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ORIGINAL ARTICLE

Urban Land Use Changes: Effect of Green Urban Spaces Transformation on Urban Heat Islands in Baghdad

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Urban Land Use;
Green Urban Spaces

Abstract Urban sprawl has led to changes in landscaping. For instance, open areas and green urban spaces (GUSs)[1] are replaced by buildings, streets, and infrastructure. Permeable and wet surfaces have also been transformed into non-permeable and dry surfaces. This, unfortunately, creates a major problem known as Urban Heat Islands (UHI). The rise in temperature makes the urban centres warmer when compared to their rural outlying areas. This affects the environmental goodness, energy consumption demands, quality of wellbeing. However, there is limited knowledge concerning the change in the use of GUSs, the relationship between the area of these spaces, and the buildings formation on the exacerbation of the UHI in the cities. The research study aim is to assess the impact of the area of GUSs and the building s formation on the exacerbation of the (UHI) in Baghdad city.

The purpose of this study is to improve the understanding of an integrated approach for open green spaces by reviewing city's experience with a main focus of environmental sustainability, cooler temperature, and thermal comfort. The research selected three typical GUSs in Baghdad (Ziyouna) as a case study. Those spaces were transformed into various types of buildings for different uses. The UHI impact is identified and compared in two scenarios (GUSs and added building) using computer climate simulation (ENVI-met) tool. The tool also assessed and measured surfaces and air temperature (CLUHI & SUHI) at different points in the selection of three typical models. The results demonstrated several factors combined with the change of urban land uses that are responsible for exacerbation of UHI in terms of buildings' height, formation, ground coverage, and construction including pavement materials and colour.

1. Introduction

In recent decades, cities have been experiencing a significant rise in temperatures for several reasons. The most important

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[1] GUSs: Green Urban Spaces.

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one is population growth that causes rapid and informal urban development, which caused a change in land use, and led to the increased infrastructure supplies and mobility needs. As a result, this has increased the built-up and paving areas. All those factors have an impact on the local climate of cities [1 2].

Nevertheless, these urban developments are closely connected and interpreted based on contemporary concerns to mitigate the impact of climate change [3 4 5 6]. This is because people's living standards and lifestyle have changed, and the need to maintain design accessibility to open green areas is rising. Equally relevant, green spaces and infrastructure in addition to its relationship with culture are facing many challenges when it comes to investing in overused areas. The same challenges are strongly connected with issues if solved can collectively demonstrate a multifunctional benefit between green spaces, ecosystems, and buildings to urban communities [7 8 9].However, sustainable urban development cannot be maintained without paying attention to up-to-date social, cultural, economic, as well as ecological demands.

Similarly, temperatures in cities are gradually rising for several reasons including reduced wind speed. This is due to the height of buildings, large paving areas to match the high demands of construction, population densities, and energy consumption. Other issues are observed in the increase of heat-exposed surfaces, and lack of green spaces which means less vegetation leading to low humidity, as well as the expansion of streets, pavements areas, and increased traffic. The most important factor is the planning of land uses, which represents a very important indicator of environmental quality [10 11 12]. All of this has led to the phenomenon of Urban Heat Islands (UHI).

Equally important, Urban Heat Islands (UHI) is a phenomenon that occurs above the urban areas as a result of changing their surfaces, which affects the climate of those areas [13]. Buildings, roads, and paved surfaces store heat during the day and release it slowly at night, making urban areas hotter than their surroundings. This causes discomfort issues for the people who are occupying these areas, which means more energy is needed for cooling purposes. The heat emitted from air conditioning and fossil fuel combustion in cars and industrial activities combined, increase the temperature of surfaces and air inside the city. UHI has a negative effect on human comfort, public health, biodiversity, urban climate, air quality, and energy consumption [14 15 16]. As well as speeding up the smog formation within cities [17]. The best description for UHI phenomenon is a dome of warm stagnant air above the heavily crowded areas of the city. As a result, the urban areas is facing higher temperatures compared to surrounding rural areas, this rise could be about (1–3 °C) per million people, and the difference could be (12 °C) in large cities [18 19].

The term UHI was proposed by Luke Howard in 1820 and defined as a macro-climate phenomenon. In 1993, Michael & Aniello classified the UHI into two main types: Macro UHI, which occurs on a large scale. Second type is the Intra UHI, which is related to smaller scale [20], and this type is discussed in the current study.

Intra UHI appears on two levels, the first level is the **Horizontal UHI**,[2] and it is divided into: **Micro-scale**,[3] which covers a small area ranging from less than one meter to hundreds of meters, like covering one building or configuration from a group of buildings that form a single street. **Local-scale** is on the neighborhood scale and depends on the morphology and urban formation characteristics. The **meso-scale** covers a whole city scale, which has an area of up to several square kilometers [18 20].

The second level is the **Vertical UHI**, and it is divided into **Atmospheric UHI & Surfaces UHI** (SUHI). Atmospheric UHI comes into two types: **Canopy layer UHI**[4] starts from the ground's surface and extends to the average height of buildings. The **Boundary layer UHI**[5] can be formed above the CLUHI [18 20].

For Surfaces UHI[6] (SUHI), exposed surfaces (roofs, streets, and floors) and the air temperatures, sometimes reaches a range of (20–50 °C). While the temperature of the shaded and humid surfaces is close to the air temperature. The difference average between the temperature of surfaces in urban and rural areas during the day is about (15–20 °C) and at the night about (5–10 °C). SUHI vary depending on the seasons due to the change in weather, the intensity of solar radiation, and the change in the ground's cover, as they are more severe in the summer [18 20].

The intensity of UHI is influenced by several factors: **City Size,** which is directly proportional to the UHI. **Urban Geometry,** which refers to the mass of buildings and urban spaces between them, urban engineering affects wind speed, heat absorption, and shadows**. Reducing GUSs and the lack of vegetation in urban areas** consider a major cause of exacerbation of UHI where surfaces are paved, non-permeable, and covered with buildings where evaporation is reduced and the surface temperature rises. Trees and plants reduce air and surfaces temperature due to the process of transpiration as well as provide shadows. **Properties of urban materials** are highly thermally emitted because they are reflective to sunlight, heat-storage mass that can be twice as high as the thermal energy stored by soil covered with green plants in rural areas. **The Heat is also a result from human activities** such as mobility, heating, cooling, operation of various appliances, and industrial processes. **Additional factors** for heat is related to geographical location and weather [21 22 23 16].

In third-world countries, due to informal urban growth, many urban spaces and green areas within cities, particularly, within residential neighborhoods have been converted into buildings for different uses [24].

This study discusses the change of the urban land uses of (GUSs). This is because many green areas within the residential neighborhood of Baghdad have been converted into buildings for various uses. These spaces are transformed into large heat-stored building masses in a way that cannot get rid of their heat due to the obstacles caused by the overcrowding of buildings in these areas. The characteristics of urban materials that are transformed from moist soils and green plants into buildings and asphalt surfaces also add to the problem by storing heat and worsening the exacerbation of the UHI

[2] Horizontal UHI: HUHI.

[3] Micro UHI: MUHI.

[4] Canopy layer UHI: (CLUHI) represents the air layer where people live, and extend from the ground to the roofs and tree tops, which is most commonly observed when referring to UHI, [20].

[5] Boundary layer UHI It extends from the surfaces and the highest tree tops up to the urban views have an impact in the atmosphere as they extend to more than (1.5 km) from the surface, [20].

[6] Surface UHI: SUHI.

in the city. However, green spaces can reduce air temperature by about (0.5–5 °C), and by reducing air temperature (1 °C), cooling loads are also reduced by about (2–4 %). Hence, green spaces positively contribute to the environment by saving energy and reducing the incidence of smog or other atmospheric pollutants [16 24].

To achieve the goal of this study, the research focuses on measuring the impact of different areas of GUSs in Ziyouna district, which demonstrates more than one type of buildings formation on the UHI phenomenon. The research measures UHI at the horizontal and vertical levels. At the HUHI level, the research approach focuses solely on MUHI measurement, which is on small areas such as GUSs. At the VUHI level, the research measures SUHI and CLUHI, particularly, perceptible and the effect of thermal comfort.

2. Literature review

The research addresses previous studies that discussed the main research terms (UHI and GUSs). Many studies have considered the increase in temperatures in urban areas when compared to the surrounding rural areas [25 26]. Moreover, urbanization is the main cause of heating local micro-climate in cities, and high energy consumption due/or the cause to the formation of (UHI). Surfaces UHI and Canopy Layer UHI are the most important type that affects human comfort [18 20].

Some studies have mainly focused on urban geometry as they considered the distribution of (UHI) is less dense in the non-built-up areas in comparison to the built-up areas. The density of (UHI) also varies within the built-up areas, as it is affected by the urban formation type in cities. Because of the different characteristics of the urban geometry and by comparing and simulating many urban forms using computer, studies have concluded that the compact organic form is the least urban form that formed of (UHI). This is because it recorded the lowest rates of (UHI) in the complex urban form (organic) [27 28 29]. Through the selection and testing of a number of cities, it was found that (UHI) increases with the increase of the urban form area. Also, the rest of the urban engineering factors in terms of (buildings height, area, spacing of the buildings, engineering of roads and walkways, shading systems, and the design of green urban spaces GUSs) have a significant impact on the formation of (UHI) and thus on the local micro-climate [30].

