Iraqi Journal of Physics, 2024 *Vol. 22, No. 3, PP. 126-138*
https://doi.org/10.30723/ijp.v22i3.1238 *P-ISSN: 2070-4003*
E-ISSN: 2664-5548

Measuring Changes in Temperature Rates due to Urban Expansion in Selected Municipalities of Baghdad using GIS Technology

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Abstract

The expansion of building blocks at the expense of agricultural land is one of the main problems causing climate change within the urban area of a city. The research came to determine these indicators, as a study was conducted on the expansion of the building blocks in three municipalities in the city of Baghdad for a period of four decades extended in the form of time cycles for the period (1981-2021) and using ArcMap GIS 10.7 technology. Then, the impact of this expansion on temperature rates was evaluated, as they are the most important climatic elements due to their significant effect on the rest of the elements. The results showed a clear, direct relationship between the increase in urban expansion rates and the corresponding rise in temperature rates, which results in urban heat islands. The results for the last time cycle showed high expansion rates for the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad (62.2, 82.4, and 92.1), respectively, and were offset by high-temperature rates (25.2, 25.49, and 25.67) for the same municipalities, respectively, as the highest rates were recorded in the New Baghdad municipality, followed by the municipality of Al-Shaala, in second place, then the municipality of Al-Kadhimiya, with the lowest rates due to its location on the Tigris River.

Article Info.

Keywords:
Urban Expansion, Temperatures, GIS Technology, Urban Heat Islands, Baghdad.

Article history:
Received: Feb. 07, 2024
Revised: Jul. 23, 2024
Accepted: Jul. 28, 2024
Published:Sep.01, 2024

1. Introduction

Urban lifestyles have begun to impose themselves on a large scale in all world cities, represented by urban expansion at the expense of agricultural lands and open spaces [1]. Cities have become the heart of global issues because they are an area of the interrelationship between the development of human societies and the biosphere [2], they contribute to enhancing the phenomenon of climate change as a result of urban growth and the change in the shape of the city [3]. Here the focus is on two main areas: urban expansion and climate change. This relationship is based on assessing the impact of urban expansion on climate change [4], as climate rates depend greatly on the relative size of green spaces and built-up areas [5], and temperatures are the main indicator for measuring climate change within cities, according to what was indicated by the Intergovernmental Panel on Climate Change [6].

The city of Baghdad has witnessed irregular urban expansion at the expense of agricultural areas during the last four decades in the period extending from (1981 to 2021) [7]. There appeared to be a huge increase in the proportion of urban area compared to agricultural land, which affected the shape and climate of the city [8]. Therefore, the planning approach for the city of Baghdad emphasized the necessity of imposing a green belt around the city as a means of controlling its growth. However, the city's location within flat land encourages horizontal expansion [9]. Urban heat islands began to appear as a result of urban sprawl, which hinders the absorption of carbon dioxide [10], and increases greenhouse gas emissions, creating a radiation imbalance. In

addition, urban expansion represented by building blocks increases the high thermal storage property of the land, resulting in the rise of surface temperature and the temperature of the air in contact with it [11, 12]. Thus, the climatic element most affected by urban expansion within the urban area is temperature averages [13].

This research focuses on the vital role of geographic information systems technology in calculating the rates of urban expansion in three municipalities of the city of Baghdad over cultivated areas within four decades to arrive at the impact of this expansion of temperatures [14]. Many studies have dealt from different aspects with the urban expansion of Baghdad.

Saleh analyzed the spatial distribution property of surface temperature and its relationship with urban spatial information in Baghdad city from 1961 to 2002, to determine the relationship between thermal behavior and urban structures using remote sensing data and geographic information systems. The researcher verified the effect of expansion on surface temperature [15].

Tawfeek et al. studied the canopy urban heat island (CUHI) phenomenon over the city of Baghdad for years 2008, 2013, and 2019. It was found that the built-up areas on the surface of the city increased in 2019, and with the high population density, adverse thermal effects on the atmospheric environment were produced. Its impact on the daily, seasonal and annual air temperature averages was investigated at two locations, one urban and the other rural, using an index. From NDVI, NDBI and spatial mapping of the urban area by means of ArcGis 10.4, it was concluded that the highest rate of urbanization was in 2019, which clearly affected the local climate and made the site a heat island [16].

Repeva dealt with the concept of slums in the city of Baghdad, encroaching on agricultural lands, on state buildings and converting them into residential use. The researcher used the descriptive research method in order to determine the factors that caused the irregular expansion by adopting satellite images that showed the extent of expansion for the post-war period 2003, and the researcher suggested future solutions represented encouraging vertical expansion instead of horizontal in an attempt to maintain the green belt surrounding the city [17]. Although previous research made great strides, the representation of urban sprawl and its impact on climate change was somewhat restricted, as it is limited to temperature changes. Finally, the availability of data from scientific sites and government institutions supported by scientific techniques enabled us to study the impact of urban expansion on temperatures averages [18].

A comparative study was conducted regarding changes in urban expansion rates and vegetation cover. The effect of these changes on temperature rates for the same time cycles was determined. For this study, three municipalities of Baghdad city were chosen, namely Al-Shaala and New Baghdad municipalities, because they are located on the same latitude, 33 degrees north, one east of the city and the other west of the city. Al-Kadhimiya municipality was chosen because it is located on the Tigris River to determine the effect of water bodies on temperatures.

