IMPACT OF GREENING ON MINIMIZING THE URBAN HEAT ISLAND EFFECT TO IMPROVE THERMAL COMFORT (THE AREA BETWEEN THE TWO HOLY SHRINES IN KARBALA)

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ABSTRACT

This research aimed to reduce the effect of the urban heat island phenomenon during the early evening hours to provide the best thermal comfort for the large numbers of visitors of the two holly shrines in Karbala .To achieve the study goal, the research carried out its practical side by using the environmental simulation program, ENVI- met, where it prepared two models for the study area, one of them is a model that simulates the reality, and the other is a model proposed by the research, in which the area was planted with a type of shade-giving trees to provide the highest possible shading rate in the area in an attempt to reduce the phenomenon of the urban heat island in the evening. The research concluded that the proposed model, whose results were calculated at nine o'clock in the evening, succeeded to reduce the phenomenon of the urban heat island in the study area by increasing radient heat and decreasing air temperature which improved feeling of thermal comfort.

Keywords: TMRT, air temperature, relative humidity, PMV.

أثر التشجير في الحد من ظاهرة جزيرة الحرارة الحضرية لتحسين الشعور بالراحة الحرارية (منطقة ما بين الحرمين الشريفين في كربلاء)

هالة حسين موسى
مدرس

المستخلص

تعد المنطقة الواقعة بين الحرمين الشريفين في كربلاء من أكثر المناطق ازدحاماً حيث يزورها الملايين سنوياً، عدد كبير منهم في المساء لتجنب التعرض لدرجات الحرارة المرتفعة نهارا، وظاهرة الجزيرة الحرارية الحضرية التي تظهر في المساء تجعل هذه المنطقة غير مريحة حرارياً ، يهدف هذا البحث الى محاولة تقليل تأثير هذه الظاهرة لتوفير أفضل راحة حرارية. ولتحقيق هدف الدراسة، قام البحث في جانبه العملي باستخدام برنامج المحاكاة البيئية ENVI-met، حيث أعد نموذجين لمنطقة الدراسة أحدهما نموذج يحاكي واقع الحال، والآخر نموذج مقترح من قبل البحث، حيث تم اقتراح مناطق تشجير بنوع من الأشجار المظللة لتوفير أعلى نسبة تظليل ممكنة. وتوصل البحث إلى أن النموذج المقترح والذي تم حساب نتائجه عند الساعة التاسعة مساءا نجح في الحد من ظاهرة جزيرة الحرارة الحضرية.

الكلمات المفتاحية: الحرارة المشعة، درجة حرارة الهواء، الرطوبة النسبية، معامل متوسط قيمة تقييم المناخ.

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INTRODUCTION

Attaining thermal comfort for urban space occupants is a fundamental objective of urban architecture. (2, 7) To attain this objective, various environmental strategies are implemented to enhance shading and diminish heat absorption and radiation. Planting trees is the most prevalent and advantageous solution, (10) since it enhances the atmospheric oxygen levels and supplies the fresh air essential for human survival. This study will examine afforestation's role in mitigating heat radiation from surfaces and its connection to the urban heat island effect, as well as its impact on enhancing thermal comfort. This study also acts as a useful reference for resolving numerous functional concerns that may develop. Many research investigations have shown that green solutions have a substantial impact on urban planning rules for environmental cooling, saving energy, and thermal comfort for human. (14) The research conducted by (18) finds that the environmental movement achieved significant headway in sustainable design field, using studies and tactical methodologies to address environmental concerns. This signified a shift toward prioritizing conventional planning principles in regions that depend less on technology and energy. (1) Some wages have risen as a result of the existing knowledge deficit on the ways for achieving thermal comfort in urban outdoor environments, including the area between the two holy shrines in Karbala in particular. The area located between the two holy shrines in Karbala is regarded as one of the most crowded areas, visited by millions of pilgrims yearly, big number of them visiting this area in the evening in an attempt to avoid exposure to high temperatures during the day. (6) Still the urban heat island phenomenon, which appears in the evening, (15) makes this area thermally uncomfortable during the evening. The goal of this research is to improve the impression of thermal comfort in outdoor areas. Urban heat island is most visible during the the early hours of the night, (12) when individuals congregate outdoor. To investigate this phenomenon, the study used current analytical studies on urban heat island, thermal comfort, and the meteorological elements that influence them. Furthermore, the study looked at the specific condition of the study region, being an area marked by the entry of very big numbers of pilgrims throughout the day, especially in the evening, where the urban heat island phenomenon began to function. The examination was conducted using modern technical methods, such as the ENVI-met program. Thus, the study investigates the state of the outside spaces of the area between the two holy shrines in Karbala model. This is accomplished by incorporating the area model's inputs into the programme and reviewing the findings to determine a link between the findings and the selection of the best thermal zone. As a result, this will serve as the foundation for the entire Enhancement of outdoor spaces in places of pilgrimage, with a particular emphasis on the area between the two holy shrines in Karbala spaces.