Several studies have focused on the effect of building density on the composition of (UHI). The classification and density of buildings affect the environmental performance as urban areas have a complex microclimate which impacts the comfort and safety of pedestrians in those areas. UHI is increased in densely built urban areas and that calls for a change in current urban design practices. UHI can be mitigated by urban design and density modification to include urban green spaces, green and blue infrastructure as well as home gardens [30 31 29 32].

Some studies have dealt with the possibility of mitigating UHI by modifying urban land uses and thus, improving the external thermal comfort conditions [33], and increasing green spaces through afforestation of sidewalks, the areas of (GUSs), and the implementation of roof gardens [34 16]. When it comes to design strategies, architects and designers have dealt with climate-responsive strategies through the use of building elements such as courtyards. The main function of courtyards design is to moderate high temperature and reduce environmental-thermal stress for the occupants of that environment by adopting the thermal attenuation strategy inside the courtyards [35 36].

To some extent, it is evident that the role of architecture revolves about expressing both the culture and environment of the residents who dwelled in that part of the area [37]. Similarly, landscaping and green infrastructure are an integrated design approach in a way that provides resilience, for it provides solutions to the effects caused by climate change [38]. Equally relevant, green infrastructure takes into consideration the presence of environmental features and elements designed to deliver various benefits [39 40 41].

Nevertheless, the effect of globalization, and the copy and paste method had affected the role of environmental sustainability including the perception of open green spaces. Therefore, there is a need to explore other suggestions to revive design strategies. For instance, the significance of courtyards concept has been present through time, and shows its sustainability aspects through various types of historical and contemporary buildings in the Middle East [42 43].

More importantly, the complex nature of the cities combines more than just a place to embrace its residents. It involves the culture in addition to other features related to the green areas, buildings, streets and infrastructure [44 45]. Equally relevant, it is essential to restore the role of open green spaces to improve accessibility and build resilient communities. This is because such areas have a positive impact on the environment and the surroundings for their intertwined relationship between aesthetic appreciation, health, well-being standards, and view restorative potential [46 47 48].

However, the areas of the contemporary city are also the result of settlement, social imbalances, ecological and environmental fragility as they suffer under the act of alienation. The impact of climate change, extreme weather conditions, heat waves, drought, have consequences that jeopardize the quality of urban areas. Even though urban areas cover only 2 % of the Earth's surface, nevertheless they produce 60 % of pollutant emissions and 2/3 of greenhouse gases [49 50]. Accordingly, it is important to encourage the reuse of green and natural resources and hardscape materials in urban areas.

The approach of modernization in design should be illustrated with the measures that prevent the effects of climate change towards a clean sustainable resources [51]. Many researchers, architects, landscapers, and designers have made innovative explorations on various green design and infrastructure scale and provided suggestions to enhance resilience when implementing GI areas [52]. The approach of the research study emphasizes on the importance of sustaining an efficient green area infrastructure and thermal comfort in the design context.

Accordingly, this research focuses on the importance of enhancing resilience when implementing open green spaces in the Ziyouna district in Baghdad. This is in order to maintain the balance between neighborhood's characteristics and the adoption of many new buildings, for instance schools and shopping centers. This is achieved by using the multifunctional dimension of green spaces in order to support sustainable development demands as well as to enhance specific features of local settings while preserving environmental and social aspects.

In addition to the effect of built roofs and paved surfaces on the formation of (UHI) in urban areas, the use of white surfaces and urban building materials can also add positively in terms of the reflection and absorption of sunlight in order to minimize the UHI phenomenon impact in order [30 34 16].

Based on what has been discussed in the previous literature, some key points can be concluded as follows:

- The studies focused on the procedure of (UHI) formation and strategies to mitigate them, starting from the city scale and ending with the building details.
- There is limited knowledge about the effect of GUSs exploited area and its relationship to exacerbation of (UHI), as well as the building formation and its effect on attenuation of (UHI).

As to the above, the missing knowledge can be diagnosed in the light of research main terms (UHI and GUSs). Accordingly, the research problem can be identified as "the lack of knowledge concerning the change in the use of GUSs, the impact of the formation of added buildings, and how to mitigate the effect of UHI in the Baghdad city". The aim of the research is to "assess the impact of the area of GUSs and the buildings formations on the exacerbation of the (UHI) in Baghdad city".

3. Methods and materials

In this section, the research emphasizes on testing the selected case studies, to measure SUHI and CLUHI within MUHI, and by adopting mathematical approaches.

- **The Case Study Selection:**

The research selected Ziyouna district as a case study, it is located in Al-Rusafa Municipality southeast of Baghdad, Ziyouna is surrounded on the north by the Al- Jaeish Water Canal. The location of the case study is on the south by Muhammad Al-Qasim Highway, and on the east by Al-Ghadeer District, and on the west by the Ministries Complex on Palestine Street. It was selected as a case study for a number of reasons:

- The selection of any area for testing is done because that area is exposed to risks due to UHI, which affects the environmental, social, and physical resources [26]. Ziyouna was chosen as a case study because of the significant increase in UHI during the last ten years, as the temperature difference reached 7 °C, as seen in Fig. 1
- Ziyouna is one of Baghdad's districts, which gives the possibility to test multi-area urban spaces. This district has a relatively large number of typical (GUSs) of varying sizes (200*200 m) (250*250 m) (300*300 m), acting as the region's lungs.
- Due to informal urban growth, these spaces have been transformed into new and varied uses and different building formations (traditional enclosed courtyard building, three sided courtyard building with U shape design, compact building surrounded by open area) according to their size.

To achieve its goal, three (GUSs) were selected in Ziyouna district, various areas that were occupied by buildings (Schools and Mall) to measure the exacerbation of the UHI phenomenon in it, Fig. 2, Table 1.

- **Data Collection:**

The main aim of the study is to provide knowledge about the impact of the area of GUSs in the first scenario and the buildings formations in the second scenario on the exacerbation of the (UHI) in Baghdad city. To achieve its goal, the research works on verifying the three models of building in Ziyouna district. The research spatial data were collected through field surveys, ArcGIS Earth available maps, and satellite images of selected models. The research data is illustrated and tested according to two scenarios:

- GUSs scenario: Before the change in land use of GUSs selected in 2010.
- Building scenario: After changing the land use of GUSs to buildings for different uses, (research preparations time) in 2022.

To detect the exacerbation of SUHI and CLUHI within MUHI, the three models were selected and their data is shown in table 1.

- **UHI Measures:**

The research has adopted a computer simulation software known as ENVI-met (version 5.0.3), to measure (UHI) in selected models. It is a predictive system that simulates buildings in a 3D technique designed to model and simulate the climate in urban areas through the model network with a resolution ranging from (0.5–10 m) and extending into the urban spaces for the simulation of the UHI phenomenon. This is in order to measure the impact of local climate factors affecting thermal comfort, the temperature of radiant surfaces, and the impact of vegetation, [21].

Several studies have confirmed the effectiveness of the (ENVI-met) program in simulating the climatic conditions of the urban environment compared to other simulation programs. This is due to its ability to analyze the basic physical factors (radiation, irradiation, air exchange, heat exchange, evaporation) [53]. (ENVI-met) program is distinguished from other simulation programs such as (RayMan and ANSYS) for its ability to simulate all environmental elements of the site, while (RayMan) focuses only on simulating the effects of the plants on the buildings. Equally as relevant, the potentials of (ENVI-met) also include calculating the human thermal comfort factor (PMV) in contrast to other programs such as (ANSYS). ENVI-met has the ability to calculate microclimate factors (air temperature, relative humidity, radiant temperature, and wind speed) [54 52 55].

ENVI-met program calculates and simulates (SUHI and CLUHI) according to the following steps:

- Entering the data of the three selected models into the ENVI-met program to measure the (UHI).
- Entering climate element data (temperatures, relative humidity, direction, and wind speed) for the warmest day in Baghdad for the last 10 years and during a 24-hour day cycle.

