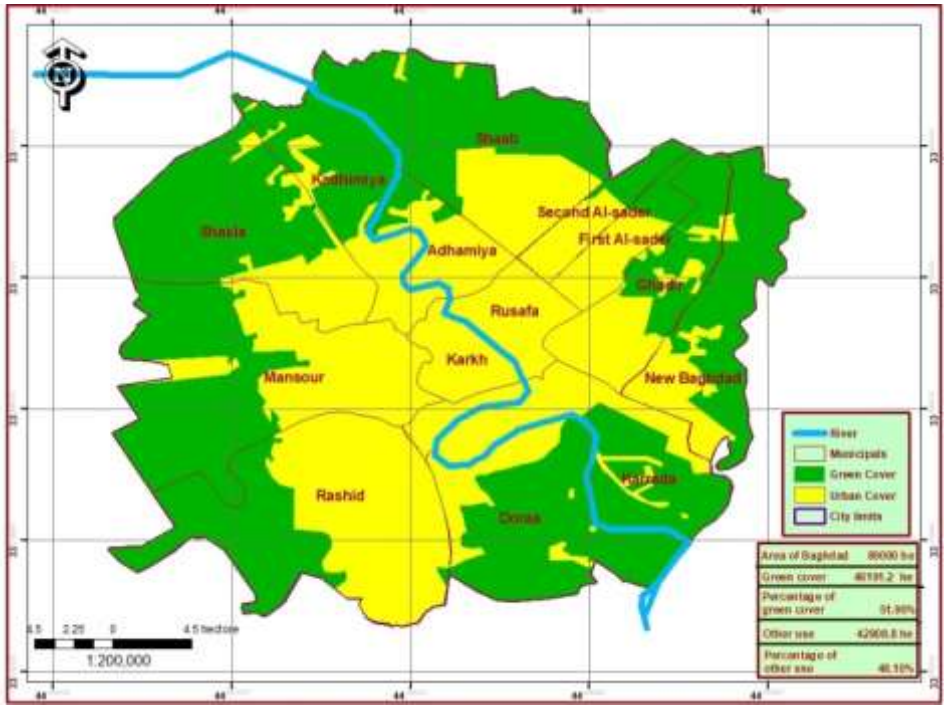

Figure 3: Baghdad and its sectors, the green usage and urban cover for the period (1991-2000) [18].

3.1.3. Period (2001-2010): during this period, the area of the green cover reached (32047.3) hectares, equivalent to (36.01%) of the city's area, while the urban expansion covered approximately (56952.7) hectares, equivalent to (63.99%) of the total area of the city, as clarified in Figure 4.

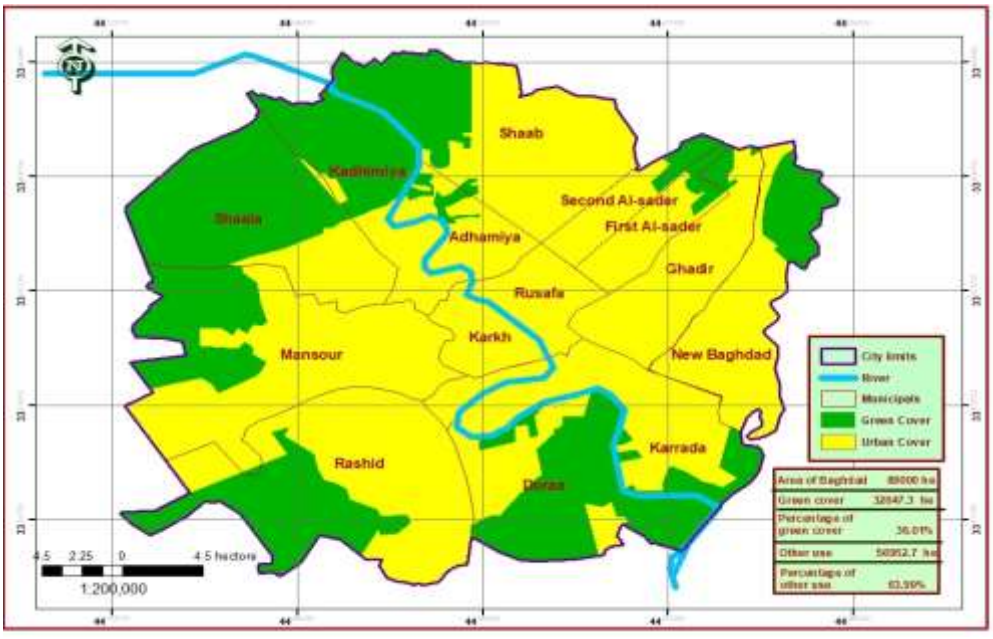

Figure 4: Baghdad and its sectors, the green usage and urban cover for the period (2001-2010) [18].

