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MODELLING THE INTERACTIONS BETWEEN URBANHEAT ISLAND AND URBAN GEOMETRY

Abstract

Cities are a complex, adaptive, and self-organizing systems, that are faced with several challenges due to rapid urbanization such as socio-demographic problems, air pollution, threat of climate change, and urban heat island effect (Kim and Han, 2012). Urbanization, is one of the greatest challenges of this century, that is strongly affecting the atmosphere and urban context of cities. In the light of these challenges there is a crucial need to study the effect of urban heat island phenomenon, which is characterized by an increased air temperature, from the periphery to the center of the cities, which it is partly caused by the urban geometry and alter the energy balance of these cities. Urban heat island is generally considered a problem because it induces many undesirable effects, such as discomfort in people life, health problems, the need for more energy consumption and more pollution. Therefore, investigating the relation between urban Geometry and Urban heat island is essential according to Bittencourt and Candido (2010) they stated the importance of analyzing urban aerodynamics phenomenon to determine environmental air quality, wind pressure on urban geometry, as understanding the wind dispersion through the city help in improving quality of urban design thus quality of life. This research aims in investigating UHI characteristics and suggests some feasible mitigation strategies in order to reduce the air temperature and save energy using ENVI- met. Aiming to adapt this model to real urban conditions in New Borg El Arab City, Alexandria, Egypt, as it is affected by severe heatwaves in summer, providing visual and numeric information that can be used by urban planners and architects to support their decisions.

Keywords

Urban Heat Island, Urban Geometry, Improving Quality of Life, ENVI- met

MODELLING THE INTERACTIONS BETWEEN URBAN HEAT ISLAND AND URBAN GEOMETRY

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ABSTRACT: *Cities are a complex, adaptive, and self-organizing systems, that are faced with several challenges due to rapid urbanization such as socio-demographic problems, air pollution, threat of climate change, and urban heat island effect (Kim and Han, 2012). Urbanization, is one of the greatest challenges of this century, that is strongly affecting the atmosphere and urban context of cities. In the light of these challenges there is a crucial need to study the effect of urban heat island phenomenon, which is characterized by an increased air temperature, from the periphery to the center of the cities, which it is partly caused by the urban geometry and alter the energy balance of these cities. Urban heat island is generally considered a problem because it induces many undesirable effects, such as discomfort in people life, health problems, the need for more energy consumption and more pollution. Therefore, investigating the relation between urban Geometry and Urban heat island is essential according to Bittencourt and Candido (2010) they stated the importance of analyzing urban aerodynamics phenomenon to determine environmental air quality, wind pressure on urban geometry, as understanding the wind dispersion through the city help in improving quality of urban design thus quality of life. This research aims in investigating UHI characteristics and suggests some feasible mitigation strategies in order to reduce the air temperature and save energy using ENVI- met. Aiming to adapt this model to real urban conditions in New Borg El Arab City, Alexandria, Egypt, as it is affected by severe heatwaves in summer, providing visual and numeric information that can be used by urban planners and architects to support their decisions.*

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1. INTRODUCTION

Urban Heat Island (UHI) has become one of the world's leading urban environmental issues. Urbanization has increased concerns about the UHI, particularly in terms of human health and a healthy environment, as it has negative influences on the environment, including air, temperature and alteration of landscape. The fraction of people living in urban areas is expected to grow up to almost 70% by 2050, then, the energy consumption in cities is likely to follow that trend. During the next decades, urban planners and stakeholders will have to face major issues in term of energy, traffic and resource flows. In addition to that, building patterns, structures and materials are related to the increase in urban temperature, energy consumption, pollution and the production of waste (Santamouris et. al., 2001). UHI is a contributing factor to enormous health problems which will be aggravated by the explosive growth of population and increasing impact of climate change. Referring to Oke, 2006 the size and structure of the UHI vary in time and space due to meteorological conditions and urban characteristic, while the presence of vegetation and winds are factors that contribute to easing its development.

Bittencourt and Candido (2010) investigated the relation between urban Geometry and UHI, mentioning how it is essential to analyze the urban aerodynamics phenomenon to determine environmental air quality, wind pressure on urban geometry, as understanding the wind dispersion through the city help in improving quality of urban design thus quality of life. In this context, the urban geometry is treated as one of the factors that significantly influence the formation of heat islands, in many studies, this geometry is measured by the ratio of H/W (height/width), which is the height of buildings divided by the width of the path relative to a point. Thus, the higher the dimensions are of the first compared to the second, the higher the values of H/W will be. The influence of this relationship on the urban microclimate was studied by Oke (1981, 1988). Oke (1981) verified via experimental simulations with reduced models that the cooling is lowest when the H/W ratio increases. The study of Oke (1981) demonstrated that urban geometry effectively contributes to the formation of nocturnal heat islands. In addition to that, there are various causes for the formation of the UHI in the cities, from the important factors causing the UHI are the high fraction of built-up areas (Buildings and

pavements) as well as the lack of vegetation, different types and properties of materials, the types of coverage of buildings, the low albedo and the high heat capacity of built-up surfaces such as concrete or asphalt, which absorb high amount of the short-wave radiation during the day, this energy is then slowly released during the night as long-wave radiation and leads to higher air temperature in the urban areas (Nakata, Souza, 2013) .

One of major problems in urban design and planning, is that often the urban planning regulations used in hot dry countries, most of which are in the developing world, are imported from temperate climates and are thus poorly adapted to the local climate. Additionally, they may be very inflexible and thereby restrict the possibility of climate-conscious urban design. Consequently, urban areas often become unnecessarily uncomfortable (Johansson 2006). Therefore, research is concerned with studying UHI characteristics, factors responsible for its formation and scales of UHI and finally suggesting some feasible mitigation strategies in order to reduce the air temperature and save energy using ENVI- met. Aiming to adapt this model to real urban conditions in New Borg El Arab City, Alexandria, Egypt, as it is affected by severe heatwaves in summer, providing visual and numeric information that can be used by urban planners and architects to support their decisions.