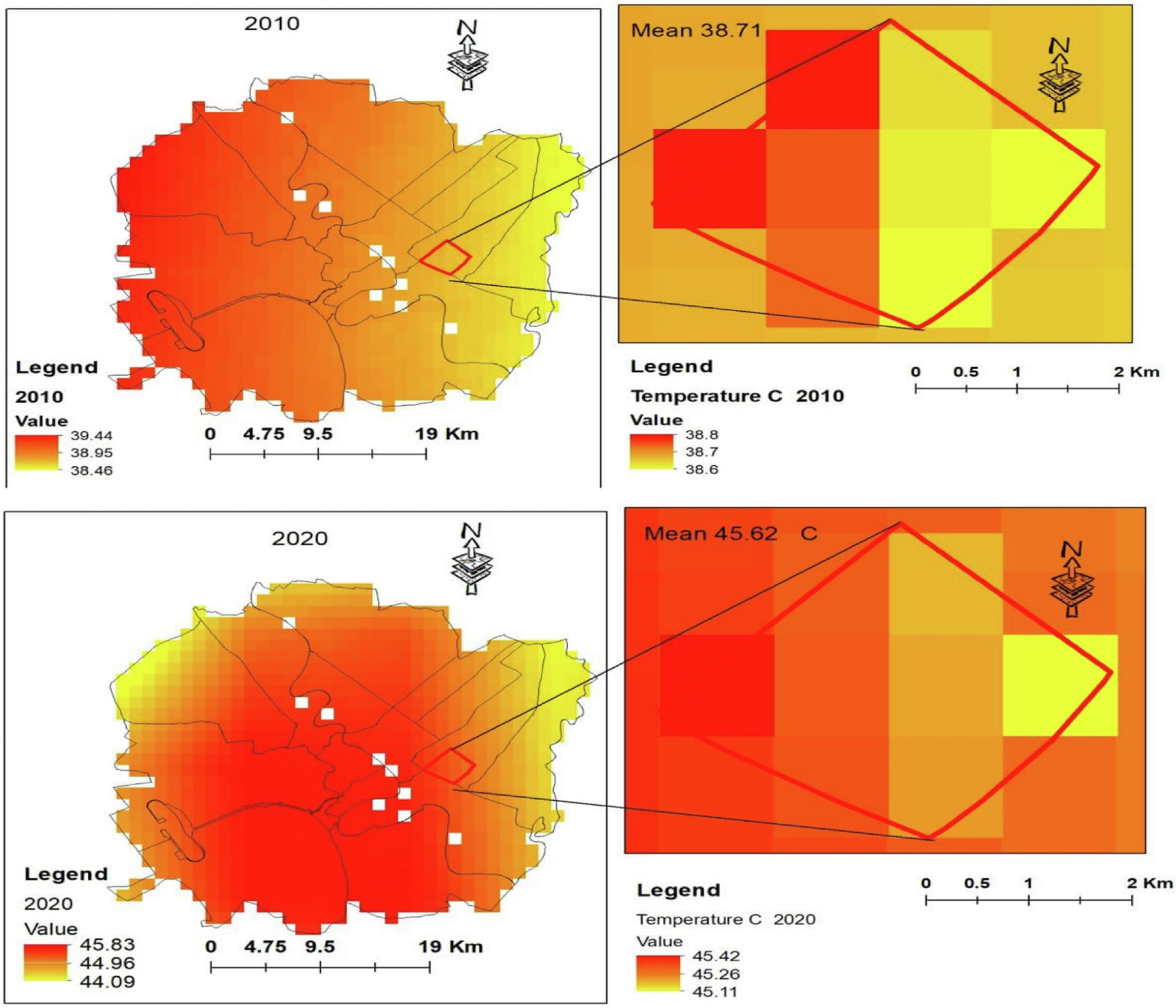


Fig. 1 Baghdad map and Ziyouna UHI in 2010 and 2020 (The reserchers).

- Converting the dimensions of case studies to the program's (dx/dy/dz) for drawing and analyzing them in (2d) level. This is to obtain the results of environmental readings and simulations, on which the research focused to measure the exacerbation (UHI) of selected models at 12 PM. The research mainly focused on the results of simulations to calculate air temperature (CLUHI), and surface temperature (SUHI) within (MUHI) which affect thermal comfort rates (*PMV*), as seen in Table 2, and Table 3.

4. Result Discussion:

To achieve the aim of the research "assesses the impact of the area of GUSs and the buildings formations on the exacerbation of the (*UHI*) in Baghdad city", three models were tested and compared within the demonstration of two scenarios in Ziyouna district, Baghdad. The first scenario is the green urban spaces GUSs scenario and the second scenario is the Building scenario. The results of each scenario and their three models are compared to reveal the effect of the loss of the green areas in the first scenario in favor to buildings with different formations and uses in the second scenario. This comparison is important to highlight the major problem of the aggravation of the UHI phenomenon. The main idea is to show how important to conserve the green areas to reach the optimal environmental form as a mean to reduce the UHI effect. After simulating the *GUSs* and Building scenarios, the results and value of (*Ta, Tmrt, PMV*) in each scenario were extracted and discussed for the three selected models (A, B, and C). The first results are discussed in Table 4 which demonstrates the impact of green areas when compared to the impact after the insertion of **Al- Alamia School** buildings shape on the environment.

Table 4 and Fig. 4 discuss the impact in three aspects which are as follows:

- When analysing and discussing the results of (CLUHI), it is clear that *Ta* index at 12 PM showed that the air temperature before the replacement of the open and green spaces in GUSs scenario is around (35.58 °C). Accordingly, the air temperature is less than the air temperature in the Buildings

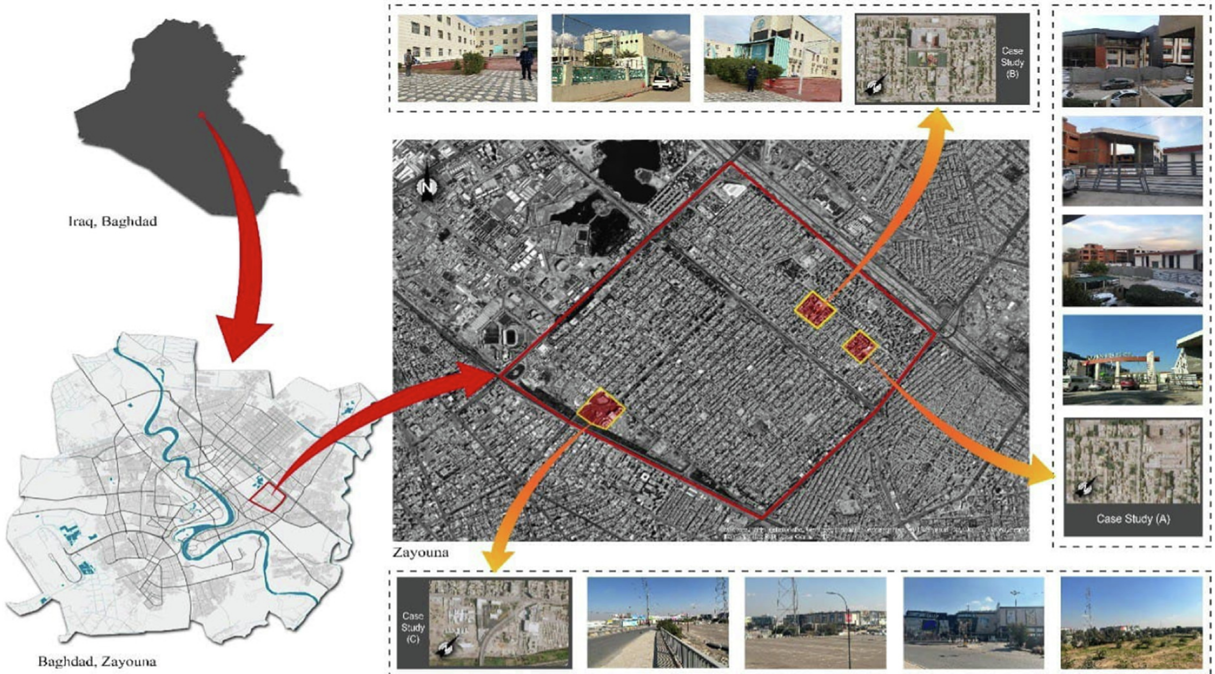


Fig. 2 Baghdad map and Ziyouna location, Ziyouna location map and the Case Studies locations. (The researchers & https://wikimapia.org/#lang = en&lat = 33.379871&lon = 44.339640&z = 16&m = o&search = baghdad).

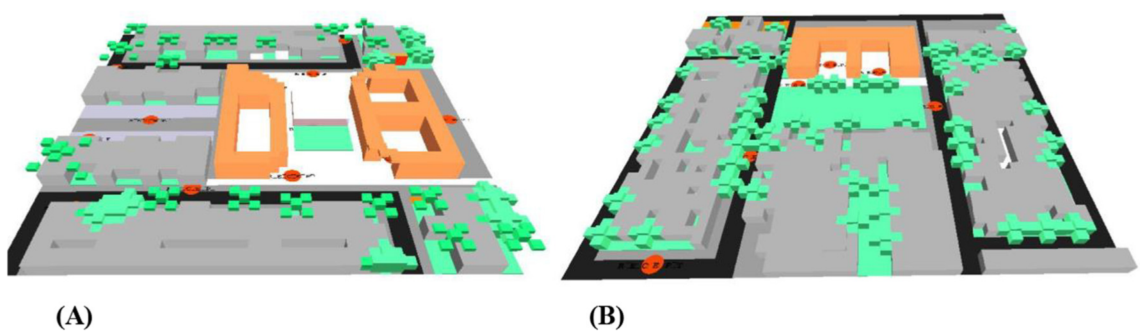


Fig. 3 Demonstrates of the courtyards shapes highlighted in orang to be identified from the surroundings. (A) illustrates the **Al- Alamia School** compact building with its three four-sided enclosed courtyards, while (B) demonstrates **Al- Alamia School and its U shape courtyard.**

scenario. This is because **the injection of compact building of** Al- Alamia school **with its three enclosed courtyards** increased the *Ta* index to about 36.9 °C in the courtyard building.