3.1.4. Period (2011-2021): The area of the green cover reached (12,570) hectares, equivalent to (14.10%) of the city's area, while the urban expansion covered approximately (76430) hectares, equivalent to (85.90%) of the total area of the city, as shown in Figure 5.

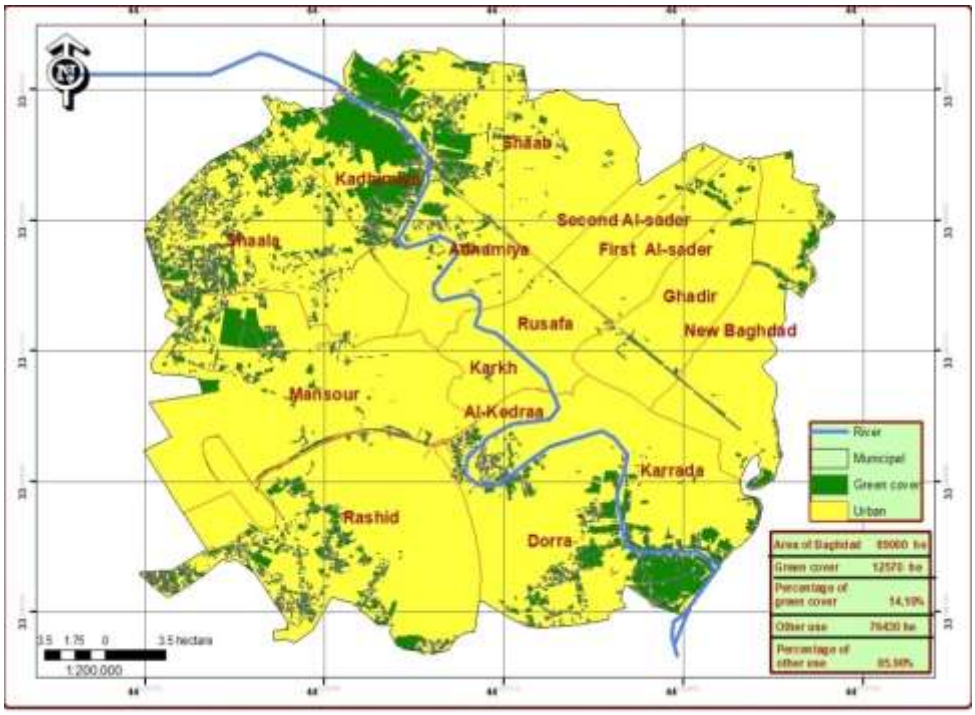

Figure 5: Baghdad and its sectors, the green usage and urban cover for the period (2011-2021) [18].

From Figures (2-5) that reflect the urban expansion of the city, it is noted that the widest expansion of the city was during the fourth time cycle (2011-2021). Table 1 shows the area of the city of Baghdad and its municipalities in hectares in addition to the amount and percentages of urban expansion at the expense of green areas.

Table 1: The area of the city of Baghdad and its municipalities for four time cycles [19]

Municipals	area/he	1981-1990				1991-2000				2001-2010				2011-2021			
		Green cover		Urban cover		Green cover		Urban cover		Green cover		Urban cover		Green cover		Urban cover	
		area/he	rat	area/he	Rat	area/he	rat	area/he	rat	area/he	Rat	area/he	rat	area/he	Rat	area/he	rat
Shaab	9920	6179.6	61	3868.8	39	5826	58	4233	42	3075.2	31	6970.1	69	1660	17	8260	82.7
New Baghdad	6530	3850.5	57	2807.9	43	3729	56	2939.8	44	1763.1	27	4895	73	520	7.9	6010	92.1
Karrada	6940	4153.6	58	2914.8	42	3820	54	3259	46	1596.2	23	5472	77	750	11	6190	89.2

