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

Yusra K. H. Moussa1*, Abdelwehab A. Alwehab2
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: 6/2/2022 Accepted: 7/6/2022 Published: 30/11/2022

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 24±6°C 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

يسرى كاظم حسون موسى*، عبد الوهاب أحمد عبد الوهاب
1 قسم التحسس النائي ونظم المعلومات الجغرافية، كلية العلوم، جامعة بغداد، بغداد، العراق
2 مركز التخطيط الحضري والإقليمي للدراسات العليا، جامعة بغداد، بغداد، العراق

الخلاصة
يشكل كل من ظاهرة 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 لمدينة بغداد 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 بعد نفس النفس، وتوضيح وتحليل العلاقة بين التوسع والبيانات المناخية استخدم 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 24±6 درجة، وكذلك معدلات*Email: yosra.k@sc.uobaghdad.edu.iq
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 (33° 15′ -33° 28′N) and longitudes (44° 15′- 44°31′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].
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 1: Baghdad city location [17]](image1)

![Figure 2: Baghdad and its sectors, the green usage and urban cover for the period (1981-1990) [18].](image2)
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](image)

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](image)

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]
<table>
<thead>
<tr>
<th>Location</th>
<th>Area 1 (ha)</th>
<th>Area 2 (ha)</th>
<th>Area 3 (ha)</th>
<th>Area 4 (ha)</th>
<th>Total Area (ha)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghadir</td>
<td>515</td>
<td>234</td>
<td>43</td>
<td>29</td>
<td>57</td>
<td>177</td>
</tr>
<tr>
<td>Secon Al-sader</td>
<td>209</td>
<td>188</td>
<td>84</td>
<td>33</td>
<td>16</td>
<td>783</td>
</tr>
<tr>
<td>Adhamiya</td>
<td>273</td>
<td>920</td>
<td>29</td>
<td>19</td>
<td>71</td>
<td>645</td>
</tr>
<tr>
<td>First Al-sader</td>
<td>230</td>
<td>795</td>
<td>29</td>
<td>16</td>
<td>71</td>
<td>624</td>
</tr>
<tr>
<td>Rusafa</td>
<td>238</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Rashid</td>
<td>123</td>
<td>863</td>
<td>69</td>
<td>38</td>
<td>31</td>
<td>821</td>
</tr>
<tr>
<td>Mansor</td>
<td>125</td>
<td>917</td>
<td>72</td>
<td>35</td>
<td>28</td>
<td>672</td>
</tr>
<tr>
<td>Shaala</td>
<td>910</td>
<td>695</td>
<td>75</td>
<td>22</td>
<td>25</td>
<td>562</td>
</tr>
<tr>
<td>Dorra</td>
<td>821</td>
<td>645</td>
<td>77</td>
<td>18</td>
<td>23</td>
<td>516</td>
</tr>
<tr>
<td>Kadhamiya</td>
<td>560</td>
<td>404</td>
<td>70</td>
<td>16</td>
<td>30</td>
<td>326</td>
</tr>
<tr>
<td>Karkh</td>
<td>149</td>
<td>590</td>
<td>31</td>
<td>10</td>
<td>69</td>
<td>14</td>
</tr>
<tr>
<td>Al-Kedraa</td>
<td>167</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>890</td>
<td>55976.8</td>
<td>33023.2</td>
<td>46191.2</td>
<td>42808.8</td>
<td>32047.3</td>
</tr>
</tbody>
</table>

Figure 6 (a-b) shows the stages of urban expansion for the city 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].

**Figure 6:** The urban expansion Stages of Baghdad during the four time cycles.
Table 2: Climate rates for the four time cycles [19,20].

<table>
<thead>
<tr>
<th>climatic cycles</th>
<th>Solar radiation (W/m²)</th>
<th>Temperatures (°C)</th>
<th>Atmospheric pressure (kPa)</th>
<th>Wind speed (m/s)</th>
<th>Humidity</th>
<th>Rainfall (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tm    max  min</td>
<td>10 m  50 m</td>
<td>Specific (g/kg)</td>
<td>Relative (%)</td>
<td></td>
</tr>
<tr>
<td>1981-1990</td>
<td>352.931</td>
<td>23.71  37.34</td>
<td>11.3</td>
<td>100.68</td>
<td>3.52</td>
<td>5.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.56</td>
<td>4.96</td>
<td>34.11</td>
</tr>
<tr>
<td>1991-2000</td>
<td>352.952</td>
<td>23.682 37.36</td>
<td>11.5</td>
<td>100.67</td>
<td>3.51</td>
<td>5.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.56</td>
<td>5.15</td>
<td>35.03</td>
</tr>
<tr>
<td>2001-2010</td>
<td>352.973</td>
<td>23.937 37.73</td>
<td>11.6</td>
<td>100.66</td>
<td>3.50</td>
<td>5.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.56</td>
<td>5.25</td>
<td>35.55</td>
</tr>
<tr>
<td>2011-2021</td>
<td>352.974</td>
<td>24.362 37.33</td>
<td>12.5</td>
<td>100.64</td>
<td>3.48</td>
<td>5.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.59</td>
<td>5.53</td>
<td>35.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.543</td>
<td></td>
</tr>
</tbody>
</table>

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.

- **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 7: Solar radiation and urban expansion relationship for four climatic cycles.](image)

![Figure 8: Temperature and urban expansion relationship for four climatic cycles.](image)
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.](image)

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.](image)

➢ **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.](image)
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.

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.

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.
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.

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.
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.

References:
05001, Jun 2021.


[17] Baghdad Municipality, Basic Design Department, Geographic Information Systems Division..

[18] Ministry of Water Resources (the General Directorate of Survey), and Municipality of Baghdad/Department of Engineering Designs (Urban Planning Division, GIS Division).