The same results are observed for the (***Ta)*** on sidewalks with dark shades of Asphalt and Concrete Pavement. Before change in GUSs scenario, ***Ta*** is around 38.5 °C recorded on (sidewalks). After the change in the second scenario, it is increased to about 39.1 °C.

The (***Tmrt***) is also increased to around 66.58 °C on with dark shades of Asphalt and Concrete Pavement (sidewalks) in the second scenario when compared to the First scenario. The (***Tmrt)*** recorder a lower temperature about 48.42 °C in the First GUSs scenario which is due to the positive effect of open and green spaces before they are replaced with Al-Alamia school compact building.

The same results are observed when comparing ***PMV*** value with dark shades of Asphalt and Concrete Pavement. The ***PMV*** value of in the GUSs scenario is around 4.21 on (sidewalks), while in the Second scenario, after the insertion of the compact **buildings of** Al-Alamia school the value is increased to about 5.69.

The impact of the insertion of another building (**Al-Maearif School)** in Ziyouna district is also discussed in Table 5. Table 5 and Fig. 5 also discuss the differences between the two scenarios, particularly, the impact of losing the open green spaces in favor of buildings as demonstrated in **Al- Maearif School**. The results of the discussion are also divided into three aspects as follows:

- When discussing the results of (CLUHI), the results of *Ta* index at 12 PM showed the range of air temperature before the replacement of the open and green spaces in GUSs sce-

Table 1 Shows data of selected Models (GUSs) to measure the UHI phenomenon**,** (The researchers).

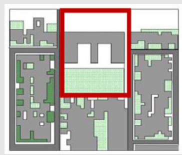
Case study	Building Function	The Area (m^2)	Building Plan	Building (B)& Paving (P)Coverage	Building Form description
Model -A-	Al-Alamia school	200 × 200		B = 47 % P(concrete dark) = 23 % P (concrete light) = 20 % P (Asphalt) = 10 % Green area = 0.05 %	A compact building with three enclosed four-sided courtyards. Building height = 8–12 *m*
Model -B-	Al-Maearif school	250 × 250		B = 34 % P(concrete dark) = 24 % P (concrete light) = 12 % Green area = 30 %	A building with central U shape three-sided courtyards opened to gardens and playground areas. Building height = 8–12 *m*
Model -C-	Dream mall	300 × 300		B = 26.7 % P(concrete dark) = 30 % P(concrete light) = 3 % P (Asphalt) = 54.25 % Green area = 1 %	A building surrounded by three-way open spaces paved with asphalt used as parking. Building height = 12–20 *m*

Table 2 Shows ENVI-met indicators adopted by the research to measure (CLUHI, SUHI) for models within MUHI, (The researchers).

Indicators	Indicators Identify	Indicators Measurements	VUHI	HUHI
Ta	the Air Temperature	An indicator to measure the impact of air temperature within the city	CLUHI	**MUHI**
Tmrt	Mean Radiation Temperature	An indicator that summarizes all direct and reflected radiation flows (short and long waves) to which humans are exposed	SUHI	
PMV	Predicted Mean Vote	An indicator for calculating human thermal comfort		

nario is between (37.36 °C to 39.49 °C), while the range of air temperature is higher after the insertion of the three-sided U shape of **Al- Maearif School** building between (37.99 °C to 40.32 °C).

Accordingly, the lowest air temperature (***Ta)*** is observed in the GUSs scenario when compared to the scenario of **Al-Maearif School** U shape building. This is because of the role that open green spaces used to deliver in terms of providing cooler temperature and better air quality.

As for simulation of the highest (***Ta)*** on sidewalks**, the Building's scenario of Model B** recorded the highest **Ta** on dark shades of Asphalt and Concrete Pavement of around 40.32 °C to 41.32 °C. This result is higher when compared to the highest (***Ta)*** recorded in GUSs scenario on the sidewalks which is only around (39.49 °C to 40.4 °C).

The (***Tmrt***) is also increased to around (62.13 °C) on with dark shades of Asphalt and Concrete Pavement (sidewalks) in the second scenario when compared to the First scenario. The (***Tmrt)*** recorder a lower temperature about (55.45 °C) and that is due to the positive effect of open and green spaces before they are replaced with **Al- Maearif School and its three-sided U shape** building.

The same results are observed when comparing ***PMV*** value on Asphalt Road, and Dark Concrete Pavement between the two scenarios. The lowest range for ***PMV*** value in the GUSs scenario is between (4.91 to 5.26), while the range of ***PMV*** value in the Second scenario is much higher around (5.55 to 5.91) on sidewalks. This is because of the insertion of the **Al-Maearif School** building and its **three-sided U shape courtyard**.

Accordingly, the thermal differences between the two scenarios proved that the fist scenario with its open green space used to deliver better quality for thermal comfort with a decrease in the ranges of temperatures both (TA), (Tmrt), and (PMV). Similarly, the green spaces disappearance in the second scenario accompanied with the insertion of Al-Maearif School compact building caused the rise in temperature and badly affected the conditions of the surrounding environment.

However, it is important to realize the role of building's courtyards shape and formation also has an impact in lowering air temperatures (***Ta and Tmrt)***. In this research study, it is observed that Model A with the three-sided U shape courtyard building of **Al- Maearif School** (highlighted in orange colour) provides better cooling effect and thermal comfort value when compared to Model B with the four-sided three compact Buildings of **Al- Alamia School, as seen in** Fig. 3.

Another building (**Al- Maearif School), particularly,** the **i**mpact of its insertion in Ziyouna district is also discussed in Table 6.

Table 6 and Fig. 6 discuss the differences between the role of open green spaces in the first scenario, and after the injec-

Table 3 Shows the case studies data, (The researchers).

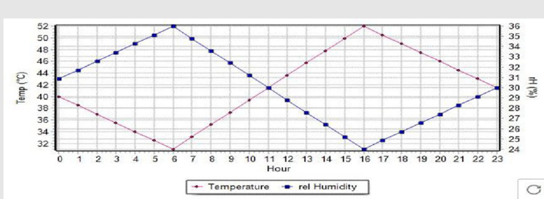
Model domain settings	Model Location	Iraq/Baghdad/Ziyouna, Latitude: 33.34,Longitude: 44.40	
	Model Geometry	Model 1	Model Dimensions: x-Grids 50 / y-Grids 50 / z-Grids 20 Size of grid cell in meter, dx = 4 / dy = 4 / dz = 2 (base height) Model rotation out of grid north: 41
		Model 2	Model Dimensions: x-Grids 50 / y-Grids 50 / z-Grids 20 Size of grid cell in meter, dx = 5 / dy = 5 / dz = 2 (base height) Model rotation out of grid north: 41
		Model 3	Model Dimensions: x-Grids 50 / y-Grids 50 / z-Grids 20 Size of grid cell in meter: dx = 6 / dy = 6 / dz = 3 (base height) Model rotation out of grid north: 44
	Default Settings for Walls and Roofs	Wall material	
		Brick wall	0000B3
		Aluminum wall	0000AL
		Foamed Glass	0100G3
		Roof material	
		Roofing: Tile	0000R1
	Default Settings for Soil and Asphalt	Loamy Soil	000,000
		Asphalt Road	0000ST
		Concrete Pavement Dark	0000PD
		Concrete Pavement Light	0000PL
		Pavement (Concrete),used/ dirty	0000PP
	Vegetation	Grass 25 cm aver. dense	0100XX
		Palm, large trunk, dense, medium	01PLDM
		Sophora Japonica	0000 s2
Simulation	Simulation cases study day	18 Jun 2022	
	Simulation starting time	00:00 AM	
	Simulation duration	24 h	
Initial meteorological conditions	Wind speed measured in 10 m height (m/s)	3.9	
	Wind direction (deg)	315 (0 = from North ...180 = from South)	
	Temperature of atmosphere	MIN 26C at 06:00 AM, MAX 48C at 16:00 PM	
	Relative humidity in 2 m (%)	MIN 24 at 16:00 PM, MAX 36 at 06:00 AM.	
Simple Forcing			

Table 4.1 Shows ENVI-met simulation of (CLUHI (data for Model –A, (Al- Alamia School), (The researchers).

