Climate change risk assessment in Baghdad: examining population vulnerability

M F Abdulateef¹, H A S Al-Alwan²
¹² Architectural Department, College of Engineering, University of Baghdad, Iraq
Corresponding author’s email: archi.maryam89@gmail.com

Abstract. Studying climate change risks has acquired increased importance and attention around the world in recent years. Every city has its special points of strength and vulnerability that define its specific level of climate change risk. The assessment of this level offers multiple advantages by not just defining potentially impacted areas but also identifying the highest priority areas for the development of sustainable solutions. In Baghdad, surface urban heat island (SUHI) has been noted as one of the main climate change impacts, yet a review of the related literature suggested that few studies have previously assessed the risk level of SUHI, particularly in terms of population impacts in the Baghdad areas. Accordingly, this research aimed to classify the various Baghdad areas according to population exposure to SUHI risks, and to define the risk level as a result of the overlay and the intersection of two main factor layers, intensity of and vulnerability to climate change impact. The research results thus identified areas with the highest level of risk to populations, which thus represent the highest priority areas for any adaptation efforts. Conducting this assessment constitutes a basic step in defining sustainable future adaptation strategies, as well as identifying areas with lower levels of SUHI risk, where measures may be carefully taken to sustain and improve current environmental performance, allowing for a more long-term focus on environmental quality.

1. Introduction

During the 20th century and the first decades of the 21st century, the world has witnessed a large and a growing number of major changes; construction processes have multiplied, technology has spread everywhere, and the innovations are constantly competing in terms of speed of discovery and development. Not all of such changes have been positive, however, and some negative changes have created dangerous threats to the future. At the top of the list of these threats is climate change, and its highly negative impacts on life on Earth.

In general, climate change can be defined as any alteration in climate conditions over a long time, whether these result from human intervention or natural changes [1]. On a global scale, several climate change impacts have already been noticed: the second half of the 20th century, witnessed an increase in global average temperature by 0.74 °C, a drop in ice cover by 40% and a rise in natural sea-level of 17cm [2]. This climate change is generally associated with the increase in long-lived greenhouse gases (GHG) within the atmosphere, caused by anthropogenic activity, which have caused an unequivocal rise in global temperature averages, leading the underlying climate change to often be called Global Warming [3] [4] [5].

On the scale of areas such as a city or a neighbourhood, climate change can cause a wide range of local risks. Climate change risk can be defined as “the potential for impacts where something of value is at stake and where the outcome is uncertain”, referring to the likelihood of the occurrence of negative impacts that may harm the social, environmental and physical resources [6]. In 2006, Mimura presented five concepts defining climate change adaptation: risk avoidance, negative impact reduction, risk
sharing, risk acceptance, and exploitation of opportunities [7]. Many of these concepts are based on dealing with risk before it occurs, thus involving prior action such as risk avoidance, while other concepts are based on dealing with risk after it occurs, involving posterior actions such as exploitation of opportunities [8]. According to some global adaptation-promoting organizations such as UNFCCC and UNDP, assessing climate change risk must be considered one of the basic steps for planning a successful climate change adaptation strategy [9] [10]. Accordingly, assessing the level of risk becomes a necessity not just to define the potential negative impacts of climate change but also to determine the most suitable solutions, and to reduce and even create benefit from the impacts.

At the scale of Baghdad city, an increase in temperature represents the most obvious impact of climate change. During the second half of the 20th century and in the early 21st century, Baghdad, like all of the governorates in Iraq, suffered from a warming pattern reflected in an increasing trend in annual maximum, minimum, and mean temperatures. For example, the annual mean temperature increased by 3 °C in the period between 1995 and 2015 [11], and these increases in temperature are projected to continue in future. Baghdad is thus set to become hotter over time [12].