2. FACTORS CAUSING URBAN HEAT ISLAND FORMATION:

A combination of factors leads to the development of the UHI, the most important type of UHIs is the one that extends from the ground to the top of roofs and canopy levels (canopy layer heat island) which cause different thermal projections throughout the city. From main Factors are listed as follows; Urban design geometry, roads width and directions, existence of canyons, where urban canyons are created by narrow streets and tall buildings decreases wind speed and increase impervious surfaces that trap heat. Building materials thermal properties, are some of the factors that contribute to UHI phenomenon. Building materials are effective factor in UHI formation, as the reflectance is low, so they reflect less and absorb more energy, which lead to temperature increase at surface level. Common building materials such as tar, asphalt, brick and concrete store solar energy during the day and release it at night, so UHI intensity is reported to be stronger at night time. Anthropogenic factors such as waste heat from vehicles. Existing land use/cover, altitudes and altered land surface cover like porous vegetation is replaced with non-porous materials, thus restricting evaporative cooling (Cynthia &et. al., 2005). Urban heat island studies are generally conducted in two ways; Urban Boundary Layer or Urban Canopy Layer; the UBL is governed by processes relevant to the mesoscale with the higher altitude thermal inversion dominant during the daytime, while the latter by those at the microscale with the lower altitude inversion dominant during night-time at the urban canopy layer, below the roof tops in the spaces between buildings as shown in figure (1).

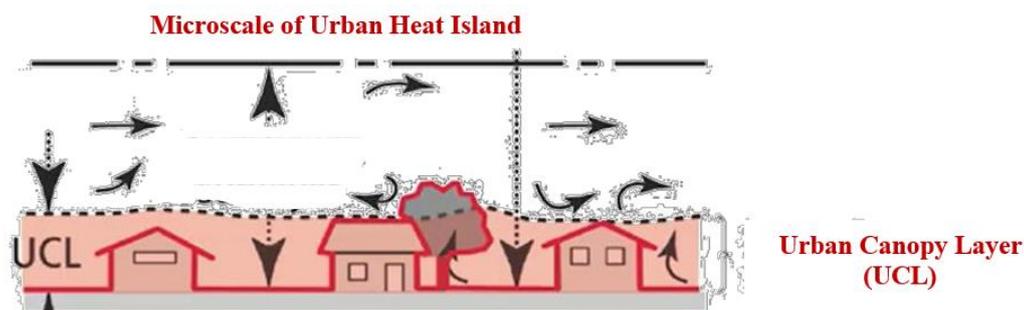


Fig. 1 illustrating Microscale of UHI, Urban canopy Layer
Reference: Author

2.1 Urban Geometry and Thermal properties of urban Surfaces.

Urban geometry and thermal properties of urban surfaces have been found to be the two main parameters influencing urban climate (Johannsons, 2006). The ratio between the height of buildings (H) and the distance between them (W) influences the amount of both incoming and outgoing radiation and affects wind speeds. The nocturnal heat island has been shown to increase with the $H=W$ ratio since the net outgoing longwave radiation decreases due to reduced sky view factor (SVF). High thermal capacity of urban surface materials also contributes to the nocturnal heat island as a large part of the incoming radiation during the day is stored in such materials and not released until the night. Air pollution affects both incoming and outgoing radiation but the net effect on air temperatures has usually proved to be small

((Manioğlu & Yılmaz, 2008). Since urban form and the properties of surface materials have a strong influence on the microclimate around buildings, urban design is a promising area for improving the thermal comfort of outdoor environments. However, urban climate and outdoor thermal comfort are generally given little importance in the planning and design processes (Monam, Ruckert, 2013 & Axarli, Teli, 2008). In a hot and dry climate, where the diurnal temperature range is large with cool nights, the high daytime temperature during summer is the main problem rather than the nocturnal heat island (even though the latter may reduce the efficiency of night ventilation of buildings in summer). Compact urban forms in hot dry regions typically found in old city centers are known to be well adapted to the climate (Toudert, Mayer, 2006, 2007). There are, however, few studies from hot dry climates on urban microclimate, where wind and humidity are two main variables, which control the intensity of UHI. Also, the formation of UHI phenomenon depends upon the size and density of the population. As the Highly populated areas mandate cities to develop either vertically or horizontally, resulting in more released anthropogenic heat, a higher blockage effect against urban ventilation, a higher absorption of solar radiation due to the implementation of artificial materials, and eventually a reduced long-wave emission to sky due to the blockage effect of buildings (Mirzaei, 2015).

Buildings and the density of built-up area modify the wind, the radiative balance, and the temperature conditions near the ground level as built up area have lower albedo and higher heat capacity comparing to natural surfaces. Therefore, the fraction of built up area is a relevant factor in formation of UHI (Emmanuel, Rosenlund, Johansson, 2007). Urban geometry can impede the release of long-wave radiation into the atmosphere, when buildings absorb incoming shortwave radiation, they can re-radiate that energy as longwave energy, or heat. However, at night, due to the dense infrastructure in some developed areas that have low sky view factors, urban areas cannot easily release long-wave radiation to the cooler, open sky, and this trapped heat contributes to the urban heat island. The different urban form has the significant effect on the urban microclimate and outdoor thermal effect, as compared to urban geometry massive building area is not the main reason to affect the urban micro-climate. The average building height offered enough urban shading which is an important factor that impacts the value of temperature. Normally, courtyard building model can provide better outdoor thermal comfort, but a simulation showed that the distance between the buildings plays more important role than the building type (Li, Wang, Wong, 2016). The combination of other site-specific factors such as green space amount, anthropogenic heat, and distance to water bodies is recommended to explain the differences in intra-urban UHI intensities than meteorological conditions (Ningrum W., 2017).