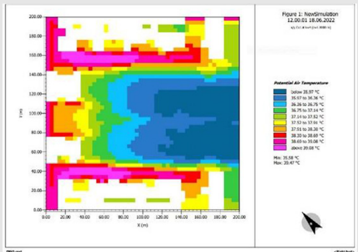
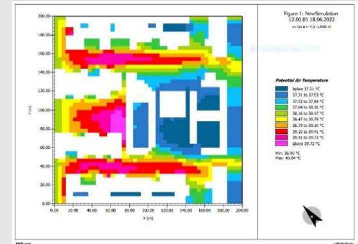
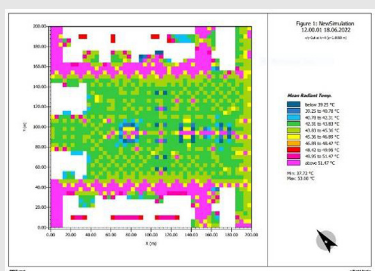
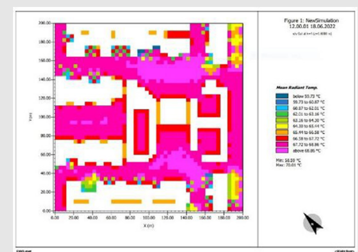
GUSs Scenario			Building Scenario		
Potential Air Temperature (*Ta*) at 12:00PM) CLUHI (			*Potential Air Temperature* (*Ta*) at 12:00 PM (CLUHI (		
MIN MAX D. B. MAX and MIN	35.58 °C 39.47 °C 3.89 °C		MIN MAX D. B. MAX and MIN	36.9 °C 40.04 °C 3.14 °C	
• Through simulation, it could be noted that the lowest ***Ta*** was recorded in the green areas, around 35.58 °C to 38.5 °C. Through simulation, the highest ***Ta*** was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 38.5 °C to 39.47.			• Through simulation, it could be noted that the lowest ***Ta*** was recorded in the shadowy places of the buildings, four–sided enclosed courtyards, and green areas, around 36.9 °C to 39.1 °C. Through simulation, the highest ***Ta*** was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 39.1 °C to 40.04 °C.		

Table 4.2 Shows ENVI-met simulation of (SUHI (data for Model –A, (Al- Alamia School), (The researchers).

Mean Radiant Temperature (*Tmrt*)at 12:00 PM (SUHI(			*Mean Radiant Temperature* (*Tmrt*)) at 12:00 PM (SUHI)		
MIN MAX D. B. MAX and MIN	37.72 °C 53 °C 15.28 °C		MIN MAX D. B. MAX and MIN	58.59 °C 70.01 °C 11.42 °C	
• Through simulation, the lowest *Tmrt* was recorded in the green areas and the shadowy places of the surrounding buildings, courtyards, around 37.72 °C to 48.42 °C. Through simulation, the highest *Tmrt* was recorded on Asphalt Road, Concrete Pavement Dark (sidewalks), and green areas, around 48.42 °C to 53 °C.			• Through simulation, the lowest *Tmrt* was recorded in the shadowy places of the buildings, four-sided enclosed courtyards, and the green areas, around 58.59 °C to 66.58 °C. Through simulation, the highest *Tmrt* was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 66.58 °C to 70.01 °C.		
Regarding the results of (SUHI), the lowest (Tmrt***)*** is recorded around 37.72 °C in the open and green spaces and the shadowy places of the surrounding buildings, courtyards. However, when the results are compared with those of the Second scenario, it is clear that (***Tmrt***) is significantly increased to around 58.59 °C **in the shadowy places of the three enclosed courtyards buildings of** Al-Alamia school.					

tion of **(Dream mall) building in Model- C** in three aspects as follows:

- The results associated with (CLUHI) in GUSs scenario showed the lowest range of *Ta* index at 12 PM is between (36.49 °C to 38.76 °C.) due to the role of the open and green spaces in GUSs scenario. However, after the injection of the Dream Mall Building the range of *Ta* index has increased dramatically to around (38.2 °C to 40.34°) in the shadowy places of the buildings.

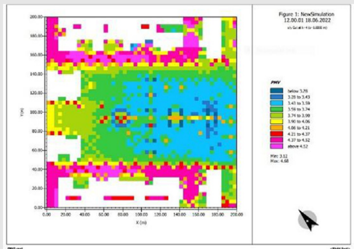
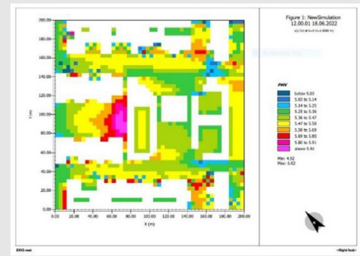
Accordingly, the lowest air temperature (***Ta)*** is observed in the GUSs scenario when compared to the scenario of the Dream Mall Building. In this case, open green spaces have an advantage by providing cooler temperature and better air quality.

As for simulation of the highest (***Ta)*** on sidewalks**, the Building's scenario** recorded the highest range for **Ta** on dark shades of Asphalt and Concrete Pavement (sidewalks) of around (40.34 °C to 41.26 °C). This result is higher when compared to the range of the (***Ta)*** recorded in GUSs scenario which is only around (38.76 °C to 39.74 °C.).

The (***Tmrt***) is also increased to around (64.03 °C) on dark shades of Asphalt and Concrete Pavement (sidewalks) in the second scenario. The (***Tmrt)*** recorder a lower temperature about (55.45 °C) in the first GUSs scenario due to the impact of the open green spaces.

The same results are observed when comparing ***PMV*** value on Asphalt Road, and Dark Concrete Pavement between the two scenarios. The lowest range for ***PMV*** value in the GUSs scenario is between (4.47 to 4.78), while the range of ***PMV***

Table 4.3 Shows ENVI-met simulation of (PM (data for Model –A, (Al- Alamia School), (The researchers).

Thermal Comfort (PMV) at 12:00 PM		*Thermal Comfort (PMV)* at 12:00 PM	
MIN 3.12 MAX 4.68 D. B. MAX and MIN 1.56		MIN 4.92 MAX 6.02 D. B. MAX and MIN 1.1	
• Through simulation, the lowest *PMV* was recorded in parts of green areas and the shadowy places of the surrounding buildings and courtyards, around 3.12 to 4.21. Through simulation, the highest *PMV* was recorded on Asphalt Road, and Concrete Pavement Dark (sidewalks) 4.21 to 4.68.		• Through simulation, the lowest *PMV* was recorded in the shadowy places of the buildings, four sided courtyards, and the green areas, around 4.92 to 5.69. Through simulation, the highest *PMV* was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 5.69 to 6.02.	

When discussing the value of thermal comfort, the lowest ***PMV*** value is found in GUSs Scenario around 3.12 due to the role of open and green spaces. However, after the insertion of the compact **buildings of** Al-Alamia school **and its three enclosed courtyards, the *PMV*** value is recorder higher around 4.92 in the shadowy places of the buildings and courtyards.

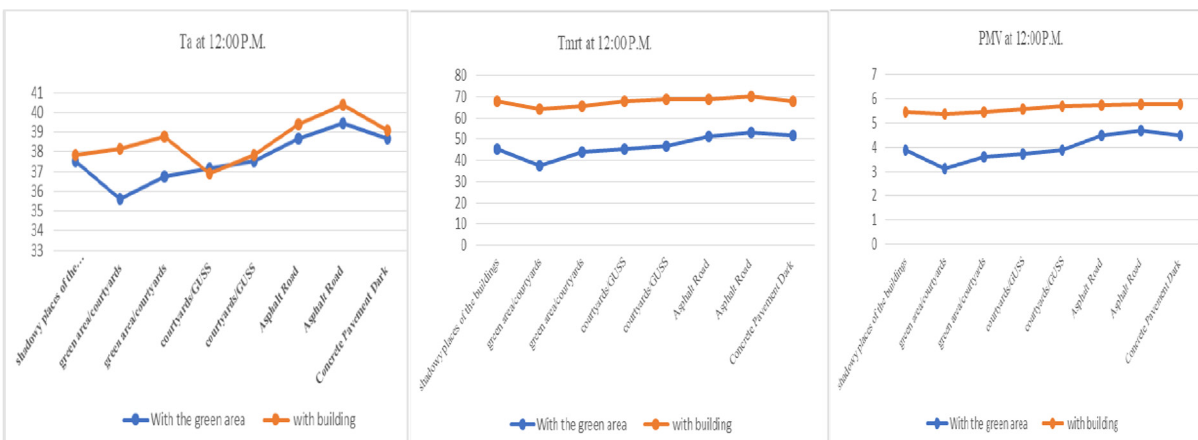


Fig. 4 Shows the difference in (*Ta, Tmrt, PMV*) between the GUSs & the building Scenarios for Model (A), (The researchers).

value in the Second scenario is much higher around (5.69 to 6.05) on sidewalks.

As for (*Model –C*), the formation of the buildings that are surrounded by open spaces from all sides, as well as the ratio of the height of the building to the surrounding open spaces is low. This affected the aggravation of the (*SUHI & CLUHI*). Accordingly, this type of building formation failed in its environmental performance. Previous studies proved that *UHI* increases with the increase in the area of urban form, the spacing of buildings and their proportions. From the study of the three selected models demonstrated in the two scenarios of (Ziyouna) district, (*Ta*) analysis revealed that *CLUHI* is directly proportional to the area of *GUSs* occupied in buildings. As a result, the greater the area of *GUSs* used for the building, the higher of *CLUHI*.