Baghdad also suffers from a clear state of surface urban heat island (SUHI) [13] [14]. SUHI refers to the temperature increase in urban built areas in comparison with surrounding rural areas [15]. By using computer analysis based on GIS software, one Iraqi researcher pointed out that in winter 2001, a SUHI differential existed between Baghdad’s built-up area and nearby green areas of about 12 °C: the built-up area had the maximum value surface temperature of 30 °C, while the green area had the minimum value of 18 °C [13]. In another analytic study conducted to verify Baghdad UHI intensity in the summer of 2013, the results showed that, in general, the differences between Baghdad’s built-up areas and blue-green areas had increased to about 15˚C [14].

On reviewing related previous studies [11] [13] [14] [16], however, limited research on the risk level of SUHI in Baghdad areas was found. To develop a full understanding of climate change impacts, there is a clear necessity to assess this risk locally; accordingly, this research aimed to assess the risk level of SUHI in Baghdad areas. The results of this research are hoped to assist in defining those areas at higher levels of risk, to offer clear starting points for sustainable adaptation plans, as these areas represent higher priority regions that require accelerated and sustainable solutions.

2. Study Area Description

Geographically, Baghdad governorate lies to the right if the centre of Iraq, at latitude 33°18' N and longitude 44°21' E, being elevated above the sea level by about 39 m (128 feet) [17]. The Tigris river passes through the city from north to south, dividing the city in half. The eastern side is generally called Al-Risafa, while the western side is Al-Karkh.

The study area of this research was limited to boundaries of the Baghdad Mayoralty, which represents most of the governorate’s urbanised entity, with an area of about 840 km². This area is divided into 14 municipalities, which in turn consist of many Mahalas (Figure 1) [18]. In 2010, the population living within Baghdad Mayoralty was about 6,133,000. The ratio of the urbanised area in the region has significantly increased over time; in 2006, it was about 60%, while in 2011, it was about 80% [18].
According to the Köppen climate classification, Baghdad has a hot desert climate (Köppen BWh), being in one of the four divisions of the dry climate group (B) [19]. The hot desert climate pertains to areas in the lower middle latitudes (between 20° to 33° north and south) under the subtropical ridge, which are generally characterised by hot and arid conditions with strong sunshine [20]. Baghdad is one of the world hottest cities, and on hot days, the temperature can increase to nearly 50 °C. In July 2015, the city of Baghdad recorded its highest temperature ever at 51°C. Generally, summer is longest season of the year, at about seven months ling, and there is little rainfall, with this being limited only to winter seasons. For the rest of the year, conditions are dry, clear and sunny. In the Baghdad climatic region, the average relative humidity is about 27%, so the city suffers from a clear, dry climate [21] [22].

3. Methodology

In general, defining climate change risk depends on identifying place-related factors. In 1999, the economic researcher David Crichton produced the “Risk Triangle” to represent risk as the area of a triangle, with the three sides being hazard, exposure and vulnerability; thus, when any of these three sides is reduced, the total area of risk is accordingly also reduced (Figure 2) [23]. This relationship can be presented in the following way:

\[
Risk = Hazard \times Exposure \times Vulnerability
\]  

(1)

Figure 1. Municipalities of Baghdad city.

Figure 2. The risk tringle.
A- The three factors of the risk triangle.

B- When any factor (here vulnerability) is reduced, the total area of the triangle is simultaneously reduced.

In 2004, Downing and Patwardhan presented another relationship to assess climate change risk. They considered exposure to be part of vulnerability rather than a separate component of risk. Accordingly, they defined assessing exposure as a part of assessing vulnerability, creating another equation [24]:

\[
\text{Risk} = \text{Hazard (impact)} \times \text{Vulnerability (Exposure)}
\]  

In this research, the latter equation was used to determine those areas with higher risk in Baghdad, allowing the two main factors, SUHI impact and vulnerability, to be assessed and overlaid to define the relevant risk levels. GIS ArcMap 10.4.1 was used to conduct this process, with the research methodology divided into three main steps as follows (Figure 3):

- Step 1: Assessment of the impact of Surface Urban Heat Island in Baghdad.
- Step 2: Assessment of Vulnerability to Surface Urban Heat Island in Baghdad.
- Step 3: Identifying Risk Level by overlaying the results of steps 1 and 2.