2. Methodology

ArcGIS is a software platform linked to geographic information systems and sciences. It is a set of programs provided by Esri that create, manage, share, collect, analyse, and display geographic data in the form of accurate maps[19]. So that:

1. It allows the city structure and arrangements to be clearly and easily seen, and provides a detailed view of the distribution of green spaces and urban buildings.
2. The geographic mapping system produces maps with a high degree of accuracy, which allows determining urban expansion rates over different periods and then

benefiting from this data in managing of the city's environmental and planning fields.

The inductive approach was adopted to extrapolate the data on urban expansion obtained by the Baghdad Municipality/Engineering Projects Department, apply it within the ArcGIS program, review the climate data and then move to the deductive approach to reach the results.

3. Study Area

Baghdad is located in the center of the governorate, which is in central Iraq. It extends on both banks of the Tigris River between latitudes (33°.15 – 33°.28) north and longitudes (44°.15 – 44°.31) east [20, 21]. It is 25 km east of the Euphrates River [22, 23]. It occupies an area of approximately 890 km^2, equivalent to 89.000 hectares, and constitutes only 20% of the governorate's area of 4.450 km^2, equivalent to 455.000 hectares. It is characterized by being low and flat. It is 34 m above sea level [24].

The city has witnessed an increase in rates of urban sprawl at the expense of agricultural land during recent decades, as it has been studied over four-time periods: the first time cycle (1981-1990), the second time cycle (1991-2000), the third time cycle (2001-2010), and the fourth time cycle (2011-2021), which has witnessed the highest rate of urban expansion, reaching (85.9%) of the city's area, while it was 37.1%, during the first time cycle, as is clear in Table 1 and Fig.1 [25]**.**

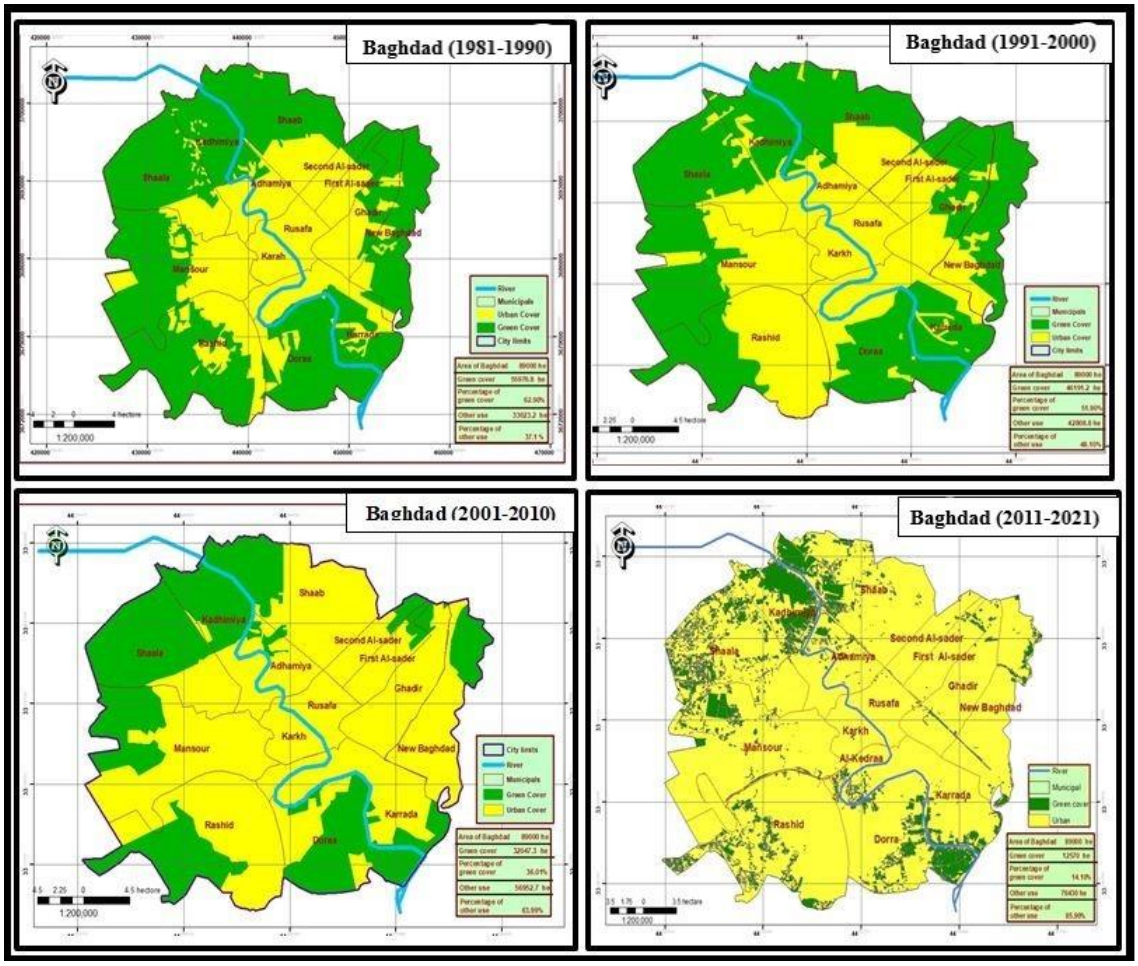

Figure 1: Urban expansion rates and green cover in Baghdad city during four-time cycles.