Several studies confirmed the importance of traditional enclosed four-sided courtyards in thermal attenuation. However, through the analysis of the three models, the results showed that the best heat attenuation for *CLUHI* is in three-sided U shape courtyards (*Model -B*), when compared to enclosed four-sided courtyards in (*Model -A*) and Fig. 6.

According to the comparison between the two scenarios, *Tmrt* analysis in the three models proved that SUHI was not affected by the increase in the area of *GUSs*. However, *Tmrt* is more affected by the building's formation, the amount of shadows formed, the materials used in construction and flooring. The lowest value of *SUHI* was recorded in (*Model –B*). The reason is due to the building formation, which includes shaded courtyards open to the vegetated squares, the ratio of the building height to its surface area, green playgrounds, the smallness of the building ground coverage relative to the green spaces, as most of the green areas were preserved on the site. Even though several studies confirmed the efficiency of traditional enclosed courtyards to maintain environmental sustainability, nevertheless, this research study proved that the three-sided U shape courtyard in Model (B) is more efficient with better SUHI results and thermal comfort quality than the traditional four-sided courtyard in Model (A).

Table 5.1 Shows ENVI-met simulation of (CLUHI (data for Model –B, (Al- Maearif School), (The researchers).

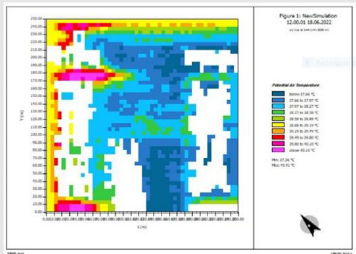
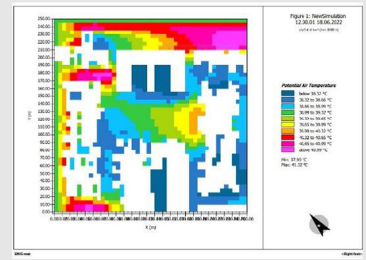
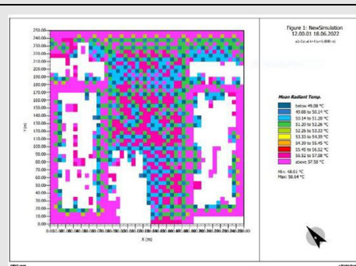
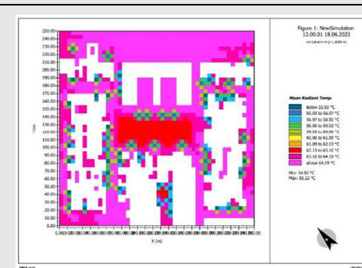
GUSs Scenario	Building Scenario
Potential Air Temperature (*Ta*) At 12:00PM) CLUHI (	*Potential Air Temperature* (*Ta*) at 12:00 PM) CLUHI (
MIN 37.36 °C MAX 40.4 °C D. B. MAX and MIN 3.04 °C	MIN 37.99 °C MAX 41.32 °C D. B. MAX and MIN 3 0.33 °C
	
• Through simulation, the lowest ***Ta*** was recorded in the green areas and some of Asphalt Road and Concrete Pavement Dark (sidewalks), around 37.36 °C to 39.49 °C. Through simulation, the highest ***Ta*** was recorded on some of the Asphalt Road and Concrete Pavement Dark (sidewalks), around 39.49 °C to 40.4 °C.	• Through simulation, the lowest ***Ta*** was recorded in the shadowy places of the buildings, three-sided U shape courtyards, and green areas, around 37.99 °C to 40.32 °C. Through simulation, the highest ***Ta*** was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 40.32 °C to 41.32 °C.

Table 5.2 Shows ENVI-met simulation of (SUHI (data for Model –B, (Al- Maearif School), (The researchers).

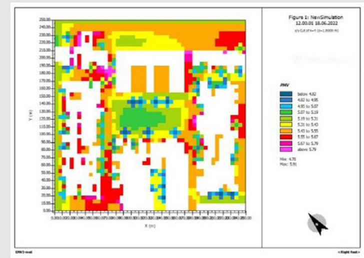
Mean Radiant Temperature (*Tmrt*) at 12:00 PM (SUHI(	*Mean Radiant Temperature* (*Tmrt*) at 12:00 PM (SUHI(
MIN 48.01 °C MAX 58.64 °C D. B. MAX and MIN 10.03 °C	MIN 54.9 °C MAX 65.22 °C D. B. MAX and MIN 10.32 °C
	
• Through simulation, the lowest ***Tmrt*** was recorded in the shadowy places of buildings and courtyards, around 48.01 °C to 55.45 °C. Through simulation, the highest ***Tmrt*** was recorded on Asphalt Road, Concrete Pavement Dark (sidewalks), and some of the green areas. 55.45 °C to 58.64 °C.	• Through simulation, the lowest ***Tmrt*** was recorded in the shadowy places of the buildings and three-sided U shape courtyards, around 54.9 °C to 62.13 °C. Through simulation, the highest ***Tmrt*** was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 62.13 °C to 65.22 °C.
Regarding the results of (SUHI), the lowest (***Tmrt)*** is recorded around 48.01 °C in the open and green spaces of the fist (GUSs) Scenario. However, when the results are compared with those of the Second (Building) scenario, it is clear that the lowest (***Tmrt***) is highly increased to around 54.9 °C **in the shadowy places of the three-sided U shape courtyard building of Al- Maearif School**.	

The analysis of (*Ta, Tmrt*) during the daytime shows that there are several factors combined responsible for increasing the aggravation of the effect of (*SUHI & CLUHI*). This issue is a result of the transformation of (*GUSs*) into buildings with different uses. These factors are summarized in the area of (*GUSs*), Building shape and height, and floor coverage ratio, as demonstrated in Fig 7,Fig 8,Fig 9.

According to what was presented, GUSs scenario was more efficient with better thermal comfort value when there was a vacant area of open and green spaces before the transformation into buildings, streets, and infrastructure. Also, the building with a U shape courtyard and open access to green areas achieves an ideal environmental behavior and it is better than an enclosed courtyard at the level of the study area. In this way, more models can be tested in other areas to generalize the results at the level of the city of Baghdad.

Hence, this change has a negative impact on the efficiency and quality of the urban environment. Even with similar micro-climate conditions, it is in evitable that the injection of these buildings illustrates a physical barrier in a way that affected the accessibility benefits in addition to the aesthetic appreciation that used to be provided by these open green spaces. Hence, it is important to conserve the role of open green spaces. This is because after change as demonstrated in the second scenario for all the three models, people who live in the residential areas as part of surrounding environment are now unable to have access or communicate or enjoy the view of that area after the loss of the urban green and open spaces.

Table 5.3 Shows ENVI-met simulation of (PM (data for Model –B, (Al- Maearif School), (The researchers).

Thermal Comfort (PMV) at 12:00 PM			*Thermal Comfort (PMV)* at 12:00 PM		
MIN	4.09		MIN	4.7	
MAX	5.26		MAX	5.91	
D. B. MAX and MIN	1.17		D. B. MAX and MIN	1.21	
• Through simulation, the lowest *PMV* was recorded in the shadowy places of buildings, some parts of the green areas, and the asphalt. 4.09 to 4.91. Through simulation, the highest *PMV* was recorded on Asphalt Road, Concrete Pavement Dark (sidewalks), and some of the green areas around 4.91 to 5.26.			• Through simulation, the lowest *PMV* was recorded in the shadowy places of the buildings, and three-sided U shape courtyards, and green areas, around 4.7 to 5.55. Through simulation, the highest *PMV* was recorded on Asphalt Road and Concrete Pavement Dark (sidewalks), around 5.55 to 5.91.		

When discussing the value of thermal comfort, the lowest range ***PMV*** value is found between (4.09 to 4.91) in GUSs Scenario due to the role of open and green spaces. However, after the insertion of **the shadowy places of the three-sided U shape courtyard building of Al- Maearif School, the *PMV*** value is recorder higher values around (4.7 to 5.55).

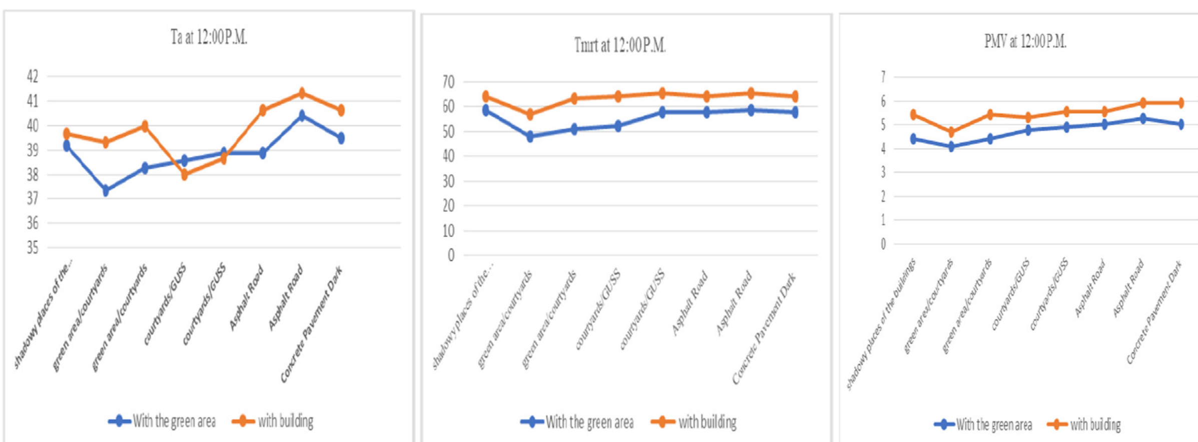


Fig. 5 Shows the difference in (*Ta, Tmrt, PMV*) between the GUSs & the building Scenarios for Model (B), (The researchers).