Bosselmann and Arens (2005) examine the effects of buildings on wind conditions at street level, and of sun and wind conditions on pedestrian comfort. Their study clearly shows a strong relationship between urban form and climate, dimensions of streets and the position of buildings strongly affect city climate. (Bosselmann and Arens 2005) categorized the following physical parameters obtained from the previous studies are grouped in three categories as follows;

- Urban configuration: location, urban pattern, urban density, street width and orientation, nature of ground surface.
- Landscape elements: pavement materials and colors, planting and green spaces, pools, fountains, fixed or operable shadings and other design elements.
- Building configuration: distance between the buildings, average building height, H/W ratio, surface materials, façade characteristics and other design settings as well as the installations on the buildings.

Therefore, for a successful urban design these physical settings have to be studied to decrease effect of Urban heat island in order to reduce energy consumption, using natural resources and providing comfortable, healthier and sustainable living spaces are the aims of a climatically responsive sustainable design. In order to be able to Study mitigation strategies of UHI at neighborhood scale, then it is important to differentiate scales of UHI to focus study on neighborhood scale.

3. SCALES OF URBAN HEAT ISLAND

The UHI models are diverse in terms of scale with respect to the aim of a study, changing from building-scale known as Building Energy models (BEM), to Micro Scale Models known as Microclimate models (MCM) for investigation of the impact of the UHI on thermal comfort of a pedestrian to urban scale for exploring the effect of synoptic wind on urban ventilation, finally the City scale model. The building energy

models (BEM), are mainly limited to an isolated building envelope where the influence of neighboring buildings on its energy performance is neglected. This implies that BEMs are developed based on an energy balance applied to the building's control volume. Outdoor parameters such as temperature, solar radiation, long-wave radiation, and moisture are external inputs into such models. Obviously, these models are simplistic in representing the mutual impact of a building with its surrounding area and thus their integration with larger scale models is inevitable when the effect of UHI on building energy performance is investigated. While in the Micro scale model the interaction of a building with its surrounding environment in the surface layer is the basis of the development of microclimate models (MCM), In principle, solar radiation and surface convection from the buildings' surfaces can be included in such models. In many MCMs, the airflow patterns around and within buildings are resolved using computational fluid dynamics (CFD) technique. Another type of MCM, is the urban canopy model (UCM), has been broadly utilized to investigate the energy budget of an urban canopy layer (Masson, 2000).

Where, the impact of different parameters such as building orientation, street canyon aspect ratio, surface materials, vegetation and tree planting on the calculation of surface convection, pedestrian comfort, and urban ventilation can be investigated using CFD and UCM. As the shape of a building, the ratio of a street's height to its width, orientation, pedestrian sidewalk, building block configuration, street design, urban corridors and green spaces are amongst parameters influencing the heat removal from the surfaces of building. Therefore, the airflow detail plays a key role in understanding how heat is exchanged between a street canyon and its environment. Therefore, a thorough understanding of the factors contributing to the UHI effect is important to devise appropriate policy mechanism and planning for cities to mitigate the UHI effect, and thereby, to avoid severe undesirable consequences for both human being and the environment (Deilami, K., Kamruzzaman, M., Liu, Y., 2018). Finally, the City-scale observation and modeling of the UHI is one of the applications of the remote sensing. The thermal images taken by satellites (e.g. Terra and Aqua) and airborne measurement devices are processed to correlate surface temperatures and land-use/ land-cover of a city.

According to what is mentioned above, the scale of research is the Micro Scale Models known as Microclimate models (MCM) using the Urban Canopy Model (UCM), it aims in investigating UHI characteristics and suggests some feasible mitigation strategies in order to reduce the air temperature and save energy using ENVI-met as a simulation tool. Aiming to adapt this model to real urban conditions in New Borg El Arab City (hot arid city) according to Middleton and Thomas (1997), Alexandria, Egypt. According to Ali-Toudert and Mayer (2006) identified aspect ratio and orientation of an urban street canyon as important factors affecting the outdoor thermal comfort in hot and dry climate by means of a numerical study with ENVI-met. They showed that for many configurations, additional shading and cooling effects by vegetation and wind are needed to keep the outdoor comfort within acceptable ranges, and that different configurations might be optimal regarding peak heat stress and diurnal comfort evaluations respectively. As In hot arid climate, residential neighborhoods are responsible for the high request of energy to provide cooling needs for the occupants' comfort. The main problem is the non-responsive contemporary urban design to human thermal comfort and energy efficiency. Due to recent changes in the urban density and street networks of contemporary urban context, controlling micro-climate of neighborhoods imposes difficult challenges to achieve human thermal comfort. In Egypt, the overwhelming rate of population growth did not allow time for full environmental studies for both the built and the natural environments where buildings and open spaces must be adequately climatic responsive (El Araby, M. 2002). Thus, the urban design must be strongly dependent on climate interactions which can improve or have moderate impacts on the formation of Urban Heat Island (UHI). This leads to a better understanding and analysis of all the forces affecting the Urban Heat Island formation in urban environment, can be used as a tool to support urban designers and planners in decision making. Thus, designs will ensure reduced UHI formation, reduced energy consumption and improve human thermal comfort and improving quality of life.

4. SIMULATION MODEL

ENVI-met was selected as a simulation tool due to its ability to simulate the microclimate of a "complex urban structure" based on "well-founded physical basis" Ali-Toudert and Mayer (2006). Considering the environmental parameters, which is mentioned by majority of the scholars necessarily investigate environmental parameters in their studies concentrating on the built-up area. (Giridharan, et al. 2004, 2005; Johansson 2006; Bosselmann and Arens 2005; Nikolopoulou, et al. 2001; Nikolopoulou and Lykoudis 2006; Walton, et al. 2007; Gomez, et al. 2004; Johansson and Emmanuel 2006; Thorsson, et al. 2007; Manioğlu and Yılmaz 2008; Yılmaz 2007). The following environmental parameters are the most common factors used in those studies;

- Ta - Air temperature (°C-Celsius, °F-Fahrenheit, °K-Kelvin)
- RH - Relative humidity (%)
- W - Wind speed (m/s, km/h, knots and mph)
- SRD - Solar radiation (MJ/m²)

ENVI-met has been used to examine the urban microclimate or impacts of typical UHI mitigation strategies on air temperature and thermal comfort in mostly low-rise residential neighborhoods. Studies have been conducted in humid (sub)tropical cities such as Colombo, Sri Lanka, Dhaka, Bangladesh, Shanghai, China, Hong Kong, and Putrajaya, Malaysia, and hot/dry cities such as Fez, Morocco , Melbourne, Australia , Phoenix, USA , Lecce and Rome, Italy (Roth & Lim , 2017)

Two main parts of the studied areas will be modelled using ENVI-met, the area input files for the current situation (CS) considering the landscape layout, position and heights of buildings, materials of buildings, plants, soils types, and the second part will be the mitigation scenarios that will be discussed in detail.