Table 1: Rates of urban expansion and green cover for the city of Baghdad over four-time periods [25].

Baghdad city Total area/ km	1981-1990		1991-2000		2001-2010		2011-2021	
	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km
89000	559.768	330.232	461.912	428.088	320.473	569.527	125.7	764.3
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%	

Three municipalities of the city of Baghdad were considered to determine the impact of urban expansion on temperature rates in the city: Al-Kadhimiya municipality, which is located on the Tigris River, and Al-Shaala and New Baghdad Municipalities, which are located at the same latitude, as is shown in Fig. 2.

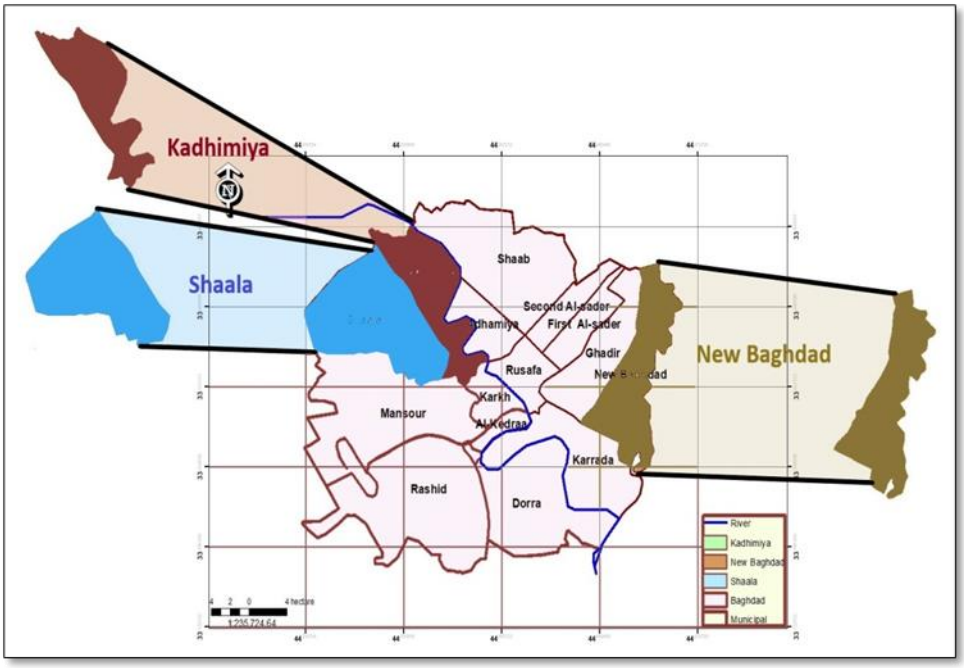

Figure 2: Study area: selected municipalities of Baghdad city (Kadhimiya, Al-Shaala and New Baghdad).

4. Data Source

4.1. Urban Expansion of the Municipalities of (Al-Kadhimiya, Al-Shaala, and New Baghdad)

The urban expansion of the three municipalities was monitored for four-time periods using ArcGIS.10.7 software. As follows:

4.1.1. Al-Kadhimiya Municipality

The municipality of Al-Kadhimiya is located northwest of the city of Baghdad, at latitude 33.38 degrees north and longitude 44.34 east. It has witnessed clear changes over the four-time periods as a result of the expansion of the building block at the expense of its vegetation cover, as in Table 2 and Fig. 3 and 4 [25].

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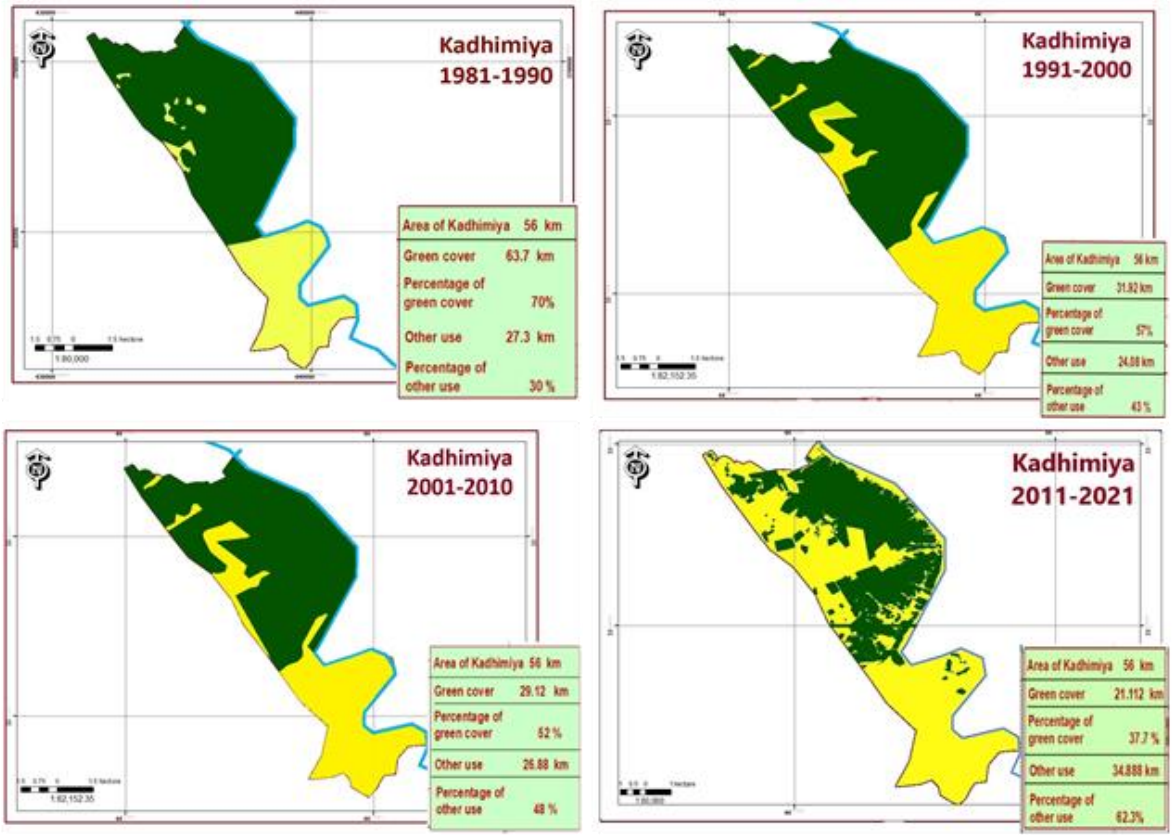