5. Conclusion

This research focuses on the importance of restoring the role of green spaces. This is because the loss of these areas and their conversion into buildings, and streets have a negative effect on the micro- climate of those areas, the environment, urban engineering and the city as a whole. It also takes into consideration the significant impact of building s shape and formation, particularly, the role of courtyards on the exacerbation of the (UHI) in hot, arid climate. This stems from the loss of open green spaces in favour of various types of buildings schools and shopping centers, in addition to streets, and infrastructure in Ziyouna district in Baghdad. ENVI-met computer simulation software and tools are used to measure and illustrate a number of factors in terms CLUHI and SUHI and PMV for three models (A, B, and C). A comparison between the results of the two scenarios (the GUSs scenario and the Building scenario), including a demonstration of 3D perspectives is illustrated to identify the importance of open green spaces in terms of CLUHI, SUHI, and quality of thermal comfort.

In general, the important role of implementing urban green spaces and infrastructure is identified to recover part of the original character of the city's site which was natural. This is because the same role has been lost by the continuous urban sprawl in favor of buildings, streets, and infrastructure. The following key conclusions are as follows:

1. Concerning the importance of open green spaces:

- Even though the open green spaces that used to be present in the first (GUSs) scenario are now mostly lost when compared to the Second (Buildings) Scenario, it is evident that the implementation of open green spaces should be integrated with proper design suggestions in terms of building's shape, height, materials' selection and colours. This is in order to comprehend the requirements of sustainable environmental design and thermal comfort.

Table 6.1 Shows ENVI-met simulation of (CLUHI (data for Model –C, (Dream mall), (The researchers).

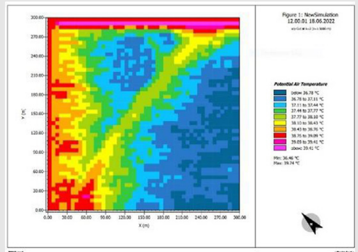
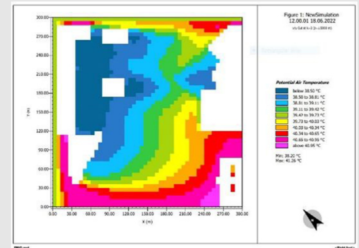
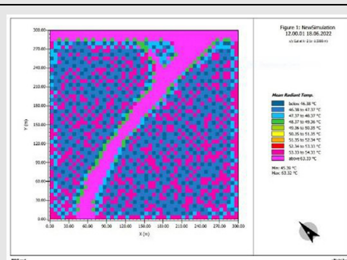
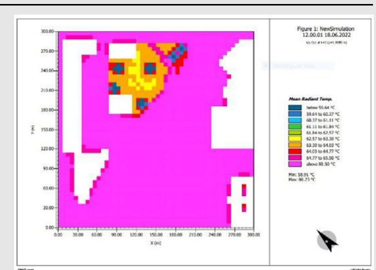
GUSs Scenario	Building Scenario
Potential Air Temperature (Ta) at 12:00 PM) CLUHI(	*Potential Air Temperature (Ta)* at 12:00 PM(CLUHI(
MIN 36.46 °C MAX 39.74 °C D. B. MAX and MIN 3.28 °C 	MIN 38.2 °C MAX 41.26 °C D. B. MAX and MIN 3.06 °C 
• Through simulation, the lowest *Ta* was recorded in the green area and some parts of the dark shades of Asphalt and Concrete Pavement (sidewalks, around 36.49 °C to 38.76 °C. Through simulation, the highest *Ta* was recorded on some parts of dark shades of Asphalt and Concrete Pavement (sidewalks), and the green areas, around 38.76 °C to 39.74 °C.	• Through simulation, the lowest *Ta* was recorded in the shadowy places of the buildings, courtyards, and green areas, around 38.2 °C to 40.34 °C. Through simulation, the highest *Ta* s was recorded on dark shades of Asphalt and Concrete Pavement (sidewalks), around 40.34 °C to 41.26 °C.

Table 6.2 Shows ENVI-met simulation of (SUHI (data for Model –C, (Dream mall), (The researchers).

Mean Radiant Temperature (Tmrt) at 12:00 PM (SUHI(	*Mean Radiant Temperature (Tmrt)* at 12:00 PM (SUHI(
MIN 45.39 °C MAX 63.32 °C D. B. MAX and MIN 17.93 °C 	MIN 58.91 °C MAX 80.23 °C D. B. MAX and MIN 21.32 °C 
• Through simulation, the lowest *Tmrt* was recorded in the shadowy places of the green areas, around 45.39 °C to 52.34 °C. Through simulation, the highest *Tmrt* was recorded on dark shades of Asphalt and Concrete Pavement (sidewalks), and some of the green areas, around 52.34 °C to 63.32 °C.	• Through simulation, the lowest *Tmrt* was recorded in the shadowy places of the buildings and courtyards, around 58.91 °C to 64.03 °C. Through simulation, the highest *Tmrt* was recorded on dark shades of Asphalt and Concrete Pavement (sidewalks), around 64.03 °C to 80.23 °C.

Regarding the results of (SUHI), the lowest (***Tmrt)*** is recorded around (45.39 °C) in the open and green paces of the fist (GUSs) Scenario. However, when the results are compared with those of the Second (Building) scenario, it is clear that the lowest (***Tmrt***) is highly increased to around ***(***58.91 °C) **in the shadowy places of** the Dream Mall Building.

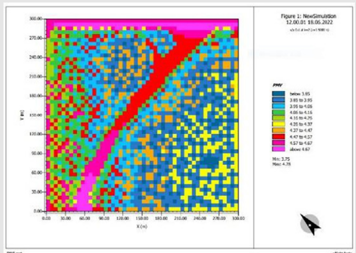
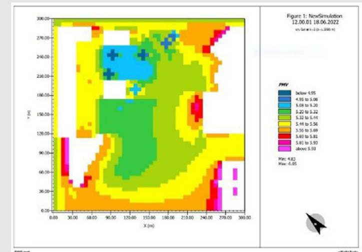
- There is a need to increase the resilience and accessibility of residential neighborhoods by implementing open green spaces to positively add to the growth of urban greenery, and the strengthening and protection of urban biodiversity.
- A proper distribution of Green spaces with lighter shades of colours for sidewalks, asphalt and concrete pavement to match the demands of Ziyouna districts and any other areas in Baghdad city provides the potentials to sustain the city's future from the devastating impact of (UHI) phenomenon.
- The efficiency of GUSs scenario is due to the open green area in the base design and their significant impact on preserving the local micro climate and mitigating UHI formed within the city.
- CLUHI & SUHI were exacerbated because of the conversion of open green spaces in the GUSs scenario into buildings of various uses such as schools and shoping centres.

2. Concerning the significant role of courtyard and building's shape:

- Three-sided U shape courtyards are more efficient in providing cooler temperature and better thermal comfort quality when compared to traditional four-sided enclosed courtyards.
- Three-sided U shape courtyard buildings provide better environmental efficiency in reducing SUHI when compared to other building with four-sided enclosed courtyards.

3. Concerning the role of technological tools:

Table 6.3 Shows ENVI-met simulation of (PM (data for Model –C, (Dream mall), (The researchers).

Thermal Comfort (PMV) at 12:00 PM	*Thermal Comfort (PMV)* at 12:00 PM
MIN 3.75 MAX 4.78 D. B. MAX and MIN 1.03 	MIN 4.83 MAX 6.05 D. B. MAX and MIN 1.22 
• Through simulation, the lowest ***PMV*** was recorded in the shadowy places on some parts of the green areas and the asphalt, around 3.75 to 4.47. Through simulation, the highest ***PMV*** was recorded on dark shades of Asphalt and Concrete Pavement (sidewalks), and some green areas, around 4.47 to 4.78.	• Through simulation, the lowest ***PMV*** was recorded in the shadowy places of the buildings, courtyards, and green areas, around 4.83 to 5.69. Through simulation, the highest ***PMV*** was recorded on dark shades of Asphalt and Concrete Pavement (sidewalks), around 5.69 to 6.05.
When discussing the value of thermal comfort, the lowest range ***PMV*** value is found between (3.75 to 4.47) in GUSs Scenario. However, after the insertion of **the shadowy places of** the Dream Mall Building**, the *PMV*** value is recorder higher values around (4.83 to 5.69).	