Ghadir	5150	2342.9	43	2935.5	57	1772	33	3517.1	67	1133	22	4146	78	370	7.2	4780	92.8
Second Al-sader	2090	1884	84	334.4	16	783.1	34	1446	66	480.7	23	1738.3	77	110	4.4	1980	95.6
Adhamiya	2730	920.9	29	1938.3	71	645.8	21	2223.3	79	354.9	13	2504	87	330	12	2400	88
First Al-sader	2300	795.4	29	1633	71	624.5	24	1815.4	76	391	17	2038	83	100	4.5	2200	95.5
Rusafa	2380	0	0	2380	100	0	0	2380	100	47.6	2	2461	98	150	6.3	2230	93.7
Rashid	12330	8636.1	69	3822.3	31	8210	66	4258.8	34	6658.2	54	5800.1	46	1400	11	10930	88.6
Mansor	12560	9171.6	72	3516.8	28	6729	53	5969.8	47	5526.4	44	7162.2	56	1270	10	11290	89.9
Shaala	9100	6953.4	75	2275	25	5624	61	3615.6	39	4004	44	5225	56	1600	18	7500	82.4
Dorra	8210	6450.1	77	1888.3	23	5163	62	3186.4	38	4105	50	4234	50	1860	23	6350	77.3
Kadhamiya	5600	4048.4	70	1680	30	3265	57	2474.6	43	2912	52	2817	48	2120	38	3480	62.3
Karkh	1490	590.3	31	1028.1	69	0	0	1490	100	0	0	1490	100	0	0	1490	100
Al-Kedraa	1670													330	20	1340	80
Total area/hectare	89000	55976.8		33023.2		46191.2		42808.8		32047.3		56952.7		12570		76430	
Percentage		62.90%		37.10%		51.90%		48.10%		36.01%		63.99%		14.10%		85.90%	
		100.00%				100.00%				100.00%				100.00%			

Figure 6 (a-b) shows the stages of urban expansion for the city during the four time cycles.