MATERIALS AND METHODS

The methodological approach applied in this study included a literature review, historical analysis, data gathering, and simulations utilizing ENVI- met software .This study deals in its theoretical framework with a review of previous research related to the topic of the urban heat island (UHI) with a short introductory explanation with focusing on a number of topics related to the concept of the urban heat island. Then the study moves to the practical framework with an explanation and analysis of the study area. The study seeks to enhance thermal performance in the area between the two holy shrines in Karbala by mitigating the urban heat island (UHI) effect. a lot of studies have been done on UHI and how it affects thermal comfort from several viewpoints. Although, enough research has not been done on how the UHI effect changes people's thoughts about how comfortable it is to be outside in open spaces for areas crowded with the shrines visitores. It is concerning that this is occurring, as these locations are vital for social gatherings and activities. A model was made as part of this investigation. This essay shows a computer image of a certain area in Karbala, Iraq, which is in a hot and dry area. The first scenario shows how things really are, and the second model shows a possible way to fix the problem. There was an evaluation of the results to show how well these interventions worked at reducing the UHI effect and improving people's sense of thermal comfort.

Urban heat islands

The Urban Heat Island (UHI) phenomena in the atmosphere above cities that is caused by differences in the surfaces of those cities. It has an effect on the temperature in thearea. (8) Most of the time, cities are warmer than their surrounding areas because buildings, roads, and covered surfaces keep heat in and transport it out of the area. The man-made structures can take in and store heat energy during the day and then slowly release it at night. There are a lot of people in these places, which makes them more uncomfortable and means that more energy has to be used to cool them down. The Earth's surface layer and atmospheric temperatures in cities are greatly affected by the release of heat from air conditioners, the process of combustion of fossil fuels in automobiles and industrial facilities, and further activities of humans that use energy. It has been shown that urban heat island (UHI) is bad for many things, including people's happiness and health, the environment, the climate in cities, the quality of the air, and the amount of energy used. (13) According to Ruddell there are two major groups. The macro (UHI) phenomenon is defined by the fact that it happens over a big area. The other type of urban heat island (UHI) is called Intra UHI, which it deals with smaller areas of land. (26) Some researchers says that the size of the Urban Heat Island (UHI) effect depends on a lot of different factors. There is a straight relationship between the size of a city and the urban heat island (UHI) effect. The general shape of buildings and the spaces between them in cities is called urban geometry. It significantly influences various environmental elements, including wind velocity, thermal absorption, and shading. (29) others agree that the loss of greenery in cities is a big reason why the urban heat island (UHI) effect gets worse. This effect is especially noticeable in places with a lot of roads, surfaces that don't let water through, and lots of buildings. These things make it harder for water to evaporate, which raises the surface temperature. (17) Air and surface temperatures are lowered by trees and plants through a process called transpiration and their ability to insulate. The high heat emission of urban materials is due to the fact that they naturally reflect sunshine. They provide a greater heat-storage capability than soil thickly filled with vegetation in rural areas. This means that they can hold twice as much thermal energy. (28) Shipping, heating and cooling systems, and appliance usage, and industry activities are all things that people do that add to the production of heat. Geographical location and weather factors are two more things that can make it hot. (12) After a certain amount of time, the heat can be released as long-wave radiation after it has been absorbed. How much absorption and reflection there is depends on the basic physical features of the ground and the outsides and roofs of buildings. In addition, plants are very important for protecting the environment from the effects of radiation because they take in direct radiation. (19)

