# The Effect of Greenery Strategies and Sky View Factor on Mean Radiant Temperature in an Arid Climate

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***Abstract*—Global warming, which is also referred as climate change, is considered as one of the critical environmental issues nowadays that comes with anticipated effects of increasing global temperatures. Reactions to this climate change and concern about its effects are also increasing. Thus, possible responses to this change are being taken, including different ways such as future climate engineering. Therefore, this work intends to observe and discuss the impact of greenery strategies and wind speed for the urban area with high rise buildings and maximum sky view factor on the urban microclimate. The mean radiant temperature is used as the indicator for the thermal comfort. The study was conducted on the hottest day in summer in Baghdad city by the evaluation of vegetation, mean radiant temperature to assess the human comfort in high rise buildings area. The assessment was done on the hottest day where the mean radiant temperature, sky view factor, air temperature distributions have been analysed using ENVI-met version 4.0 which allows simulating three-dimension geometrical configuration that performs an essential role in controlling longwave radiation heat loss, which shows the effect of different patterns of greenery strategies on the climate in the area of study. As a result of this modelling process and among the four scenarios that were simulated, the scenario of green ground was found as an effective solution to provide thermal comfort during summer time in the study area.**

***Index Terms*—Global warming, vegetation, thermal comfort, mean radiant temperature, ENVI-met.**

## I. Introduction

An unusual set of environmental issues faces Iraq as it is one of the aridest zones exposed to climate change in the latest years continue and intensive supreme weather phenomenon which caused by the change in climate patterns, led to rising environmental degradation throughout the country, more frequent and severe dust storms, droughts, and extremely high temperatures. Change in urban climate depends on the interactions between the modern construction (buildings dimensions, aspect ratio), the ground’s cover (built-up, pavement, vegetation, soil, and water), urban fabric (construction and natural materials) and the urban metabolism (heat, water, and pollutants due to human activity) [1]. The mean radiant temperature (Tmrt) is recognized as an essential factor that affects human’s thermal comfort outdoors in urban area [2]. Tmrt is the amount of all radiation waves fluxes (short and long) that the human body absorbs during the daytime, resulting in energy balance and human thermal comfort [3]. Peng et al., [4] proved that the Tmrt is more specific in indicating the thermal comfort than air temperature. According to Thorsson et al., [5] the mean radiant temperature is the most notable meteorological parameter that controlling the balance of human energy and the thermal comfort. Oke [6] described that sky view factor is directly related to the radiation exchange between the sky and the ground. Sky view factor =1 means that the radiation which is released by a surface is received by the sky, while SVF =0 implies that obstructions block the radiation entirely Fig (1). Sky view factor field is significantly affected by the distribution of surrounding buildings [7]. Accordingly, the detailed distribution of Sky view factor plays an essential role in relating the distribution and construction of buildings to the urban thermal environment.

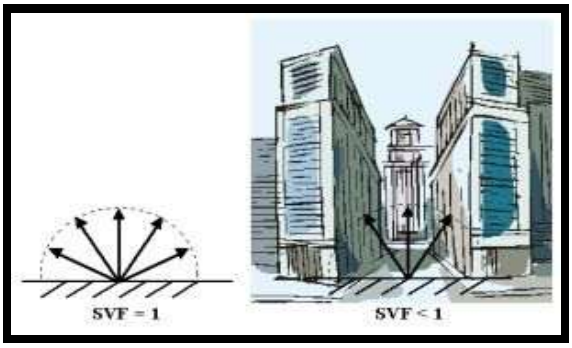


Fig. 1. Description of sky view factor (https://www.google.iq/).

Wang and Akbari [3] indicated that temperature and Tmrt for the buildings and the ground surfaces affected by many factors such as sky view factor and vegetation. This work aims to assess the human thermal comfort in high rise buildings in Baghdad city by evaluating the effect of different patterns of vegetation, the impact of sky view factor, and mean radiant temperature. The study has conducted on a hottest hot day in summer. The climate of Baghdad city is semiarid to arid precisely in the year 2010 [8]. This work has been achieved by creating a simulation model of ENVI-met version 4.0. ENVI-met allows simulating 3D geometrical configuration this objective takes a huge part in controlling long-wave radiation heat loss [3]. ENVI-met computation of Tmrt has been confirmed in recent researches [9].