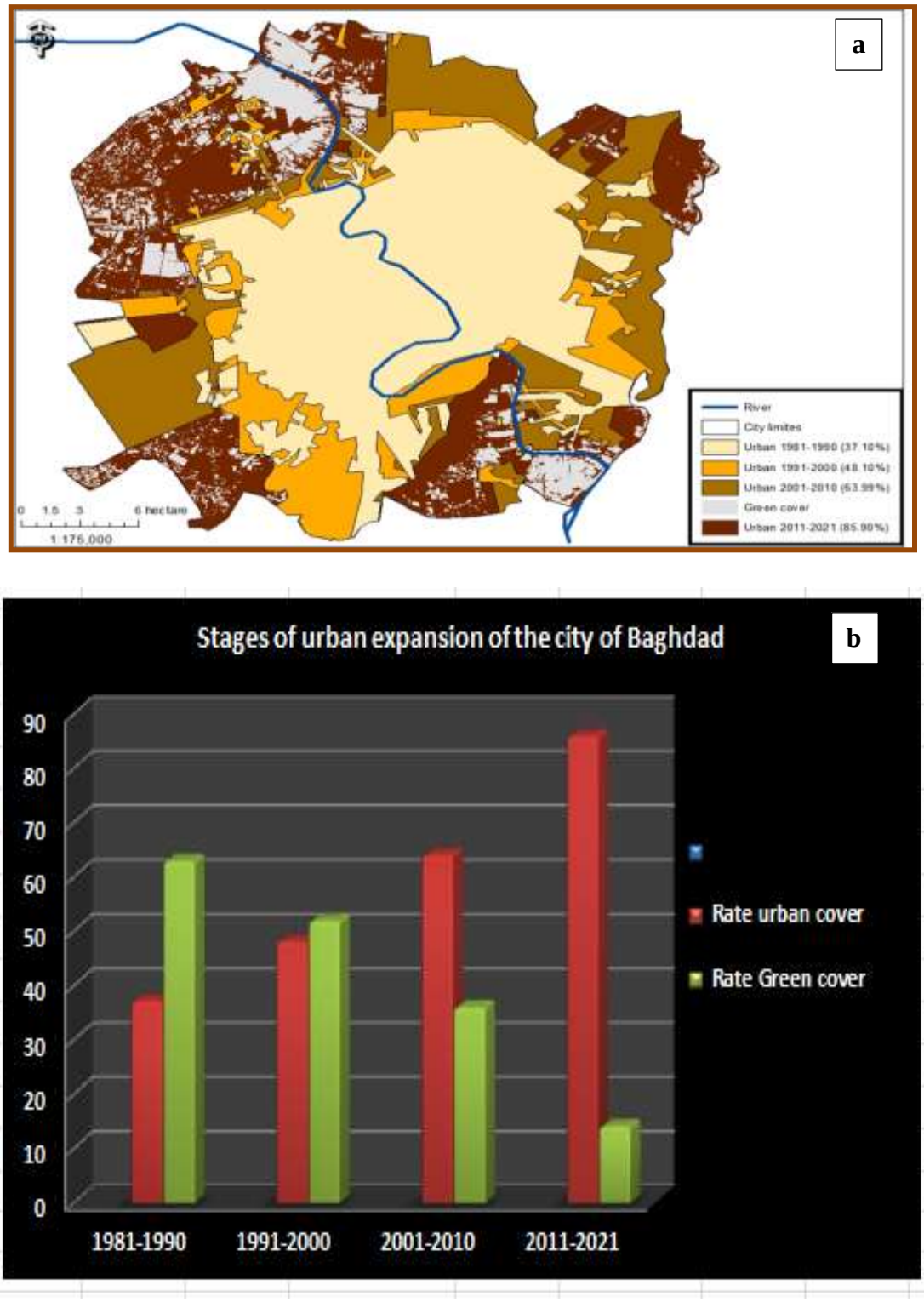

Figure 6: The urban expansion Stages of Baghdad during the four time cycles.

3.2. Climate data:

In order to know the impact of these urban expansions on the city's climate, we highlight the climate data for the same periods, where the vital role of satellites to obtain climate rates for the Baghdad station located at (33.18) degrees north, and (44.28) degrees east, as shown in Table 2[19,20].

Table 2: Climate rates for the four time cycles [19,20].

climatic cycles	Solar radiation (W/m^2)	Temperatures (C)			Atmospheric pressure (kPa)	Wind speed (m/s)		Humidity		Rainfall (mm/day)
		Tm	max	min		10 m	50 m	Specific (g/kg)	Relative (%)	
1981-1990	352.931	23.71	37.34	11.3	100.68	3.52	5.563	4.96	34.11	0.243
1991-2000	352.952	23.682	37.36	11.5	100.67	3.51	5.564	5.15	35.03	0.377
2001-2010	352.973	23.937	37.73	11.6	100.66	3.50	5.569	5.25	35.55	0.596
2011-2021	352.974	24.362	37.33	12.5	100.64	3.48	5.591	5.53	35.74	0.543

One can follow the dangerous effects of urban expansion on the vital area of Baghdad for the studied time cycles by measuring the values and rates of climate elements for the same periods. So, to understand the extent of the change that happens:

➢ **Solar radiation:** Its rates increase with the gradual increase of urban expansion, but it appears relatively stable during the fourth period due to the absorption process for solar radiation by the roofs of buildings and prevents it to reach the earth surface, as seen in Figure 7.

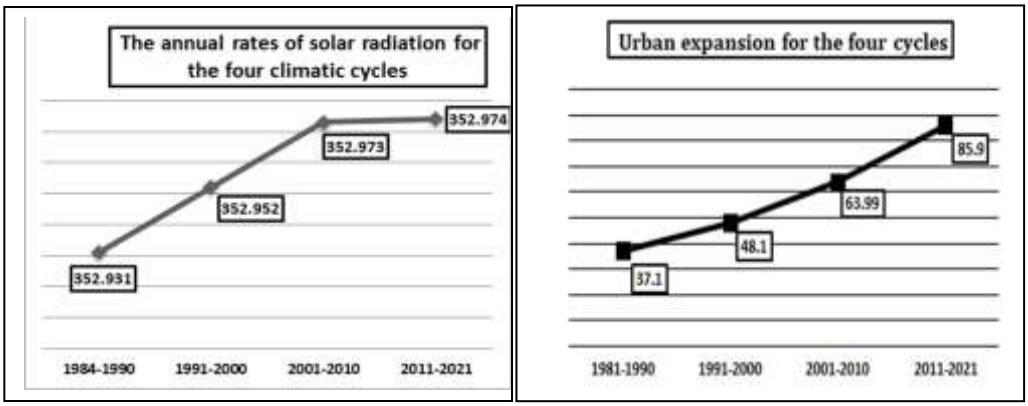

Figure 7: Solar radiation and urban expansion relationship for four climatic cycles.