4.1 STUDY AREA

The chosen site is located in New Borg El-Arab City, this site belongs to Alexandria Province in the North of Egypt and is located in an arid desert area, Borg El Arab is located in the west of Alexandria city. New Borg El-Arab is one of the newest cities of Egypt that was developed and redesigned in the 21st century, it's climate is extremely hot in summers and cold in winters; this area belongs to a hot arid climatic region. The selected neighborhood Engineers' Buildings geographical position is 30_5303000N Latitude and 29_3402400E Longitude.

Fig. 2 indicates the location of the case study site. The selected site has an area of approximately 12 acres with built-up area accounts for nearly 40% of the total area and open space area makes up about 60% of the total area and the building heights are approximately 16 m as shown in figure (3). The hard surfaces dominate the site, while the permeable surfaces are limited, there are some vegetation and green spaces, but they are randomly located and do not serve the need for shading, cooling, or wind modification. Many areas are overheated during summer because of the lack of shading and cooling. Also, traffic from the adjacent streets and the air conditioning systems of the surrounding buildings fill the open space with the extra heating load.



Fig. 2 Illustrating the whole engineering site in New Borg El Arab
Reference: Google earth, 2018

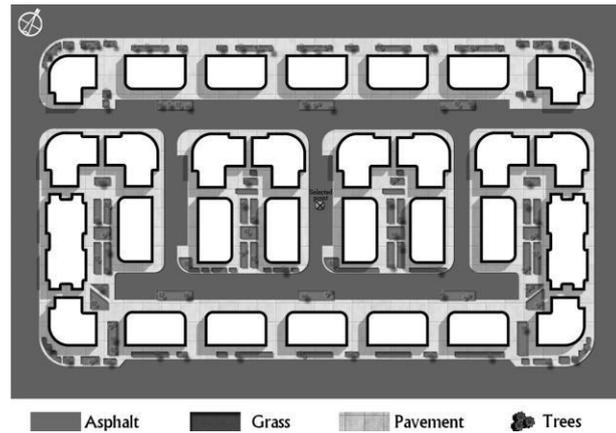


Fig.3 The current situation (CS) materials for the selected site
Reference: Author

5. ADAPTATION AND MITIGATION

Numerical Modelling with ENVI-met, a three-dimensional numerical model, was employed to study the basic pattern of the urban effects on microclimatic factors such as temperature, wind speed, and humidity in the current situation of the new Borg Arab City, as well as under some UHI mitigation strategies. ENVI -met is a simulation tool for studying the surface-plant-air interaction at microscale. The numerical model simulates aerodynamics, thermodynamics, and the radiation balance in complex urban structures. Also, it includes geocoded building dimensions (e.g., width and height), soil (e.g., type and texture), surface (e.g., concrete or asphalt), and vegetation types. It is designed for microscale with a typical horizontal resolution from 0.5 to 10m and a typical time -frame of 24 to 48 hours with a time step of 1 to 10 secs. This resolution allows small-scale interactions between individual buildings, surfaces, and plants to be analyzed. Typical domains are between a single street canyon up to a few hundred meters. ENVI-met has been widely applied in different studies on UHI mitigation, which demonstrates the model's capability. Table 1 shows the input configuration data input for the model, based upon the preliminary analyses of temperature, wind, and relative humidity obtained from "World Weather & Climate Information", a clear hot day (17July 2018) was selected for the simulation. The ENVI-met model has also been employed to examine the effect of greenery and paved areas on the thermal environment. Most investigations have focused on either the effect of vegetation and pavements on the environment or the differences between thermal stress in the current state and those in various scenarios. Some studies have investigated the effectiveness of modifying configurations of landscape designs and buildings by comparing the thermal performances of before and after a design is implemented (Tukiran, Ariffin, Ghani, 2017). Thus, the ENVI-met model will run for the simulation of the current situation (CS) for the "Engineering residential building" in New Borg El Arab, as well as for three UHI mitigation scenarios. Three different UHI mitigation strategies were applied and their cooling effects and feasibility will be discussed as follows.

- (i) Scenario 1: change current low albedo materials to high albedo materials (HAM).
- (ii) Scenario 2: cover the model area with greenery (vegetation and green roofs, VEG).
- (iii) Scenario 3: cover the model area with greenery along with high albedo materials (HYBRID).

Table 1: Input Configuration data applied in the EVI-met simulations.
Reference: <https://weather-andclimate.com>

Environmental parameters	
Wind speed (m/s)	3
Wind direction (deg)	315
Relative humidity (RH%)	62
Temperature (°C)	34

5.1 Current situation analysis:

The selected site is built on 12 acers of total area 50,994 m² , buildings of 40 % of site , material used in buildings in the investigated area is concrete with an albedo of 0.30, percentage of pavement 33.7% with an albedo

0.27 , percentage of roads 19.3 % with an albedo material of asphalt of 0.14, 0.16, and there is a lack of vegetation cover in this site greenery percentage 7.8 % as shown in the figure 4 (a,b).