Figure 3: Urban expansion rates and green cover of Al-Kadhimiya Municipality during four-time periods.

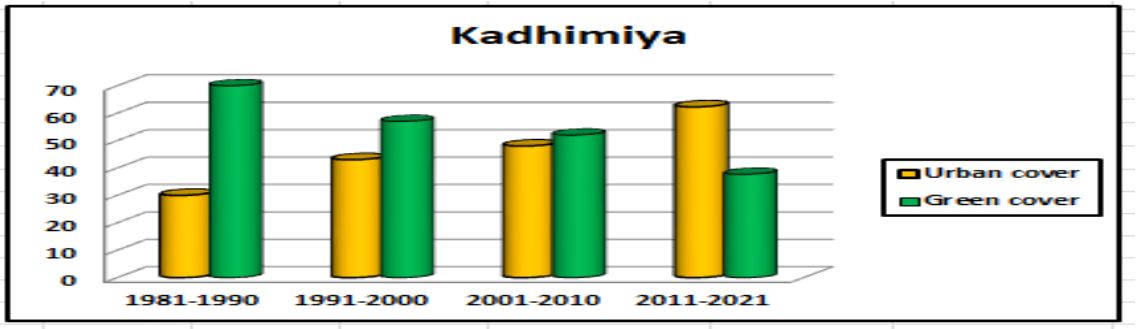

Figure 4: Rates of urban expansion and green cover for the municipality of Al-Kadhimiya for four-time periods.

Table 2: Urban expansion rates and green cover of Al-Kadhimiya Municipality during four-time periods

Al-Kadhimiya municipality Total area/ km	1981-1990		1991-2000		2001-2010		2011-2021	
	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km
56	63.7	27.3	31.92	24.08	29.12	26.88	21.112	34.888
Percentage	70%	30%	57%	43%	52%	48%	37.7%	62.3%
	100.00%		100.00%		100.00%		100.00%	

4.1.2. Al-Shaala Municipality

Al-Shaala municipality is located west of the city of Baghdad at latitude 33.36 degrees north and longitude 44.29 east, which witnessed manifestations of urban encroachment on the green cover during the four time periods, which caused many changes in its shape, as is clear in Table 3 and Fig 5 and 6. [25].