## II. Case Study

The capital city of Iraq, Baghdad, is located on both sides of Tigris River in the central part of Iraq. Baghdad’s climate is considered semi-arid, dry warm in summer, cold in winter and the shortest time is in spring. The maximum recorded temperature was 50 ℃ in summer. The area of Baghdad covers 4555 m2, which represents 1.047% of Iraq’ s entire area.

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Fig. 2. Location of the study area Haifa street. Source: (http://www.flashearth.com).

## III. Methodology

### A. Micro-scale Numerical Modeling ENVI-Met

The 3D non-hydrostatic microclimate model, which is called ENVI-met, involves a simple one-dimensional soil model, a radiative transfer model and vegetation also [10]. This program was invented by Prof. M. Bruse, University of Mainz and his team. ENVI-met is used for simulating the thermal performance of outdoor spaces showed in many researches. Monam and Ruckert [11] verified that depending on many researchers such as ([12], [13] and [14] ENVI-met results can be considered as precise reliable, and created to simulate the surface with plant and air interactions in urban areas. The most significant indicator, which specifies how much indoor heating and air conditioning consumes energy, is outdoor air temperature.

### B. Input Data for the Model

The climate information, which was collected from the Iraqi Meteorological Organization and Seismology (IMOS), was utilized to simulate the models were, the microclimates features are describing the relative humidity and air temperature of the hottest summer day conditions in Baghdad city have been used. Therefore, the hourly meteorological data on the 12th of July 2010 [8] were considered as the hottest day of the regional weather conditions that effect on Baghdad urban area in summer. 5 m/s was the rudimentary climatology settings for the preliminary situations, which were for wind speed and 315 degrees for the wind direction. Relative humidity and air temperature were used during the period of one day with simple forcing. The lowest air temperature was 35 ℃ at 6 am early in the morning, and the highest was 50 ℃ at 4 pm in the noon. The relative humidity reached its minimum at 4 pm with 24 %, while the maximum was 36% at 7 am. The time for simulation was for 24 hours. The dimensions of the modelled area were as follows: (325×150) $m^2$. Haifa Street's model has been presented with a grid with the size of x= 130, y= 60 and z= 30, this grid size is represented in a grid cell, the dimension of the grid cell is: dx= 2.5m, dy =2.5m and dz=5m, the model has been revolved of 57° according to the position of the buildings to the central North location. We assumed six receptors that are distributed as shown in Fig. 3. These receptors are selected to be located inside the model area at points where the atmosphere and soil processes are tracked in detail. The location of the receptors is given using the x, y co-ordinates.

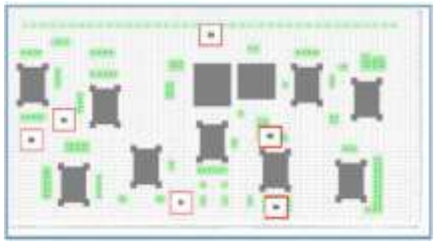

Fig. 3. Locations of the six receptors.

### C. Scenarios

In this research, we focus on assessing the effect of different patterns of vegetation and two kinds of wind blowing (one considered as the wind speed values in the real case, the second assumed the wind speed values as negligent the wind speed effect) on mean radiant temperature values. We achieved these objectives by creating eight simulation models in ENVI-met program with different cases as presented below:

1) Simulated model for the configuration area with vegetation (Genuine model) as shown in Fig. (4) and the effect of the real wind speed value that was recorded from the meteorological at the hottest day which was 5 m/s.
2) Simulated model for the configuration area without vegetation as shown in Fig. (5), and the real wind speed at the hottest day which was 5 m/s.
3) Simulated model for the configuration area with vegetation and assumed vegetation on the grounds which are equivalent to the area of the roof of the buildings as shown in Fig. (6), with the effect of the real wind speed 5 m/s.
4) Simulated model for the configuration area with vegetation and assumed vegetation on roofs as shown in Fig. (7), with the effect of the real wind speed 5 m/s.