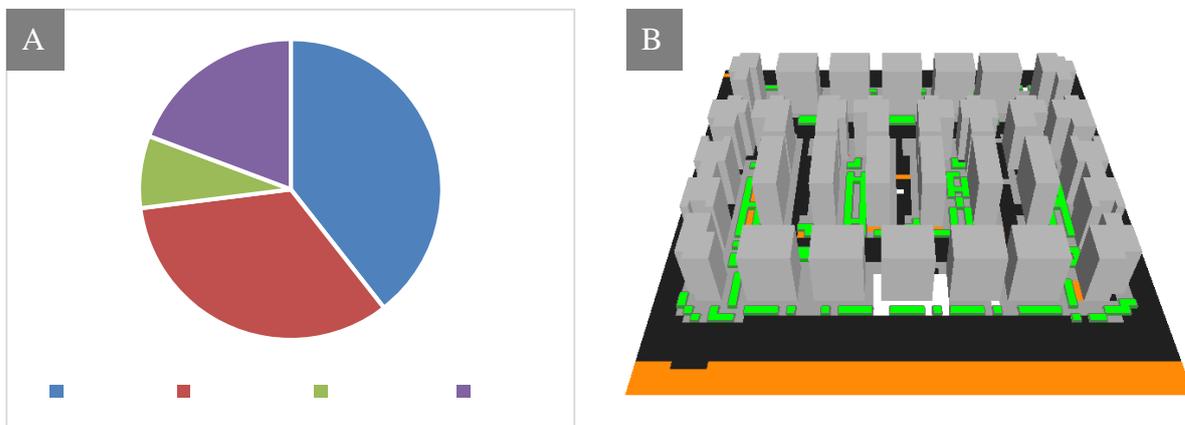


Fig.4 (a, b): (A) The current situation (CS) material percentage and (B) 3 D building heights in the selected site

Reference: Author

In order to study the UHI characteristics, the simulations of 15:00 P.m. (approximate maximum temperature timing) and 03:00 A.m. (approximate minimum temperature timing) local time were selected for the analysis. The model was simulated for 24 h starting at 7 am on July 17th and ending at 7 am on July 18th. Figure (5 a, b) shows the current situation of the investigated area (CS).

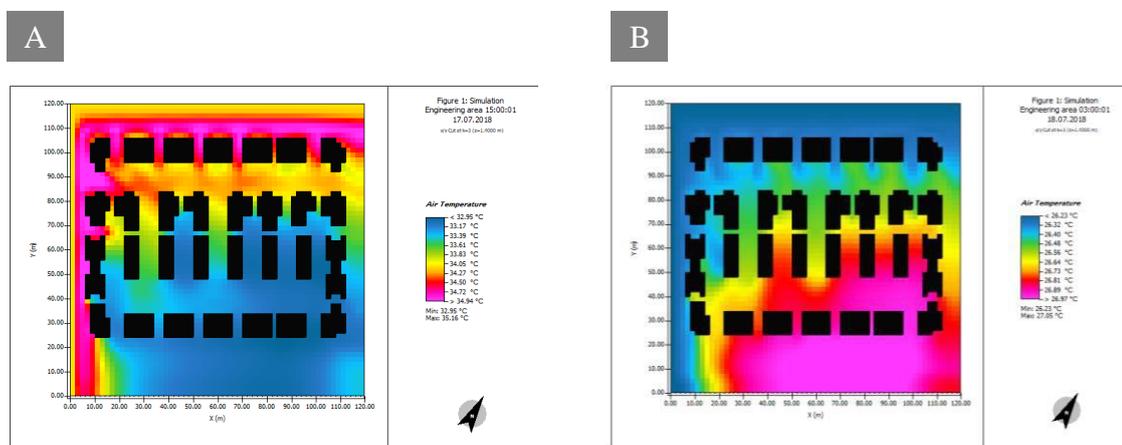


Fig.5 (a, b): (A) The simulated air temperature at 15:00 P.m. and (B) simulated air temperature at 3:00 A.m.

Reference: Author

5.2 Scenario 1: change current low albedo materials to high albedo materials (HAM)

In this scenario, low albedo materials were changed to high albedo ones, asphalt to bright asphalt with albedo of 0.55, concrete was covered with white coating with albedo of 0.85. Using high albedo materials reduces the amount of incoming solar radiation absorbed through building envelopes and urban structures and thus keeps their surfaces cooler. Changing the albedo of roofs, and pavements is chosen as a mitigation method in this study, which is more feasible due to the hot weather in summer in Borg El Arab. In Addition, Pavements (roads, pedestrian walkway, parking area, bicycle path, squares, etc.) are one of the main hardscape contributing to the development of a heat island (Tukiran, Ariffin, Ghani, 2017).

Several studies have reported that pavements cover almost 29% to 45% of the urban fabric (Rose, Akbari, Taha, 2003), in the chosen case pavements covers 34 %. Many studies report the combined effect of increasing solar reflectance of both roofs and pavements which can reduce summertime urban temperature and improve urban air quality. Heat islands can be mitigated by using “cool” materials during the summer period, as cool materials are characterized by high solar reflectance and high thermal emittance. Many studies report the combined effect of increasing solar reflectance of both roofs and pavements which can reduce summertime urban temperature and improve urban air quality (Taha, Chang, Akbari2000), results of simulation of this scenario is illustrated in figure 6 (a, b).