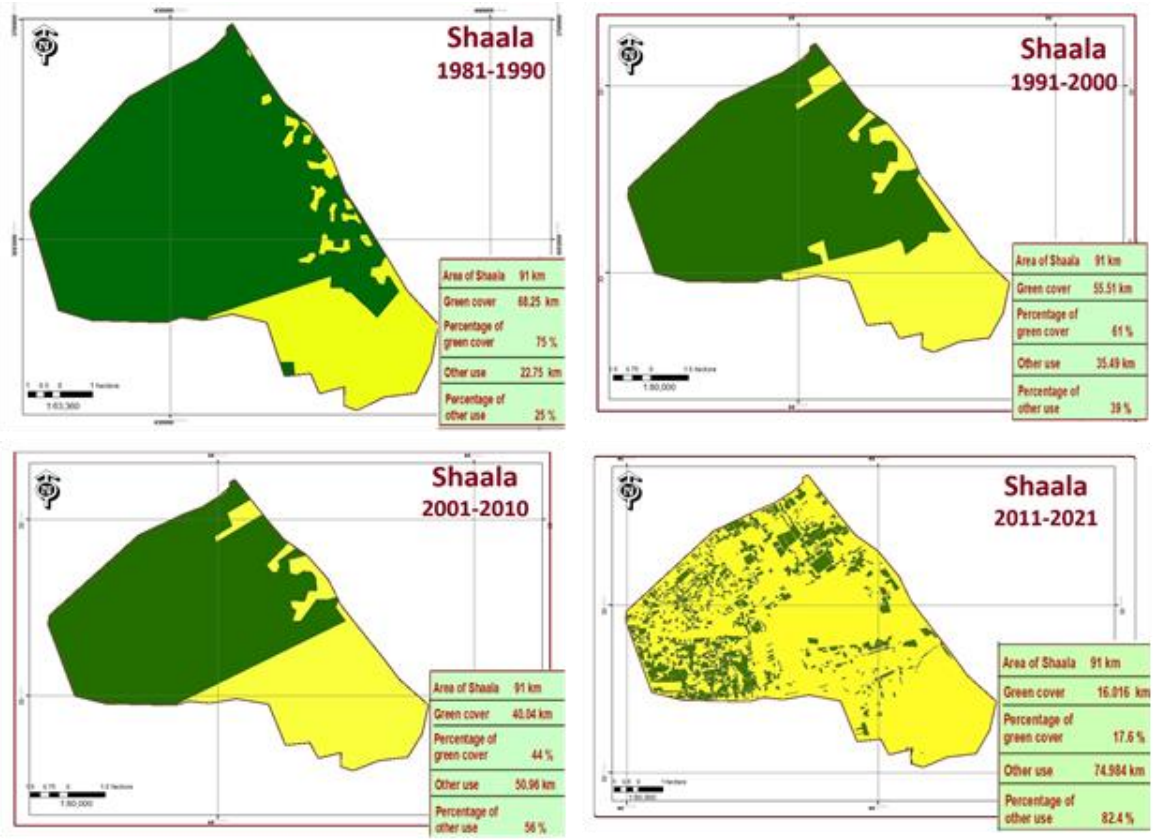

Figure 5: Morphology of Al-Shaala municipality during the four-time periods.

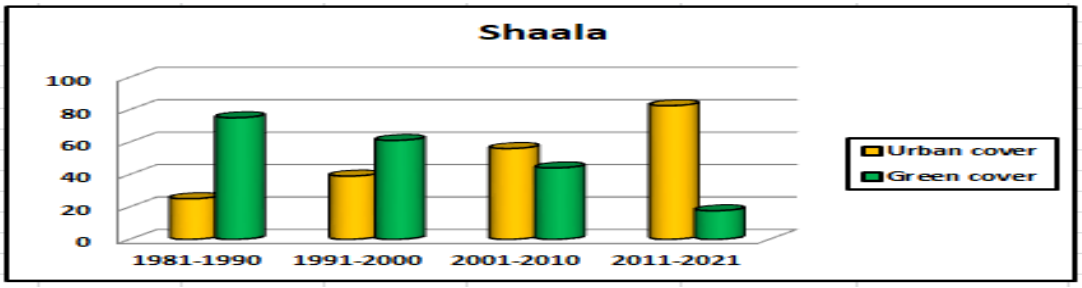

Figure 6: Rates of urban expansion and green cover for the municipality of Al-Shaala for four time periods.

Table 3: Rates of urban expansion and green cover for the municipality of Al- Shaala over four time periods.

Al-shaala municipality Total area/ km	1981-1990		1991-2000		2001-2010		2011-2021	
	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km
91	68.25	22.75	55.51	35.49	40.04	50.96	16.016	74.984
Percentage	75%	25%	61%	39%	44%	56%	17.6%	82.4%
	100.00%		100.00%		100.00%		100.00%	

4.1.3. New Baghdad Municipality

It is located east of the city of Baghdad at latitude 33.36 degrees north and longitude 44.51 east. The municipality has witnessed clear geomorphological changes, as the building block expanded significantly at the expense of vegetation cover, to the point that green spaces were almost non-existent during the fourth time period, and this is what the data in Table 4 and Fig. 7 and 8 shows [25].