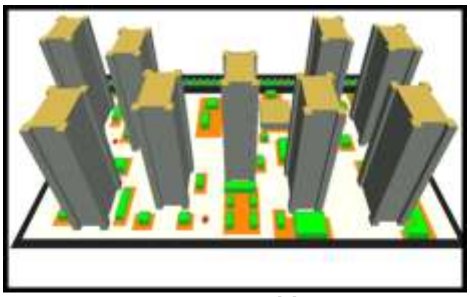

Fig. 4. Genuine model.

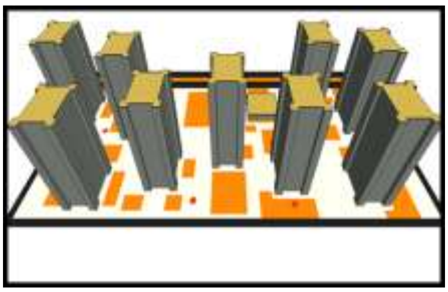

Fig. 5. Without vegetation model.

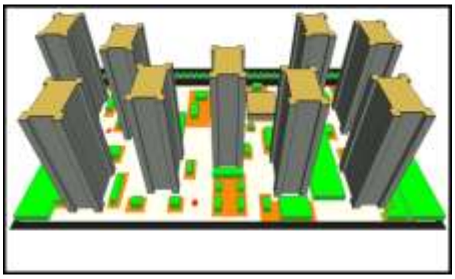
Fig. 6. Green ground model.

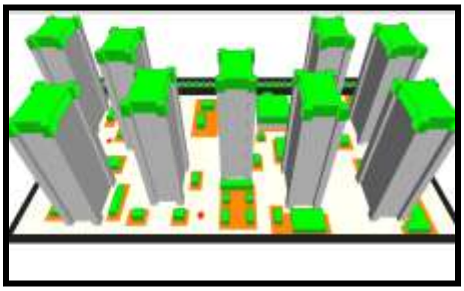
Fig. 7, Green roofs model.

### *D. The Dependence and Reliability of ENVI-met Results and the Data Measured*

The number of the receptors located in Haifa Street district was six. These were selected on points which located inside the model area, where atmospheric and soil data can be observed. The receptors used help obtaining mean radiant temperature, relative humidity, specific humidity, wind speed, air temperature, humidity and sky view factor. The comparison between the records obtained from the IMOS and the results of air temperature over the ground at 1.5 m high is depicted in Fig. (8). The outputs of this simulation are entirely not contradicting the experimental measurements. Notice that the recorded temperatures are almost the same.

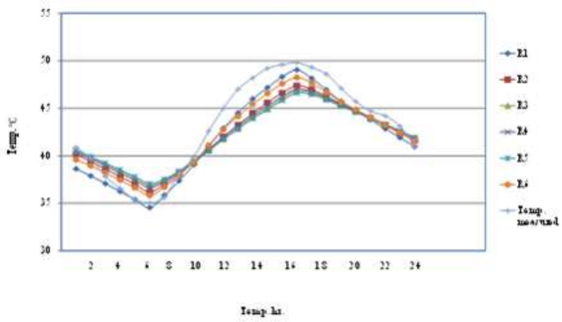
Fig. 8. Simulation and experimental results for air temperature for Haifa Street.

As is shown, early in the morning (at 6 am) the measured temperature is about 35℃, and all the receptors almost show the equivalent values. The greatest temperature determined was 50℃, it is noted that all the receptors were approximately recording this value about 4 pm.

## IV. Results

Calculating the amount of Tmrt in ENVI-met results in finding the radiation that a standing human body absorbs by using projection factor ( fp). This indicates the amount of the radiation absorbed by human skin which is influenced by the sun height. Thus, at midnoon, when the sun is high right above the head, fp becomes lower.

### *E. Results for the Simulation Models with the Real Value of Wind Speed 5 m/s*

#### *1) Air temperature*

Figure (9) depicts the temperatures distribution at height 1.5 m above the ground for 24 hr. for the genuine model for Haifa Street district at noon. Figure (10) shows air temperature values for the six receptors at height 1.5 m above the ground at noon for the four cases of the simulation works.