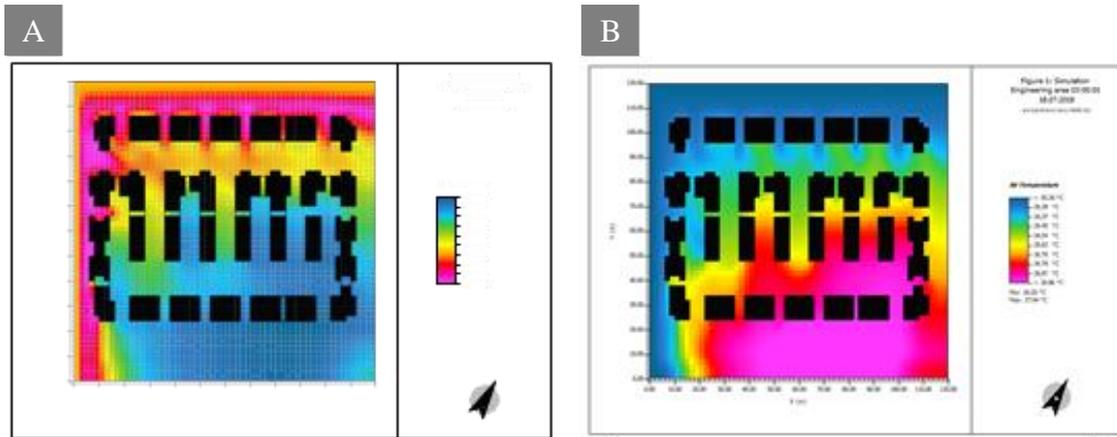


Fig. 6 (a, b): (A) The simulated air temperature at 15:00 P.M and (B) simulated air temperature at 3:00 A.M for First scenario HAM
Reference: Author

5.3 Scenario 2: cover the model area with greenery (vegetation and green roofs, VEG)

Microclimatic benefits of vegetation have been extensively investigated in previous researches (Skelhorn, Lindley, Levermore, 2014). Due to the facts that greenery is the most widely applied mitigation measure, which could achieve huge energy-saving through temperature reduction in urban areas (Sododui, 2014), it has been applied in this study. In this scenario, 60 % of the simulated area is covered by vegetation (grass and shade trees with middle density canopies, around buildings are covered by shrubs (*Buxus hyrcana* hedges), the vegetation on the roofs is considered as grass and shrubs as shown in figure 7(a, b). Shade trees are an ecological solution and one of the strategies that can be used to mitigate heat islands and improve community comfort. It is well-known that plants strategically placed around buildings can bring thermal benefits to the inhabitants. Vegetation not only provides pedestrians with pleasurable visual scenes, but also provides shading, improves air quality and reduces noise levels. The cooling effect of vegetation occurs through the process of shading, evapotranspiration and changing wind patterns.

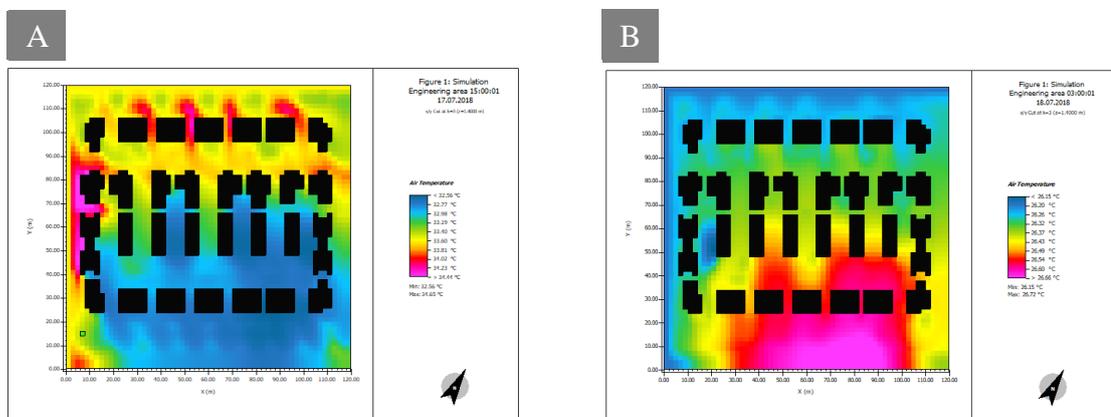


Fig. 7 (a, b): (A) The simulated air temperature at 15:00 P.M and (B) simulated air temperature at 3:00 A.M for First scenario VEG for First scenario HAM
Reference: Author

5.4 Scenario 3: cover the model area with greenery along with high albedo materials (HYBRID)

The last scenario (Hybrid) combines the effect of high albedo materials and greenery (green roofs and more vegetation) was examined to test how these two strategies together can affect the near surface temperature as illustrated in figure 8 (a, b).

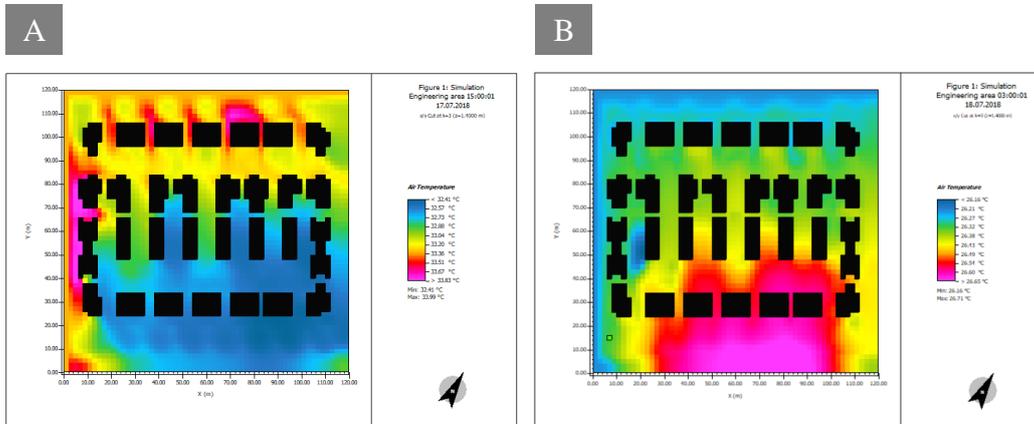


Fig. 8 (a, b): (A) The simulated air temperature at 15:00 P.M and (B) simulated air temperature at 3:00 A.M for First scenario VEG

Reference: Author

It is obvious , based on the Comparison between air temperature of mitigation scenarios and current situation as resulted from simulation as illustrated in figure 9, the cooling effect of high albedo materials can be seen especially in the built-up area and over the roads at 15:00 P.m. in scenario 1, in comparison with the current situation, the temperature was decreased by 0.51 °C in the built-up area due to reflected incoming solar radiation. The temperature reduction is higher over roads, which had an albedo increase of about 0.4 (asphalt to bright asphalt) and, in the current situation, showed the maximum temperature. In addition, maximum and minimum temperatures decreased by 0.39 °C and 0.51 °C, respectively. While, at 03:00 A.m., built-up areas started to cool slowly, and, in comparison with the current situation, the temperature decreased by 0.03 °C and 0.01 °C.