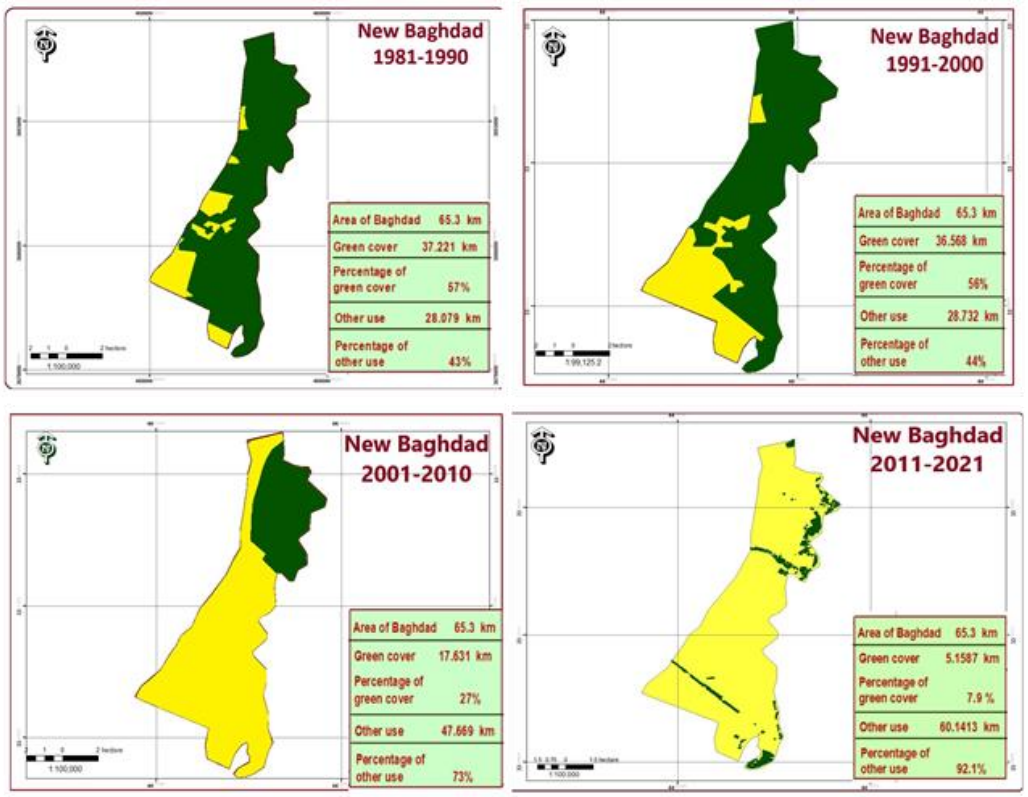

Figure 7: Morphology of New Baghdad municipality during the four time periods.

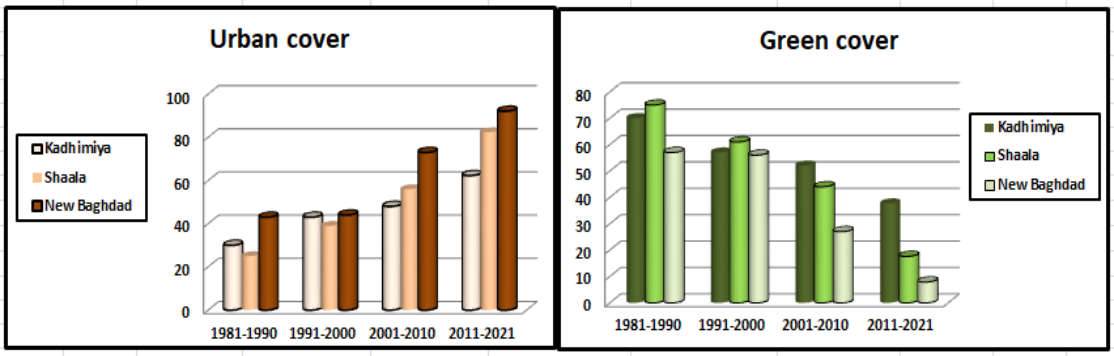

Figure 8: Rates of urban expansion and green cover for the municipality of New Baghdad for four time periods.

Table 4: Rates of urban expansion and green cover for the municipality of New Baghdad over four time periods.

New Baghdad municipality Total area/ km	1981-1990		1991-2000		2001-2010		2011-2021	
	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km	Green cover area/km	Urban cover area/km
65.3	37.221	28.079	36.568	28.732	17.631	47.669	5.1587	60.1413
Percentage	57%	43%	56%	44%	27%	73%	7.9%	92.1%
	100.00%		100.00%		100.00%		100.00%	

From the results, it is evident that the highest percentages of urban expansion were during the fourth period (2001-2010). The municipality of New Baghdad had the highest percentage of 92.1%, then Al-Shaala of 82.4%, and Al-Kadhimiya had the lowest percentage of 62.3%. On the other hand, the percentage of vegetation cover for the three municipalities decreased from one period to the other. The municipality of Al-Kadhimiya had the highest vegetation cover percentage during the fourth period (2001-2010), as shown in Fig. 9. These changes have negative effects on the climate of the three municipalities, and to determine this fact, it is necessary to take their climate data.

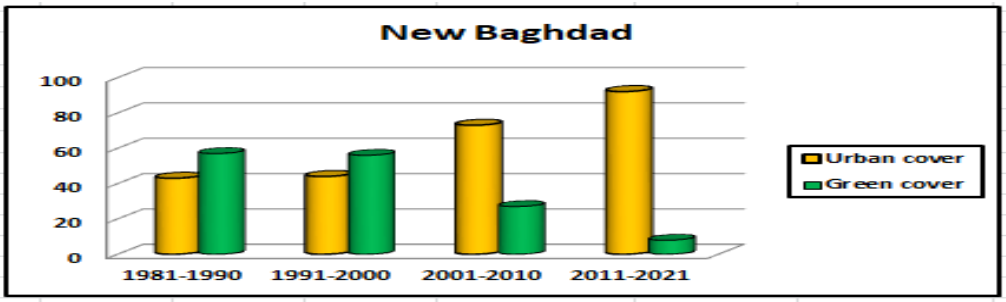

Figure 9: Rates of urban expansion and green cover for the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad, and for the four-time cycles.

4.2. Climatic Data for the Municipalities of (Al-Kadhimiya, Al-Shaala, and New Baghdad) Temperature Rates

The climate change data for Copernicus were based on ERA5 data from the Atmospheric Analysis of Global Climate conducted at a spatial resolution of 30 km [26, 27]. It has provided climate data for more than four decades. Its data is based on the analysis of satellite observations and weather station measurements [28, 29] and is preserved as archived data at the site, thus providing global data at multiple levels within the atmosphere [30, 31].

The general average annual temperature was adopted as an indicator for measuring climate change because it represents the most important climatic elements and is most affected by the city changes, which impact the rest of the climatic elements.