Figure 3. Research methodology.

3.1 Assessment of the Impact of Surface Urban Heat Islands

Assessing the impact of SUHI requires assessing the intensity of the phenomenon at a certain scale, in this case Baghdad city. Assessment is conducted by comparing the surface temperature values between the urban and rural areas of the selected study area [25] [26] [27], and in general, two methods can be used to do this: using digital infrared radiation thermometers or employing computer processing of satellite images [27] [28]. The second method, the remote sensing technique, is more reliable, as it provides information about multiple places at a certain date, revealing the relationships between urban surface temperature and land cover distribution. Assessing SUHI via computer processing can thus help in observing the trends of SUHI development and distribution across study areas [28].

Using remote sensing techniques, an assessment of Baghdad SUHI was recently conducted [29] that found that the intensity of Baghdad SUHI ranged between 30 °C in vegetated and water-covered areas to about 47 °C in soil-covered and built-up areas (Figure 4). Accordingly, the research revealed a wide
variation in SUHI intensity between different areas of the city [29]. As this research was conducted recently using a reliable measuring method, its results were employed to assess climate change risk in Baghdad city for this study.

![Figure 4. Assessment of surface urban heat island in Baghdad, 24 July 2018.](image)

### 3.2 Assessment of Vulnerability to Surface Urban Heat Islands

Assessing vulnerability is an essential part of the process in defining risk, as it defines those areas where something of value, such as a population or ecosystems, may be exposed to significant climate change impacts. However, although vulnerability is a widely used term in the field of climate change, there is as yet no unified definition for this term [24]. The Intergovernmental Panel on Climate Change (IPCC) has defined it as the propensity of a system to be negatively impacted; however, the term may also refer to many other concepts such as sensitivity or susceptibility to harm [6].

Another definition of vulnerability was presented by Mimura et al., being the susceptibility of society and natural systems to be negatively impacted by climate change; here, the term “society” refers to both humans and their built physical capital. The lower the vulnerability, the less damage these systems may experience [30], and in general, vulnerability is the opposite of site adaptive capacity; as the former increases, the latter decreases [31].

Conducting a vulnerability assessment is thus an essential step in planning responses to both current and future climate risks. In recent decades, several methods to assess vulnerability have thus been developed in many sectors, including natural hazards, poverty analysis, and food security, and these methods offer some good general methods for assessing climate change vulnerability [24].

In 2004, Downing and Patwardhan suggested a method to assess vulnerability to assist climate change adaptation. This method involves undertaking five main activities to assess vulnerability before and after adaptation. These are [24]

- **Activity 1:** framing the vulnerability assessment by setting definitions, frameworks and objectives. This setting is thus intimately linked with the context of the project for which vulnerability is to be assessed.
- **Activity 2:** identifying vulnerable groups by answering the questions of who is vulnerable, to what, why, and where. Vulnerability assessment thus usually covers populations, institutions, and places.
- **Activity 3:** assessing current vulnerability by examining a combination of the socio-economic characteristics of all vulnerable groups.
Activity 4: assessing future vulnerability, which aims to calculate the rate of vulnerability after employing specific adaptation plans.

Activity 5: linking the results of vulnerability assessment with the adaptation policy, incorporating the outputs of current and future vulnerability assessments into the decision making for adaptation measures.

In this research, the first three activities are employed, as these offer a scientific approach to assessing the current vulnerability of Baghdad to SUHI. As the latter two activities are about vulnerability after the adoption of adaptation plans, however, these are beyond the research aim (Figure 5).

3.2.1 Framing vulnerability assessment (Activity 1).

Before selection of the framework to be used to measure vulnerability in Baghdad, the national or local vulnerability frameworks already in use required review. However, previous related studies, such as “The state of the environment in Iraq 2017”, have suggested that no standard framework has been employed locally to assess vulnerability [16]. Accordingly, assessing vulnerability in Baghdad began with setting out a conceptual vulnerability definition.