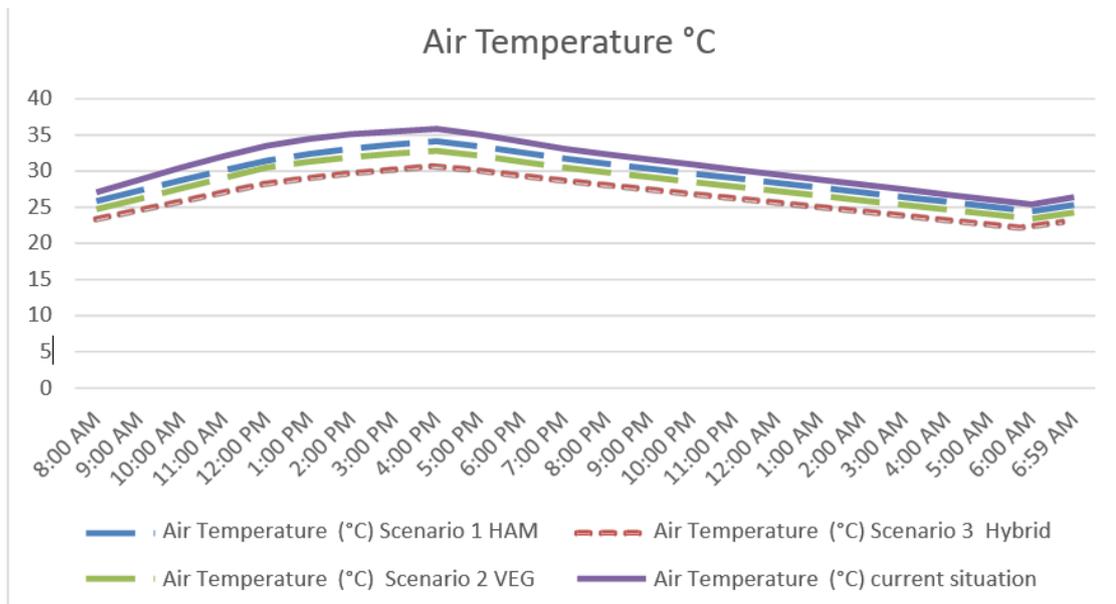


Fig. 9 Comparison between current situation and three mitigation scenarios in simulated air temperature °C

Reference: Author

Studying the temperature pattern between street canyons (H/W) in three different sections as shown in figure 10, Shows contrasting patterns in the stress heat were found between shallow and deep urban street canyons, as in zone A, section 1, 2 showing a peak difference in air temperature of 1.54 °C and 1.2 °C higher than section 3 , where the canyons with H/W = 1 , while in zone 2 the street canyons doesn't have much influence in temperature pattern.

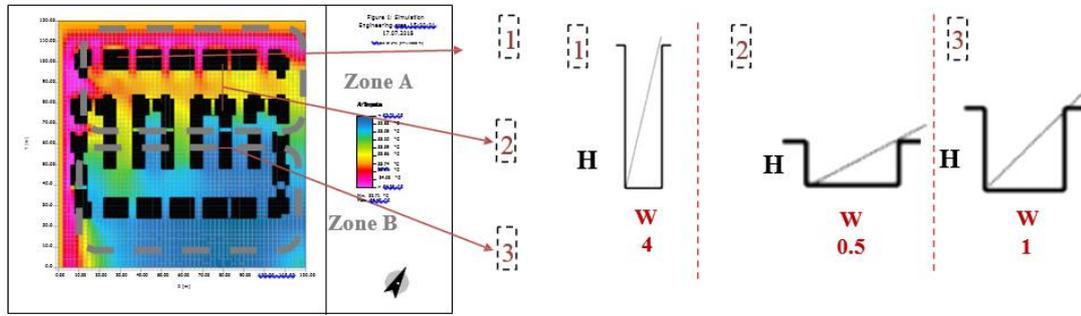


Fig. 10 Analyzing the temperature pattern between street canyons (H/W) in three different sections
Reference: Author

In Scenario 2, the temperature was decreased by 0.74 °C at 15:00 P.m. in the built-up area due to shading (in case of trees) and evapotranspiration (in the case of all vegetation types), there was still higher temperature on the roads, maximum and minimum temperatures decreased by 0.24 °C and 0.74 °C, respectively. While, at 03:00 A.m., built-up areas started to cool slowly, and, in comparison with the current situation, the temperature decreased by 0.08 °C and 0.33 °C.

As for Scenario 3 applying the HYBRID strategy leads to an overall cooling in the whole study area at 15:00 P.m., by 1.17 °C, maximum and minimum temperatures decreased by 0.54 °C and 1.17 °C, respectively. While the cooling is at 03:00 A.m., built-up areas also started to cool slowly, and, in comparison with the current situation, the temperature decreased by 0.08 °C and 0.33 °C. Table 2 shows reduction in air temperature between three scenarios.

Table 2: Comparison between reduced air Temperature in three scenarios
Reference: Author

Time	15:00 P.M	3:00 P.M
Scenario 1 (HAM)	0.51 °C	0.01 °C
Scenario 2 (VEG)	0.74 °C	0.33 °C
Scenario 3 (Hybrid)	1.17 °C	0.34 °C

Analyzing wind speed between different scenarios and current situation as illustrated in figure 11, shows a significant increase in wind speed between hybrid and current situation by 0.96 and 0.98 m/s respectively. Also, in second scenario there is an increase in wind speed, then current situation. Table 3 shows differences in wind speed between three scenarios in 15:00 P.m. and 3:00 A.m. This is a good indication that the existence of trees and vegetation in site improved the movement of wind in the whole area.