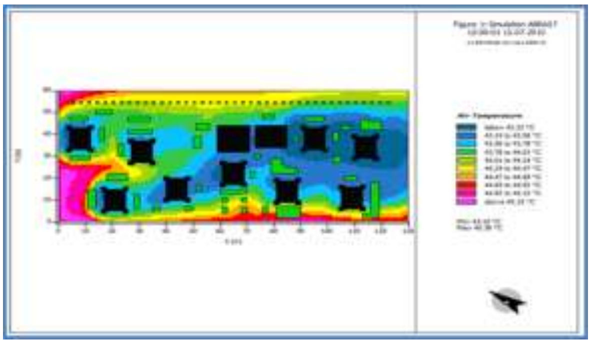
Fig. 9. Air temperature distribution with 1.5 m height over the ground at noon (Genuine model).

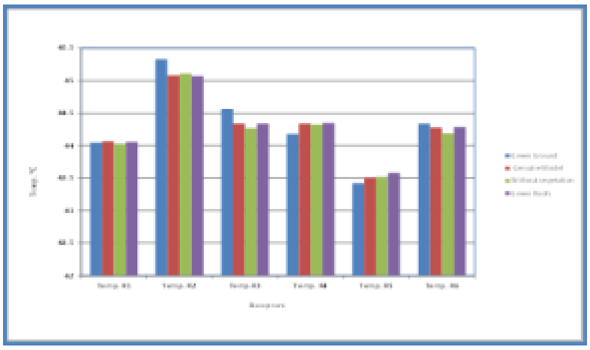
Fig. 10. Air temperature values for the six receptors with 1.5 m height over the ground at noon for the four cases of the simulation works.

#### *2) Wind speed*

Figure (11) explains the wind distribution for the genuine model at height 1.5 m over the ground. Figure (12) depicts the Wind speed values for the six receptors at level 1.5 m above the ground at noon for the four cases of the simulation works.

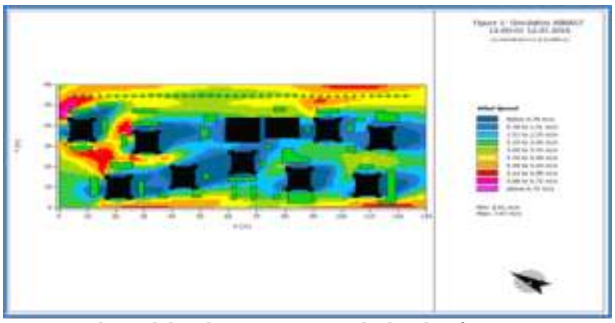
Fig. 11: Wind speed distribution at noon at the height of 1.5 m (Genuine model).

#### *3) Sky view factor*

Fig. (13) shows the effect of the different pattern of the vegetation distribution for each case of the simulation models.

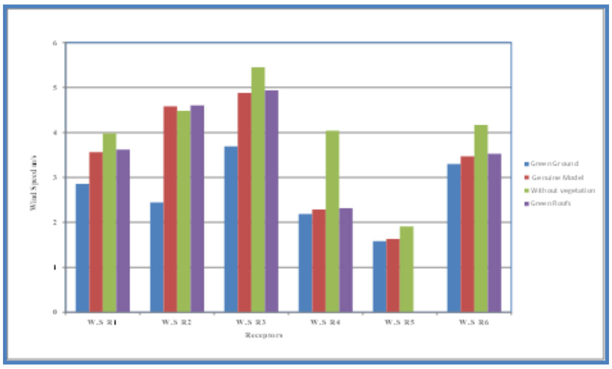

Fig. 12. Wind speed values for the six receptors at 1.5 m high at noon for the four cases of the simulation works.

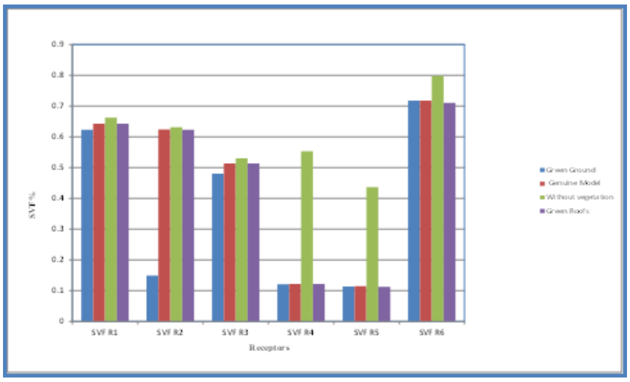

Fig. 13. SVF for the six receptors at level 1.5 m over the ground for the four cases of the simulation work.