UHI mitigation methods

Many factors affect Urban Heat Island (UHI) magnitude. Urban heat island (UHI) effect is proportional to city size. The layout of buildings and the spaces between them in urban settings effect wind speed, temperature absorption, and shading. It is commonly accepted that urban vegetation depletion intensifies the urban heat island (UHI) phenomena. (1) Pavements, impermeable surfaces, and thick building coverage impede evaporation and raise surface ambient temperatures, making this phenomenon especially evident. (5) Trees and plants lower air and surface temperature through transpiration and insulation. Urban materials' significant heat emission is due to their sunlight reflection. They can store twice as much thermal energy as soil densely inhabited with green flora in rural places. Transport, heating and cooling, appliance use, and industrial processes also generate heat. Geography and weather also contribute to heat. (9) Therefor, heat absorption generates radiation with long waves after a specific duration. The physical qualities of ground surfaces, building exteriors, and rooftops determine absorption and reflection. Vegetation absorbs direct radiation, reducing its environmental impact. (30)

UHI and its impact on outdoor thermal comfort: Abdullah, (1) observed that pedestrian thermal conditions rise significantly when the expected mean temperature (PMV) and mean radiant temperature decrease. Following a revised urban layout in Melbourne, researchers found considerable reductions in average daytime mean radiant temperature (TMRT), air temperature (T), and Predicted Mean Vote (PMV). According to Ridha, Salata and colleagues, planting plants reduced climate change the greatest in 2015. High albedo materials also improved microclimate on high sky view factor surfaces. (7) demonstrated that tree shadowing significantly affects human thermal comfort at physiologically equivalent temperature (PET). According to (20). Tree shade is sometimes used to reduce the impact of temperature on walkers, especially during peak hours. they suggest that human-caused long-wave and short-wave radiation emissions affect outdoor thermal comfort. (24)

Vegetation and thermal comfort

It is commonly known that vegetation improves thermal comfort. Vegetation improves thermal comfort even when it has little effect on air temperature. Although some experts prioritize lowering air temperature, radiant heat exchange usually has the greatest impact on thermal comfort in a dry and high-temperature environment. Vegetation is essential for external thermal comfort. This is done by shading people and reducing long-wave radiation from hard surfaces. Vegetation also reduces solar radiation reflected from these surfaces. (25) Experimental research shows that vegetation in hot climates offers the greatest benefit of shading, lowering surface radiation from intense solar radiation (10). Tree shade is sometimes used to reduce the impact of temperature on walkers, especially during peak hours. The research suggests that human-caused long-wave and short-wave radiation emissions affect outdoor thermal comfort. (4)

Vegetation and mean radiant temperature

According to Musa, (20) evapotranspiration is essential to urban greening and minimizes the impact of high temperatures. This process cools the leaf surface and air by **releasing bound heat**. Additionally, trees can **intercept solar radiation**, **lowering surface heat** by providing shade. (14) Numerous research on urban vegetation and parks shows that vegetated areas in cities are cooler than non-vegetated regions. (16) found that large parks with trees **reduce peak daytime temperatures** According to Mas'uddin (15), greenery and urban agricultural evaporation lower urban temperatures by 0.5 to 4.0°C. According to Haider, (11), adding additional greenery to metropolitan areas may lower air temperatures by 2°C. In certain climates and soil-vegetation systems, evaporation can reduce temperatures by 4°C. Based on previous studies, the urban greening process directly enhances radiant heat, by cooling surfaces exposed to heat all the day .The Japanese pagoda tree, which is also known as the Sophora japonica plant is the tree that the research adopted in planting the case study, because of its large and circular crown which provide large shaded area. (16)

Technical concept of thermal comfort

Human thermal comfort is the psychological state of feeling alleviation from thermal surroundings. (17) There are two thermal comfort models: steady-state and adaptive. The adaptive paradigm is founded on the theory that the human body can adapt to changing indoor and outdoor environments. Nibras (22) defines thermal comfort as the combination of physical, cultural, physiological, and social factors. Optimal thermal comfort depends on architectural design, clothes, food, and weather. Variations in vertical temperature differential between the lower limbs and the upper body, uneven radiant heat distribution, convection cooling, or contact with a particularly cold or hot floor substrate can cause discomfort. (11) Three categories of characteristics affect thermal comfort, according to Oke. (23)

1 -Air temperature, relative humidity, sun radiation, and velocity affect .

2 -Personality, including metabolism and clothing

3–Acclimatization to age and surroundings are elements in this phenomenon.