➢ **Temperature:** Significantly affected by the urban expansion and there is a direct relationship between them, so one can note that it gradually rises as the rate of expansion increases as in Figure 8.

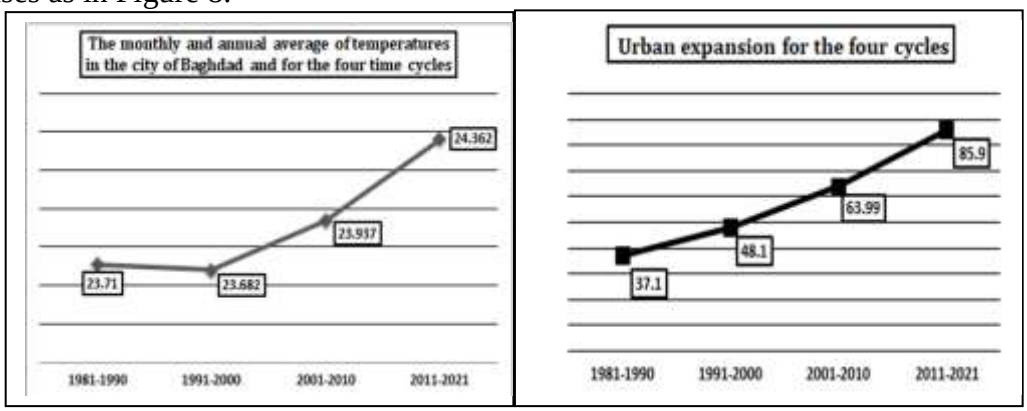

Figure 8: Temperature and urban expansion relationship for four climatic cycles.

a) Minimum temperature: It indicates an increase in its percentage whenever the rate of urban expansion increases, as shown in Figure 9.

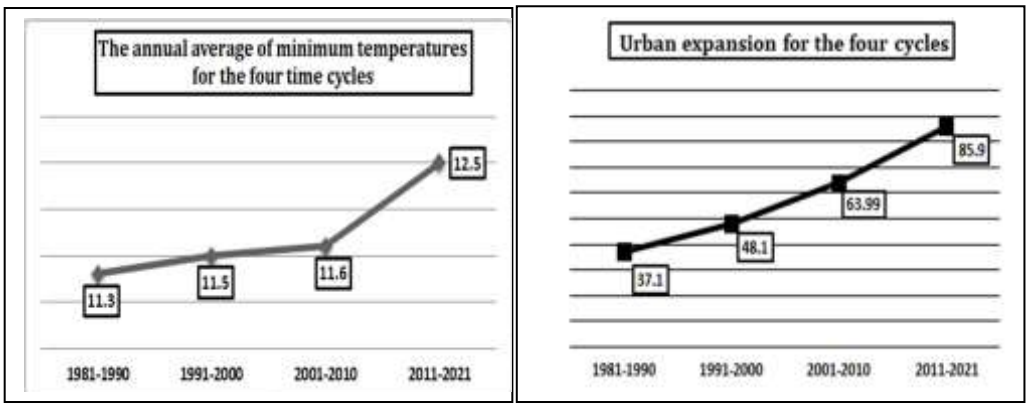

Figure 9: Minimum temperature and urban expansion relationship for four climatic cycles.

b) Maximum temperature: It indicates a fluctuation in its percentage whenever the rate of urban expansion increases, as shown in Figure 10.