As the aim of this vulnerability assessment for the current research was to determine those areas at higher risk of SUHI in Baghdad in order to plan a sustainable adaptation strategy, vulnerability was defined as “The possibility of local systems and sectors in Baghdad to be adversely impacted by surface urban heat island (SUHI)”, based on reviewing the related knowledge previously explored in 3.2.

Figure 5. Method of Vulnerability Assessment (based on Downing and Patwardhan [24]).

The objective of assessing vulnerability for this work was thus defined as “determining suitable sustainable adaptations to SUHI in Baghdad”. To achieve this objective, two main questions were thus defined:

- What systems are the most vulnerable to SUHI in Baghdad city?
- Which systems in Baghdad city can most benefit from adaptation actions?

Activity one is summarised in table 1. After this activity was conducted, the theoretical framework of the vulnerability assessment was clearly defined.
3.2.2 Identifying vulnerable groups (Activity 2).

Based on the clear definition and identified objectives developed in the vulnerability assessment, it was necessary to determine which groups are vulnerable to SUHI and in which ways they may be negatively impacted by it. As previously mentioned, the targets of vulnerability assessment can include populations, institutions, and places. Generally, population is given the greatest importance, however. Institutions, such as organisations, firms, and sectors may be significantly affected by climate change however, both with regard to resources and costs. Places which include various aspects of natural capital, such as land, ecosystems, and water, may also suffer from climate change impacts [24]. Water, for example, is one of the sectors most vulnerable to climate change. Global warming, precipitation pattern changes, extreme evapotranspiration, and the heterogenous concentration of world population have all caused significant shifts in water quantity and quality. In quantitative terms, climate change causes water shortages associated with an increase in use, especially in arid and semi-arid regions [32], while from a qualitative perspective, climate change causes many significant physical and chemical changes in water body composition, such as lowering the level of dissolved oxygen, increases in pollutant concentrations, and the loss of many aquatic species [33].

As populations are generally deemed the most important target [24], this assessment gives them centrality, particularly in terms of the impact of SUHI on health levels. Human systems are thus the target vulnerable systems examined to assess the risk of SUHI in Baghdad, and assessing the vulnerability of institutions and places (natural and physical systems) is left for future research. SUHI has a series of health consequences as well as environmental and economic impacts [34]. The impacts of urban heat islands can be devastating for those who are living in tropical and arid climates, especially in summer. Climate discomfort, especially for those working outdoors, causes many diseases, including heat stress and skin burns. In some extreme cases, especially in tropical regions, death may ensue [35]. In hot, dry climates, these risks are significantly increased, with the main effects occurring where significant temperature increases are combined with air humidity decreases, which may lead to severe states of heat stress, especially if the wind speed is limited [36]. In addition, an increase in urban temperature tends to cause an increase in cooling energy demand, leading to further GHG production, as most current energy plants depend on fossil fuels [35]. For each degree increase in UHI, the energy demand increases by 2 to 4% [37], increasing the total living costs in these cities in comparison with the surrounding countryside.

In this study, health was set as a targeted value, and population vulnerability to SUHI in terms of health thus assessed, leading to another question: who forms the most vulnerable population to SUHI in terms of health? In 2015, Norton et al answered this question for hot, dry climates, as seen in Baghdad, with the most vulnerable populations to SUHI in terms of health being [38]

- Populations with low income levels.
- Populations with low access to infrastructure.
- Elderly populations (above 65 years).
- Very young populations (below 5 years).
- Sick populations, especially those in health centres.

### Table 1. Framing the vulnerability assessment.

| Vulnerability definition | Vulnerability objectives | Vulnerability questions |
|--------------------------|--------------------------|------------------------|
| The possibility of local systems and sectors in Baghdad being adversely impacted by surface urban heat islands. | Finding sustainable adaptations to SUHI in Baghdad | - What systems or sectors are the most vulnerable to SUHI in Baghdad?  
- Which system or sector in Baghdad can benefit most from adaptation actions? |

for each of the systems: business, industry, health, agriculture, education.
Activity 2 is illustrated in figure 6; this activity allowed the groups most significantly influenced by SUHI to be clearly defined in terms of the interests of this study.