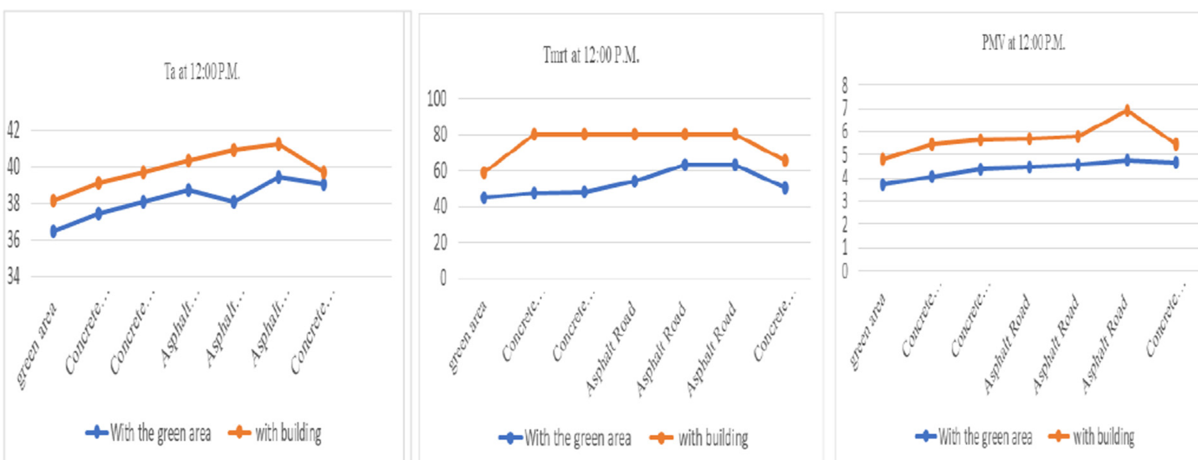


Fig. 6 Shows the difference in (*Ta, Tmrt, PMV*(The application of the PMV equation to external conditions in summer heat stress situations can certainly produce PV values in excess of 4 (8 and higher). Whereas the result is numerically correct. (https://www.model.envi-met.com/).)) between the GUSs & the building Scenarios for Model (C), (The researchers).

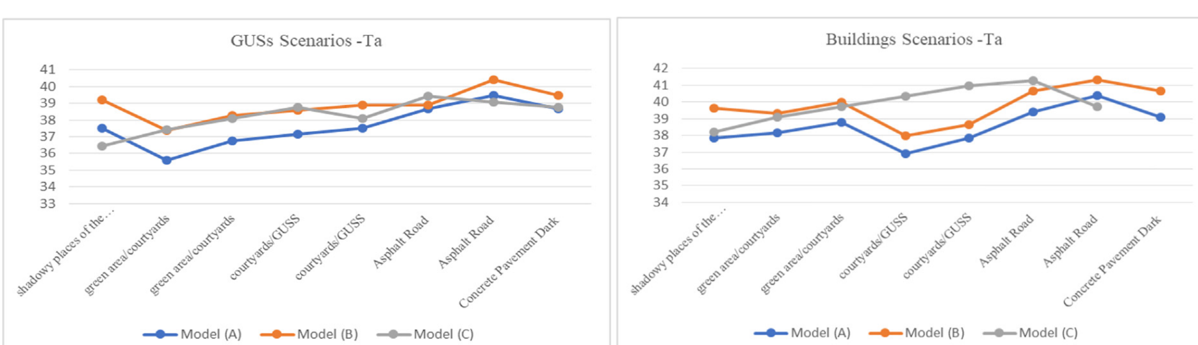


Fig. 7 Shows the difference in (*Ta*) between the GUSs & the building Scenarios for Model (A) (B) (C), (The researchers).

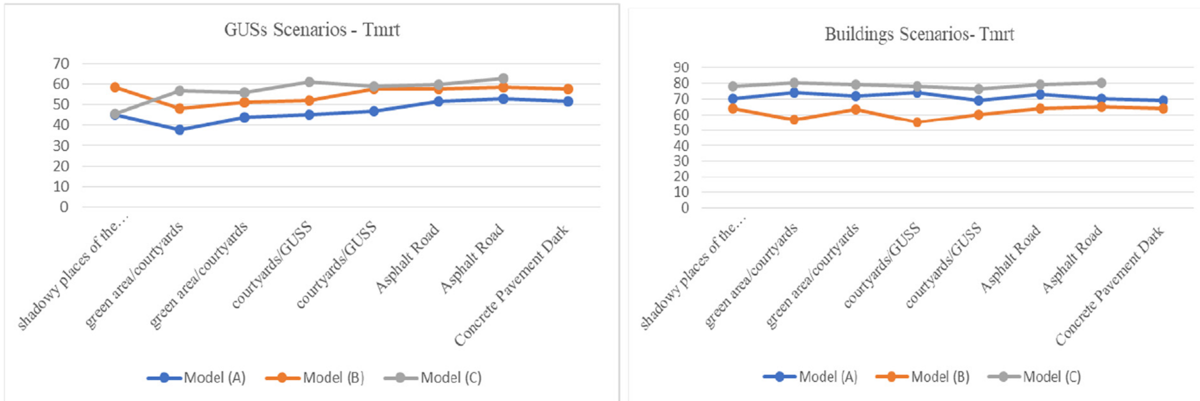


Fig. 8 Shows the difference in (*Tmrt*) between the GUSs & the building Scenarios for Model (A) (B) (C), (The researchers).

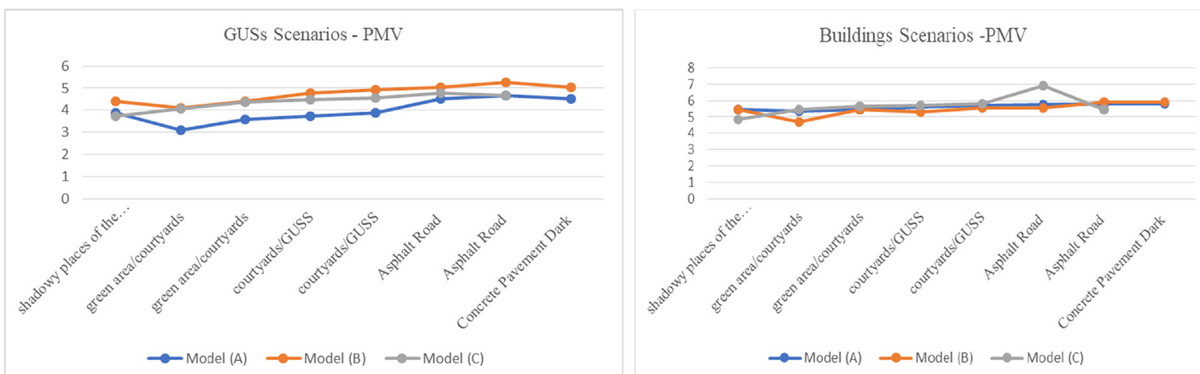


Fig. 9 Shows the difference in (*PMV*) between the GUSs & the building Scenarios for Model (A) (B) (C), (The researchers).

- (ENVI-met) simulation analysis with its tools shows the (UHI) phenomenon is exacerbated by the replacement of GUSs in favor of different types of buildings, for instance, schools and shopping centers.
- The simulation process also identifies that (CLUHI & SUHI) analysis on the scale of (MUHI) during the daytime is directly proportional to the area of the spaces, and the impact of (UHI) in large areas is increased in comparison to small areas.

6. Limitations:

There are a number of limitations based on the reflection of the researchers‘ knowledge involved in this research study. These limitations are as follows:

1. Green Surfaces are more affected by the building’s orientation. Thus, more research is needed to consider the relationship between building’s orientation and the daily solar path.
2. More systematic studies are needed to explore contemporary urban functional zones that match the Iraqi cities context with a specific up- to-date information that tackles traffic issues associated with neighbourhood‘s scale and requirements. This is in order to maintain the balance between the needs for more green areas and infrastructure implementation and buildings‘ shape design in relation to the surrounding microclimate conditions on a larger scale.

7. Research Recommendations:

Whilst this study has identified the role of green spaces and building‘s shape in mitigating the effect of UHI in hot arid climate. The following areas of study would benefit from further research:

1. Even though urban green spaces presents a good passive cooling strategy in hot arid climate areas, further research concerning the vegetation, placement of trees and their sizes is required to not obstruct the active travel modes such as the movement of cyclists and pedestrians.
2. Further research is needed on the adoption of roofs and green walls in the buildings to develop a better design vision that increases the important role of natural materials (soil, plants, and trees) and decreases the paving surfaces (concrete and asphalt).

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Conflicts of Interest Statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Declaration of Competing Interest

The authors declare that they have no known own competing financial interests of any kind[1, 2, 3, 4, 5 and 6] or personal relationships that could have appeared to influence the work reported in this paper.

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