By observing the data contained in Table 5 and Fig.10, the following is noted:

1. During the four-time cycles, the average annual temperatures recorded the highest percentages in the New Baghdad Municipality, with the municipality of Al-Shaala in second place, then the municipality of Al-Kadhimiya.
2. The general average temperature in the three municipalities gradually increased during the four cycles, and the highest increase rates were recorded during the third and fourth cycles.

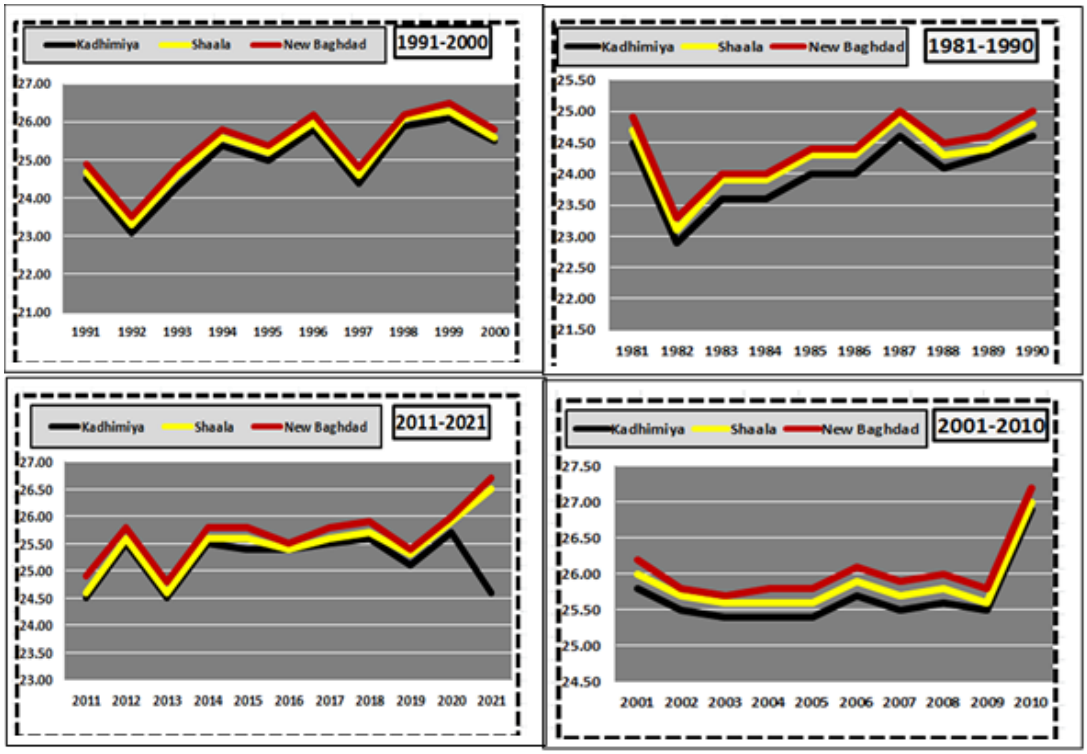

Figure 10: Average temperatures for the municipalities of Kadhimiya, Al-Shaala, and New Baghdad for four time periods

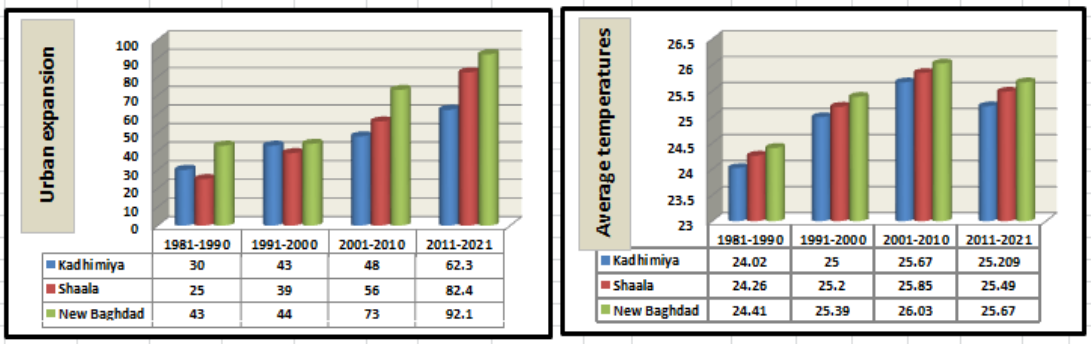

Figure 11: The effect of urban expansion on the temperatures of the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad over four time periods.

Table 5: Annual temperature averages for the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad for four-time cycles[32].

1981-1990				1991-2000			
Years	**Kadhimiya**	**Shaala**	**New Baghdad**	**Years**	**Kadhimiya**	**Shaala**	**New Baghdad**
1981	24.5	24.7	24.9	1991	24.5	24.7	24.9
1982	22.9	23.1	23.3	1992	23.1	23.3	23.5
1983	23.6	23.9	24	1993	24.3	24.6	24.8
1984	23.6	23.9	24	1994	25.4	25.6	25.8
1985	24	24.3	24.4	1995	25	25.2	25.4
1986	24	24.3	24.4	1996	25.8	26	26.2
1987	24.6	24.9	25	1997	24.4	24.6	24.8
1988	24.1	24.3	24.5	1998	25.9	26.1	26.2
1989	24.3	24.4	24.6	1999	26.1	26.3	26.5
1990	24.6	24.8	25	2000	25.5	25.6	25.8
Rate	24.02	24.26	24.41	Rate	25	25.2	25.39