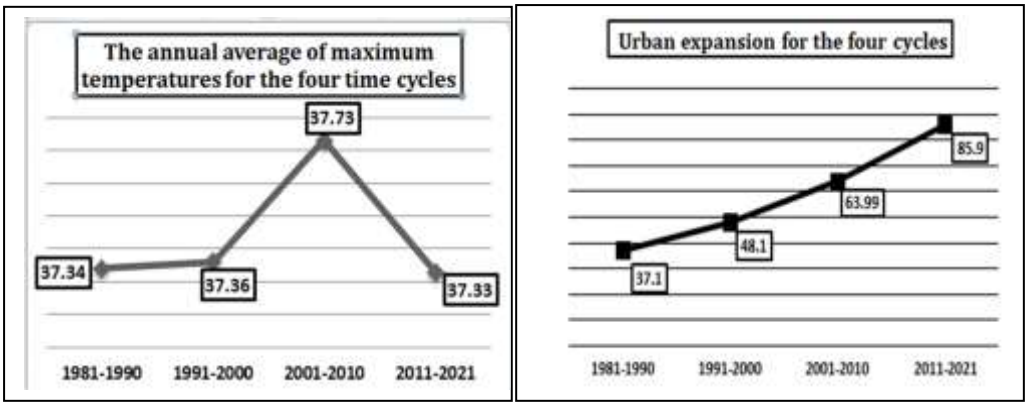

Figure 10: Maximum temperature and urban expansion relationship for four climatic cycles.

➢ **Atmospheric pressure:** Its rates decrease as a result of being affected by the temperature rise of the city, which indicates to the inverse relationship with the urban expansion rate, as in Figure 11.

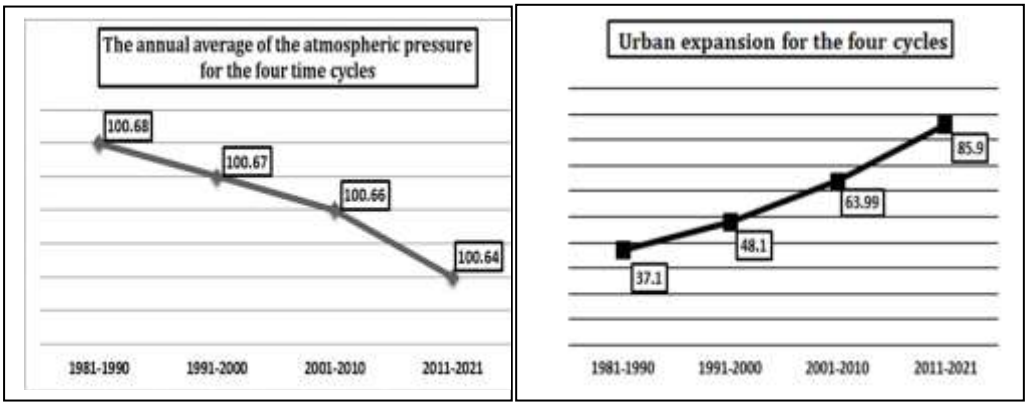

Figure 11: Atmospheric presser and urban expansion relationship for four climatic cycles.

➢ **Wind:** It has been taken at two levels:

a) **Velocity at a height of 10 meters:** Its rates gradually decrease as the rates of urban expansion increase, that is, the greater number of buildings leads to the slower wind speeds, as shown in Figure 12.

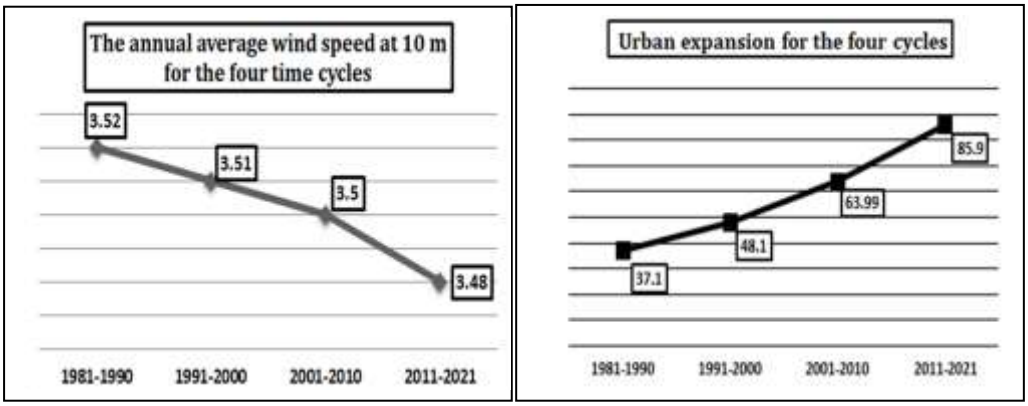

Figure 12: Wind velocity at a height of 10meters and urban expansion relationship for four climatic cycles.

b) **Velocity at a height of 50 meters:** Wind rates gradually increase as the rates of the urban expansion increase, as shown in Figure 13.