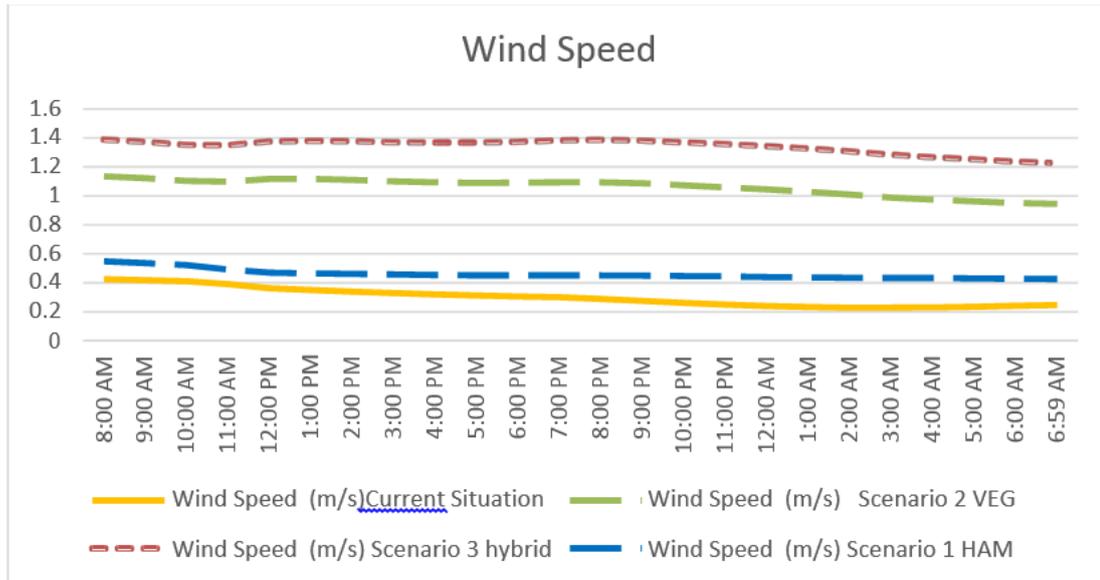


Fig. 11 Comparison between current situation and three mitigation scenarios in simulated wind speed m/s
Reference: Author

Table 3: Comparison between increased wind speed in three scenarios and current situation
Reference: Author

Time	15:00 P.M	3:00 P.M
Scenario 1 (HAM)	0.13 m/s	0.22 m/s
Scenario 2 (VEG)	0.77 m/s	0.75 m/s
Scenario 3 (Hybrid)	1.042 m/s	1.057 m/s

To Summarize, the cooling effect of scenario HAM is effective only from 12:00 to 15:00 P.m. about 0.51 °C after 15:00 P.m. there was no effective cooling. The VEG scenario shows a cooling of about 0.74°C on average, which decreases in the night-time. The HYBRID scenario had the same shape as the last two scenarios, but it leads to greater cooling (on average 1.17°C) with a maximum in the daytime. Then, the last two scenarios can bring about nocturnal cooling and can mitigate the UHI effect. It indicates that greenery along with high albedo material has a significant cooling effect on the surroundings during both, day and nighttime, which can save a huge amount of energy, which is normally used for air conditioning. In addition, ENVI-met simulation shows that the lack of greenery and materials with high albedo may cause bad thermal condition (higher temperature and lower relative humidity) especially in urban areas with hard and low albedo surfaces.

6. CONCLUSIONS

The results show that the model is capable of reasonably modeling the diurnal thermal behavior of different ground surfaces and their effect on air temperature and humidity. The simulated air temperature and humidity were generally consistent with the observations. The results from the ENVI-met simulations presented in this study clearly show that using high albedo materials (HAM) leads to a cooling of 0.51 °C in daytime (15:00 P.m.), although it is much lower (0.01 °C) in the night-time (03:00 A.m.). So, it brings only slight cooling in residential area during the night and cannot be considered as an effective mitigation strategy, although, due to the high number of hours of sunshine per day in Borg El Arab, reduction in the heat storage of sunlit surfaces seems to be important. White roof coatings could also be applied over asphalt. When it is applied, this can provide an albedo up to 0.8, which means that only 20 per cent of the sun’s energy is being absorbed as heat, which leads to higher cooling effects. In the second scenario (VEG), all free spaces within the study including roofs are covered by vegetation(grass, Buxus hyrcana, and trees with middle density

canopy), in order to obtain maximal cooling, which is generated only by vegetation. The results show that the average cooling for the whole area is about 0.74°C at 15:00 P. m. The third scenario combines the last two scenarios (HYBRID) and shows the greatest cooling. The average cooling of this scenario is on average 1.17°C at 15:00 P.m. Analyzing Urban Geometry and effect of H/W in the studied area didn't show much effect on change in temperature pattern. This study showed that all features of urban street canyons influence the Heat stress with a differentiated situation across the street between center and edges. In summer, shading is the key strategy for promoting thermal comfort in hot and dry climate. However, it is suggested for further research to experiment with more dynamic changes to other constraints such as building layout, height and orientation in order to compare the impact of retrofitting versus modifying the original design in the early design stage.

This paper demonstrates the influence of greenery compared to high albedo materials to mitigate the urban heat island intensity in Borg El Arab city. As is shown, the last two scenarios give promising insights into the benefits of urban green planning. Developing green spaces reduces the air pollution and filters the particulate matter, on the one hand, and reduces the near-surface air temperature and prevents the overheating of sunlit surfaces, on the other. Concerning the energy consumption, it can be reduced by about 5–10 per cent, which would be a huge saving in energy and would also lead to better conditions of human comfort and serve to offset global warming.

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