2001-2010				2011-2021			
Years	**Kadhimiya**	**Shaala**	**New Baghdad**	**Years**	**Kadhimiya**	**Shaala**	**New Baghdad**
2001	25.8	26	26.2	2011	24.5	24.6	24.9
2002	25.5	25.7	25.8	2012	25.5	25.6	25.8
2003	25.4	25.6	25.7	2013	24.5	24.6	24.8
2004	25.4	25.6	25.8	2014	25.5	25.6	25.8
2005	25.4	25.6	25.8	2015	25.4	25.6	25.8
2006	25.7	25.9	26.1	2016	25.4	25.4	25.5
2007	25.5	25.7	25.9	2017	25.5	25.6	25.8
2008	25.6	25.8	26	2018	25.6	25.7	25.9
2009	25.5	25.6	25.8	2019	25.1	25.3	25.4
2010	26.9	27	27.2	2020	25.7	25.9	26
Rate	25.67	25.85	26.03	2021	24.6	26.5	26.7
				Rate	25.2091	25.4909	25.6727

4. Discussion

The city of Baghdad in general, and the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad in particular, witnessed the loss of a very high percentage of green cover due to urban expansion and random tree-cutting.

Expansion in these regions is to meet the requirements of the increasing urban growth within the city, which came as a result of the urban growth of the population, which affected the urban climate represented by temperatures. The results showed rising in temperatures with the rate of urban expansion in the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad, as shown in Fig. 11. This is due to the high thermal storage property of lands covered with concrete, buildings, and asphalt areas. The highest rates of urban sprawl and temperatures were recorded during the fourth time cycle in New Baghdad Municipality, the Shaala municipality came second, and the Kadhimiya municipality came in third place. According to the urban sprawl index, the rates of urban expansion of the three municipalities are (92.1, 82.4, and 62.3%) respectively, which corresponds to the average temperatures of the three municipalities of (25.67, 25.49, and 25.20 °C) selectively.

5. Conclusions

The following points are concluded from this study:

1. This study demonstrates the possibility of investing time in the use of remote sensing techniques and geographic information systems in terms of ease and accuracy in collecting and analyzing data within limited periods and the possibility of drawing maps and subtracting parts of them while maintaining the accuracy of the data.
2. The current study of the urban area of some areas of the city of Baghdad has shown that it has gradually expanded over the last four decades (1981-2021) to a very large extent at the expense of cultivated areas. As time goes by, the city of Baghdad is on its way to being transformed into a city with a desert climate similar to some cities in the Arabian Peninsula. It was a role model among Arab cities in terms of the expansion of green spaces.
3. Urban changes, represented by the expansion of building blocks within the municipalities of Al-Kadhimiya, Al-Shaala, and New Baghdad, have affected temperature rates. Due to its location on the Tigris River, the municipality of Al-Kadhimiya recorded the lowest rates of changes.
4. It is necessary to follow strict policies by the Baghdad Municipality to prevent urban expansion at the expense of agricultural lands and the necessity of restoring the green belt around the city to maintain its vitality and achieve sustainable development.
5. This study can be used by planners and those interested in the urban framework of cities and the mechanism of expansion in the city. It also attracts researchers interested in the environmental aspect in terms of the impact of expansion within cities on the nature of the climate.

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قياس التغيرات في معدلات درجات الحرارة نتيجة التوسع العمراني لبلديات مختارة في مدينة بغداد باستخدام تقنية GIS

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الخلاصة

يعد توسع الكتل البنائية على حساب الاراضي الزراعية من المشاكل الرئيسية المسببة للتغير المناخي داخل النطاق الحضري المتمثل بالمدينة. وقد جاء البحث للوقوف على هذه المؤشرات، حيث تم إجراء دراسة لتوسع الكتل البنائية لثلاث بلديات من مدينة بغداد، ولمدة أربع عقود ممتدة على شكل دورات زمنية للفترة من (1981-2021) وباستخدام تقنية ArcMap GIS 10.7. ومن ثم تم تقييم أثر هذا التوسع على معدلات درجات الحرارة باعتبارها اهم العناصر المناخية لأثرها البالغ في بقية العناصر. وقد جاءت النتائج بأن هناك علاقة طردية واضحة بين الزيادة الحاصلة في معدلات التوسع العمراني ويقابلها التزايد في معدلات درجات الحرارة، مما ينتج عنها جزر حرارية حضرية. وقد جاءت النتائج لأخر دورة زمنية ارتفاع معدلات التوسع لبلديات الكاظمية والشعلة وبغداد الجديدة (62.2، 82.4، 92.1) على التوالي وقابلها ارتفاع معدلات الحرارة (25.2، 25.49، 25.67) لنفس البلديات على التوالي، حيث سجلت أعلى النسب في بلدية بغداد الجديدة وتأتي بلدية الشعلة بالمرتبة الثانية ومن ثم بلدية الكاظمية بأقل المعدلات بحكم موقعها على نهر دجلة.

الكلمات المفتاحية: التوسع العمراني، درجات الحرارة، تقنية نظام المعلومات الجغرافية ، جزر الحرارة الحضرية، مدينة بغداد.