### 4) *Mean radiant temperature*

Fig. (14) depicts the distribution of Tmrt at noon for the genuine model of Haifa Street district. Fig, (15) shows Tmrt values at 1.5 m high at noon for the four cases of the simulation work.

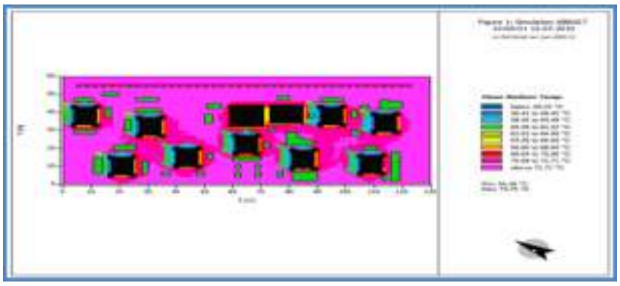
Fig. 14. Tmrt distribution with 1.5 m height over the ground at noon for the genuine model.

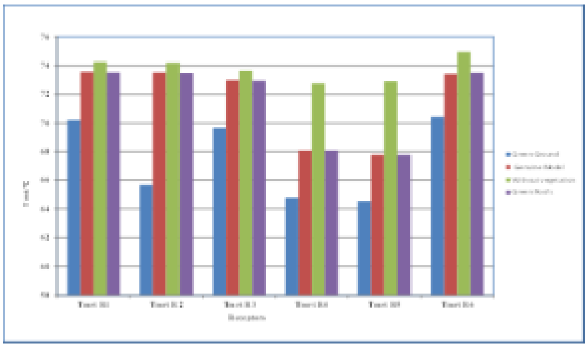
Fig. 15. Tmrt values for the six receptors at 1.5 m high.

## V. Conclusion

Increasing importance of (Global Warming) and its related researchers was the most significant factor which encouraged and leads us to this research. The fundamental objective of this work was to observe the availability of thermal comfort factor in a specific area of study in Baghdad city (which we can consider it as a typical area of research to find thermal comfort availability in Iraq and maybe the Middle East as well). And also assessing some suggested solutions which may help provide thermal comfort in cities affected by high temperatures during summer time. This research came up with many outputs, which we can list them as follows:

• ENVI-met (this software was used in this study to create our four simulated scenarios) is very reliable and sufficient to use in Iraq, we can see in Fig. (8) when we got the same temperature from the receptors as the temperature measured by the IMOS. The outputs of the simulation are entirely not contradicting the experimental measurements, considering that the records of temperature are almost the same.

• Air temperature: we can predict that as shown from the six receptors for the four simulated cases those in hot areas there isn't too much we can to do to lower the air temperature at noon. Although, green ground scenario gave the best results (even though there was much difference) among other scenarios.

• Wind speed: As we can see from Fig. (12) that green ground scenario is the best or the most efficient scenario to have acceptable wind speed in the hot area during the summer season in some of the hot cities.

• Sky view factor: here also we can observe that green ground scenario is the most productive one comparing to other scenarios may provide an acceptable sky view factor during the summer season.

• Mean radiant temperature: there isn't too much difference here as well, where we can see that green ground scenario will provide the best mean radiant temperature in our study area. According to the simulated scenarios, we can notice that there is no effect to the green roofs in improving thermal comfort. This corresponds to what came by Rajabi and Hijleh [15] who they found that green roofs function inadequately in minimizing the surface temperatures in urban area, because the cooling effect of green roofs becomes lower by distance. Thus, this outcome is considered ignorant of the temperature decrease in these domains. Also, concerning the framework of greenery, trees have the most significant influence onto the decrease of surface temperatures in such areas. Therefore, it is concluded that the scenario of the green ground is considered as an effective solution to provide thermal comfort during summer time in our study area (Haifa Street). This scenario is the most productive one among other scenarios to have an acceptable temperature, wind, SVF and Tmrt in hot cities during the summer season.

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