3.2.3 Assessing current vulnerability (Activity 3).

To assess the vulnerability of human systems to SUHI in Baghdad, relevant data were required to be collected and analysed. In the process of collecting data, quality criteria were adopted that resulted in the collection of data from local governmental agencies and international organisations. Data about the relevant vulnerable groups was sought at the district scale, yet a review of governmental studies and publications suggested that that this type of data has not been updated recently, making its adoption futile. Accordingly, in this study, data at the municipality scale was used to assess city vulnerability to SUHI, as the available relevant data was more recent as well as approved by recognised official authorities.

Five groups of populations vulnerable to SUHI were identified. No data was available on group 2, “Populations with low access to infrastructure” or group 3, “Elderly populations above 65 years old”. Accordingly, these two factors were excluded from the current research. As areas with higher densities are more vulnerable to SUHI [39], however, another factor was added in this study to assess vulnerability in Baghdad, population density. Accordingly, data was collected in relation to four factors:

- Population poverty level.
- Population density.
- The number very young residents (below 5 years).
- The number of health centres.
Most of the data and base maps used in this study were from the Baghdad Comprehensive City Development Plan 2030 (CCDP), a study conducted by the Mayoralty of Baghdad under the supervision of the World Bank; Khatib and Alami was the consulting company responsible for developing and implementing the plan [40]. The Baghdad Comprehensive City Development Plan 2030 provides detailed information about Baghdad city’s current situation, and by offering a comprehensive view, the plan offers basic guidelines for the city’s future growth and defines the basic requirements for this.

The available data is summarised in Table 2, which also explains how this data was used to assess the areas vulnerable to SUHI in Baghdad. After examination of the available information, enough data was identified for each Baghdad municipality, including density, the number of young residents, and the number of health centres. However, no data was available concerning poverty levels at municipality level, causing this factor to also be excluded from the vulnerability assessment in this study.

Using GIS ArcMap 10.4.1, all available data about the vulnerable factors was mapped. GIS ArcMap offers the potential to analyse data and arrange areas according to selected factors such as population density and kindergarten number, as these are essential in defining the vulnerability rate of each area. This program also offers the ability to overlay such maps on the SUHI impact map (step 1) to assess the risk level (step 2). Figure 7 shows the Baghdad municipalities and their vulnerability to SUHI. The municipalities shown in darker colours have higher rates of vulnerability, and vice versa.

Table 2: Data on vulnerability factors in Baghdad.
| factor no. | Factor Name                             | Available Data                                           | Possibility of using data                                                                 |
|-----------|-----------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------------------------|
| 1         | Population poverty level.               | Maps of poor population and poverty rate/Nahiya.         | These maps cannot be used, as they offer data at the scale of Baghdad Nahiya, which is bigger than required; no guidelines are offered in these maps to extract the required data. Accordingly, this factor is excluded from this study. |
| 2         | Population density (PD) or (population per area). | Tables of municipality areas (A) and populations (P) | These tables were used in calculating PD: PD= P/A                                           |
| 3         | The number of very young population (below 5 years). | Map of existing educational facilities. | This map was used to calculate the number of kindergartens in each municipality, which can be used as an indicator for the number of residents below the age of 5. |
| 4         | The number of health centres.           | Map of existing health facilities.                      | This map was used to calculate the number of hospitals and health centres in each municipality, to be used as an indicator for the level of sick population. |
In terms of population density (Figure 8), Sadr1 and Sadr2 represent the municipalities with the higher rates, with 288 and 214 people/hectare, respectively. Kadhimia and Mansour have the lowest rates, with about 22 and 30 people/hectare, respectively. In general, the municipalities on the Al-Risafa side of Baghdad are more densely populated than those on the Al-Karkh side. The differences between population density values tend to increase gradually between neighbouring municipalities, however.