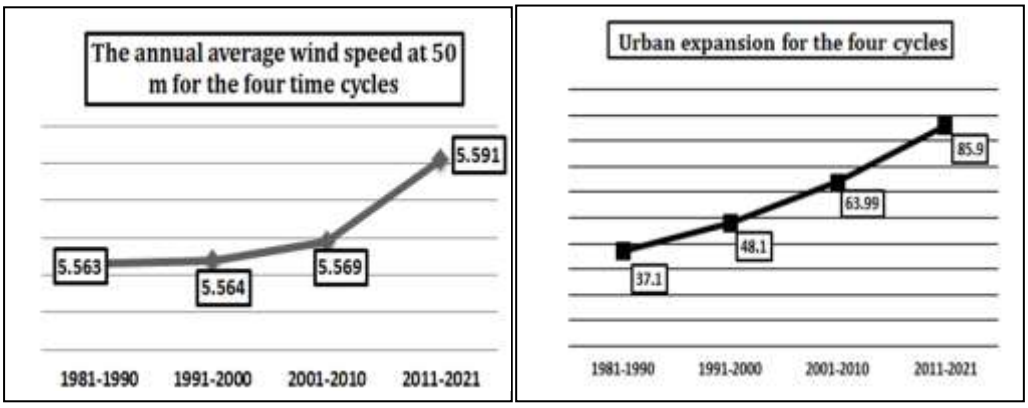

Figure 13: Wind velocity at a height of 50 meters and urban expansion relationship for four climatic cycles.

➢ **Humidity:** It includes two types:

a) Specific humidity: It expresses the amount of surface moisture and the total water vapour content in the air column, which is equal to the ratio of the masses of water vapour and dry air [17], and its percentage rises with the increase in the rate of urban expansion, as clarified in Figure 14.

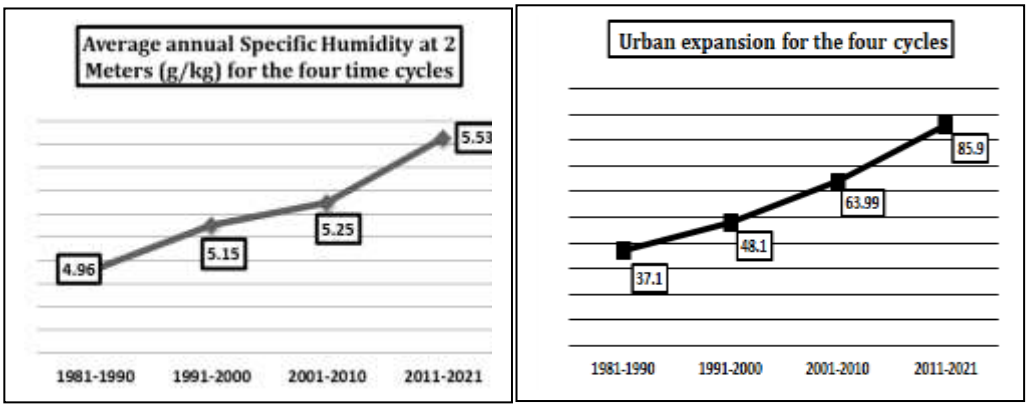

Figure 14: Specific humidity and urban expansion relationship for four climatic cycles.

➢ **Relative Humidity:** It has an inverse relationship with urban expansion, so its rates decrease significantly as a result of the expansion increase, as seen in Figure 15.