Using data about the number of kindergartens in each municipality as an indicator about the number of very young residents reveals that both Sha’ab and Mansour have the highest values, with 21 and 15 kindergartens, respectively. The lowest value, 3, appears in both Kadhimiya and Dora municipalities (Figure 9).

In terms of the final factor, health centres in each municipality, Risafa appears in first place, with about 24 centres, while Shu‘ala and Baghdad Al-Jedeeda being last with about nine centres (Figure 10). In general, the number of health facilities on the Al-Risafa side is greater than on the Al-Karkh side. The values for all vulnerability factors differ between Baghdad municipalities, with those being first according to one factor often being last according to others. This confirms the importance of overlaying
maps of these factors to define those areas with higher risk rates, a process discussed in the next section of this study.

3.3 Identifying Risk Levels
To identify risk levels, the two components of SUHI intensity (land surface temperature) (Figure 4) and area vulnerability (population density, number of kindergartens, and number of health centres) (Figure 7) were overlaid. Areas with both higher SUHI impact and vulnerability represent higher risk and should thus have priority in the adaptation process (Figure 11).

The overlaying process was achieved using GIS ArcMap to assist in producing a map of risk level and defining those areas at higher and lower risk. Figure 12 shows the overlay process. SUHI risk is divided into four levels. Level one, the lightest colours in the map, represents areas with a minimum value of risk, while level four, which is shown by the darker colours, represents the maximum value of climate change risk.
4. Results

The assessment of risk in Baghdad revealed that more than half of the city municipalities suffer from high values of risk (level 3 and 4). Most of these municipalities are located on the Al-Risafa side of Baghdad, which returns higher values of both SUHI intensity and most of the vulnerable factors. Three areas with the highest value of risk (level 4) were identified: Risafa, the northeast of Karrada, and the southwest of Mansour. These areas have higher rates of SUHI intensity and vulnerability ad urgently require the application of sustainable adaptation measures due to the existence of various populations susceptible to being harmed by the impacts of increasing temperature in these urban areas. These thus represent the optimal locations for the first thrust of adaptation plans.

Reviewing Baghdad land use maps [18] showed that most areas with the highest levels of climate change risk form the country’s largest commercial area. This area also contains the main universities and hospitals that offer services at the city level. Such uses indicate a higher level of outdoor activities during the daytime. Risafa also has high historical value, being a major destination for local and foreign tourists. Secondary trade-offs should be conducted between areas with the highest levels of climate change risk to shrink the options and define the areas with the highest need for sustainable adaptation strategy application.

The lowest value of risk (level 1) was shown in the form of scattered small islands in both Dora and Kadhimiya; these areas have not yet been fully urbanised and still have some wide green areas in the
form of palm groves. Measures should be taken to preserve the vulnerable factors in these areas by implementing processes of protection, enrichment, and uplift oriented towards retaining and promoting the remaining green areas to keep these areas safe from many of the adverse impacts of SUHI.

5. Conclusions
For sustainable results in the field of climate change adaptation to be developed, measures cannot be adopted randomly; they must follow the logic and begin where there is the greatest necessity for a rapid solution. Assessment of climate change risk should thus organise areas according to their need for urgent sustainable adaptation strategies. Accordingly, this research aimed to assess the risk levels in Baghdad as a first step towards developing a map to control the phenomenon of Surface Urban Heat Islands (SUHI), which have been previously observed in the city. Using GIS ArcMap and local available data, the factors of such a risk assessment were mapped, analysed, and overlaid, with results showing that the higher levels of risk are found in Risafa, the northeast of Karrada, and the southwest of Mansour. These areas have have higher values of both SUHI intensity and vulnerability, and continuing to accumulate population and activities in these neighbourhoods will transform them into uninhabitable and excessively overheated areas. Urgent plans are thus required to control and reduce the negative impacts of SUHI in these areas; measures should also be taken to preserve those areas with the lower values of risk is such a state, with no more urbanisation or housing development allowed until environmental impacts are carefully studied. This accurate assessment of local risk should thus allow environment and socio-economic revenues to be increased while lowering potential losses to a minimum.