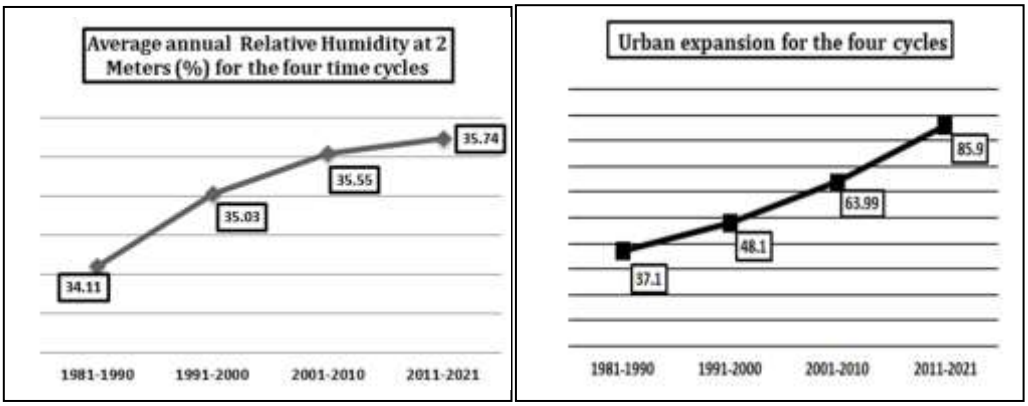

Figure 15: Relative humidity and urban expansion relationship for four climatic cycles.

➢ **Rain:** Their rates are related to relative humidity rates, so one can note the clear similarity between them in terms of their inverse relationship with the urban expansion, as shown in Figure 16.

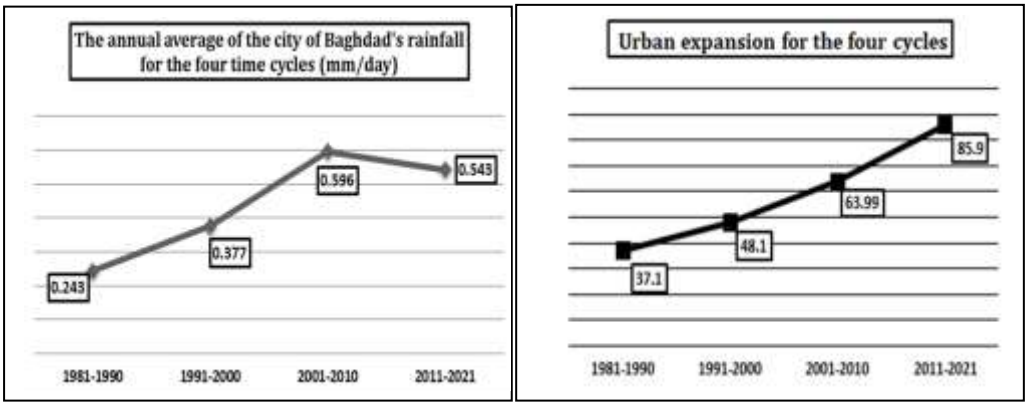

Figure 16: Rain and urban expansion relationship for four climatic cycles.

Conclusions:

There is a link between urban expansion data and climate change through this paper where the urban expansion at the expense of open spaces and agricultural lands can be considered as one of the main foundations adopted to monitor the climatic changes of a city during specific periods, because any change happened due to the urban sprawl affects the climate from two aspects. First: urban expansion means the urban and human activities increase and then an increase in greenhouse gas emissions. The second is the decrease in the vegetation cover, the main factor in mitigating the climate. By reviewing the above data on urban sprawl for the city of Baghdad and climatic data, so we can find:

1. The weakness of the planning management of lands within the city led to a change in the type of land use from agricultural to buildings, which caused negative effects on the city's climate.
2. The gradual rise in the rates of general, maximum and even minimum temperatures, especially during the fourth time cycle, indicates to the highest rates of urban expansion in the city. Humidity and an increase in the greenhouse gases emission create the global warming phenomenon, and then turn the city and its sectors into urban heat islands.
3. The city of Baghdad will be in the domain of global warming, if the urban expansion continues over the next decade.
4. The rise in temperature rates led to a gradual decrease in the rates of atmospheric pressure and wind speed at a height of 10 meters due to its proximity to the surface of the earth, in contrast to the speed at a height of 50 meters, which reached (5.596).
5. There is a clear fluctuation in precipitation rates and an increase in the specific and relative humidity rates.

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