6. References

[1] IPCC, “Climate Change 2001: Impacts, Adaptation and Vulnerability,” IPCC Third Assessment Report, Cambridge University Press, 2001.

[2] J. Berthold and M. H. Wetterwik, Examining the Ecocity: From Definition to Implementation, Sweden.: Bachelor of Science Thesis, 2013.

[3] E. W. Sulzman, The Carbon Cycle, USA: University Corporation for Atmospheric Research, 2000.

[4] UNFCCC, “Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries,” Climate Change Secretariat (UNFCCC), Bonn, Germany., 2007.

[5] UNFCCC, “Climate Action and Support Trends, Based on National Reports Submitted to the UNFCCC Secretariat,” https:// unfccc.int, Bonn, Germany, 2019.

[6] IPCC, “Annex II: Glossary,” in 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, Geneva, Switzerland, 2014b, pp. 117-130.

[7] N. Mimura, “Perspectives and Issues of Adaptation as Responses to Global Warming,” Global Environmental Research, vol. 11, no. 1, pp. 103-110, 2006.

[8] O.-D. Cardona, M. K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R. S. Pulwarty, S. F. E. Lisa and T. B. Sinh, “Determinants of Risk: Exposure and Vulnerability,” in Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC), Cambridge, UK, and New York, NY,. Cambridge University Press, 2012, pp. 65-108.

[9] UNFCCC, “Assessing the Costs and Benefits of Adaptation Options: an Overview of Approaches,” http:// unfccc.int/adaptation, Bonn, Germany, 2011.

[10] UNDP, Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures, Cambridge, UK: The Press Syndicate of The University of Cambridge, 2004.
[11] R. El-Sayed and Z. Al-Barazangi, “Mann–Kendall Trend Analysis of Surface Air Temperatures and Rainfall in Iraq,” *IDŐJÁRÁS: Quarterly Journal of the Hungarian Meteorological Service*, vol. 119, no. 4, p. 493–514, 2015.

[12] H. I. Abd AlKareem, “Assessing of Climate Change on Iraq using Meteonorm Weather Generator,” *IOSR Journal of Applied Physics (IOSR-JAP)*, vol. 8, no. 6, pp. 55-61, 2016.

[13] A. M. Al-Lami, “Study of Urban Heat Island Phenomena for Baghdad City Using Landsat- 7,” *Diyala Journal for Pure Science*, vol. 11, no. 2, pp. 82-98, 2015.

[14] J. M. Ali, S. H. Marsh and M. J. Smith, “A Comparison Between London and Baghdad Surface Urban Heat Islands and Possible Engineering Mitigation Solutions,” *Elsevier - Sustainable Cities and Society*, vol. 29, pp. 159-168, 2017.

[15] EPA, Reducing Urban Heat Islands: Compendium of Strategies, USA: EPA Publication available at (www.epa.gov, 2013.

[16] Iraqi Environmental Ministry, “’The state of the environment in Iraq 2017,” Iraqi Environmental Ministry, Baghdad, 2017.

[17] “www.latlong.net,” 2019. [Online].

[18] Khatib and Alami, “Baghdad Comprehensive Development Plan 2030, fourth stage, part 1,” Baghdad Municipality, 2014.

[19] G. J. v. Oldenborgh, “archive.is,” 2012. [Online]. Available: https://www.knmi.nl/over-het-knmi/about.

[20] W. Köppen, “Die Wärmezonen der Erde, nach der Dauer der heissen, gemässigten und kalten Zeit und nach der Wirkung der Wärme auf die organische Welt betrachtet, (translated paper published in 2011),” *Meteorologische Zeitschrift*, vol. 20, no. 3, p. 351–360, 1884.

[21] N. Salman, Towards Optimal Design Strategies in Hot-Arid Climate, A Comparative Study of Environmental and Socio-Cultural Performance of The Traditional and Modern Housing in Baghdad, IRAQ, Cardiff, Wales: Welsh School of Architecture, Cardiff University, 2016.

[22] S. Ridha, S. Ginestet and S. Lorente, “Effect of the Shadings Pattern and Greenery Strategies on the Outdoor Thermal Comfort,” *International Journal of Engineering and Technology*, vol. 10, no. 2, pp. 108-114, 2018.

[23] D. Crichton, “The Risk Triangle,” in *Natural Disaster Management*, London, Tudor Rose, 1999, pp. 102-103.

[24] T. E. Downing and A. Patwardhan, “Assessing Vulnerability for Climate Adaptation,” in *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies, and Measures*, Cambridge, Cambridge University Press, 2004.

[25] EPA, Reducing Urban Heat Island: Compendium of Strategies, 2013.

[26] S. Zakhour, “The Impact of Urban Geometry on Outdoor Thermal Comfort Conditions in Hot-arid Region,” *Journal of Civil Engineering and Architecture Research*, vol. 2, no. 8, pp. 862-875, 2015.

[27] A. M. Al-Lami, “Study of Urban Heat Island Phenomena for Baghdad City using Landsat- 7,” *Diyala Journal for Pure Science*, vol. 11, no. 2, pp. 82-98, April 2015.

[28] S. E. D. M. El-Ojaly, “Spatial Structure and Its Effect on the Thermal Variation in Benghazi 1984-2012,” *Global Libyan Journal*, vol. 4, 2015.

[29] M. F. Abdulateef and H. A. S. Al-Alwan, “Assessment of surface urban heat island intensity and its causes in the city of Baghdad,” in *IOP Conference Series: Materials Science and Engineering*, Baghdad, 2020.
[30] N. Mimura, H. Ando, S. Emori, T. Ochiai, K. Hitoshi, M. Tanaka, K. Nakata, T. Hasegawa, Y. Hijioka and K.-i. Fujita, “Approaches to Climate Change Adaptation,” The Committee on Approaches to Climate Change Adaptation, Japan, 2010.

[31] L. Schipper, W. Liu, D. Krawanchid and S. Chanthy, Review of Climate Change Adaptation Methods and Tools, MRC Technical Paper No.34, Vientiane: Mekong River Commission, ISSN: 1683-1489, 2010.

[32] M. Beniston, “Climate Change and Its Impacts: Crowding Stress Factors for Human Societies,” International Review of The Red Cross, vol. 92, no. 879, pp. 557-568, 2010.

[33] EPA, The Effect of Climate Change on Water Resources and Program, Watershed Academy Web, 2009.

[34] M. Nuruzzaman, “Urban Heat Island: Causes, Effects and Mitigation - A Review,” International Journal of Environmental, vol. 3, no. 2, pp. 67-73, 2015.

[35] J. A. Voogt, “Urban heat islands: hotter cities,” America Institute of Biological Sciences.

[36] T. R. Oke, “The Urban Energy Balance,” Progress in Physical Geography, vol. 12, pp. 471-508, 1988.

[37] H. Akbari, L. Gartland and S. Konopacki, Measured energy savings of light colored roofs: Results from three California demonstration sites: Lawrence Berkeley National Lab, Berkeley, CA (United States): Environmental Energy Technologies Div., 1998.

[38] B. A. Norton, A. M. Coutts, S. J. Livesley, R. J. Harris, A. M. Hunter and N. S. Williams, “Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes,” Landscape and Urban Planning, vol. 134, p. 127–138, 2015.

[39] A. Ramírez-Aguilar and L. C. L. Souza, “Urban form and population density: Influences on Urban Heat Island intensities in Bogotá, Colombia,” Urban Climate, vol. 29, p. 100497, 2019.

[40] Khatib and Alami, “Comprehensive development plan for the city of Baghdad 2030 : the basic report for the first phase, part 1,” Baghdad Municipality, Baghdad, 2008a.