Coseo (8) identified Mean Radiant Temperature (TMRT) as the main element impacting outdoor urban thermal comfort. Total Mass Radiation Stress (TMRT) is the aggregate amount of long-wave and short-wave radiation fluxes absorbed by the body, affecting energy equilibrium and thermal comfort. (21)

PMV: The Predicted Mean Vote (PMV) measures outdoor thermal comfort using heat balance and known temperature. The PMV index is predicted thermal sensation scale. (6) It represents a huge population's average response. The PMV metric measures population thermal comfort in a given environment. Gardens, trees, and vegetation in urban areas can lower the PMV index by 0.5 units, according to Ridha (25). This is because buildings reflect several times. The mathematical Predicted Mean Vote (PMV) is directly related to local weather. PMVs often exceed [-4] to [+4], which is outside the experimental data scale. Read more about the PMV at http://www.model.envi-met.com/. PMV values rise above +4 to +8 and higher. This result has accurate numerical values. Visit http://www.model.envi-met.com/. SP (18) PMV values are defined in operational terms as -4 for extreme cold and +4 for extreme warmth. During high July temperatures, the Predicted Mean Vote (PMV) formula may accurately estimate external thermal requirements at +8 and higher. Despite exceeding the Predicted Mean Vote, the results are mathematically accurate. (21)

Urban outer space

Urban open space is unobstructed ground with soil, grass, plants, and trees, according to Najah, F. (27). This word covers all areas with these traits, regardless of public accessibility or general management. The urban domain includes parks, playgrounds, and other leisure-oriented green spaces. Car parks and dedicated streets are also included. Neighborhoods are basic urban structures that help people succeed and construct lives. Numerous studies have examined how neighborhood elements affect residents' quality of life (17). Scholars also believe that communal contentment is a crucial factor in personal well-being and quality of life. The authors added that numerous living environment factors affect population satisfaction. These are physical and social traits .(12) Y. Wang, wrote the article that published in 2014. Environmental quality can be examined broadly in urban planning. City planning authorities consider open spaces, green areas, and playgrounds essential infrastructure for new urban districts. These procedures ensure the health and well-being of open spaces users. The lack of quality open spaces in urban districts might hinder person' well-being. This restricts healthy behaviors like outdoor hobbies, walking, and leisure. (27)

Practical framework==Study area

Location of the Study Area: Karbala is situated at the boundary between stable and unstable platforms. The research area comprises the Two Holy Shrines and the intervening region. They are located around 92 kilometers southwest of Baghdad (the capital), situated between longitudes 44.03700 and 44.03200 to the east, and latitudes 32.61800 and 32.61560 to the north. (6) There is a long space between the two holy shrines that is 378 meters long. People say that this is the exact spot where the Battle of Karbala happened. Before, the area between the two shrines wasn't empty like it is now; it had a major street and several side streets with homes and businesses Before 2003, the houses that stood between the two shrines were torn down. Once the year 2003 came around, the Karbala government started to expand the study area so that the holy places of Karbala, including the study area, would have a mostly single boundary.

Weather in karbala, Iraq

Karbala has a blistering desert climate with high summer temperatures and arid conditions, while winters are mild. No month is particularly wet, although November to April accounts for most of the annual severe rains. The mean weather in Karbala was calculated by statistically analyzing historical hourly Climatic data and simulations of models spanning from January 1980 to December 2016. (3) Karbala has a long summer with high temperatures, extreme heat, aridity, and no clouds. In contrast, winter has milder temperatures, lower humidity, and clear skies. Rare extremes below 2°C or above 47°C occur in the annual temperature range of 6°C to 44°C. Figure 7 shows that Karbala’s best warm-weather months are April, May, September, and October. The mild and hot seasons have mean daily maximum temperatures above 38°C and below 21°C, in that order. The warm and cold seasons last 3–9 months (May 25th–September 23rd) and 3–4 months (November 23rd–March 3rd). July and January have the highest and lowest temperatures. Summer mean maximum temperatures are 44°C and lowest temperatures are 30°C. In the chilly season, the mean minimum is 6°C and the mean maximum is 16°C. Note that the models were simulated at 51.80ºC. The Iraqi Meteorological Organization and Seismology (IMOS) reported the maximum temperature on July 28, 2020 .

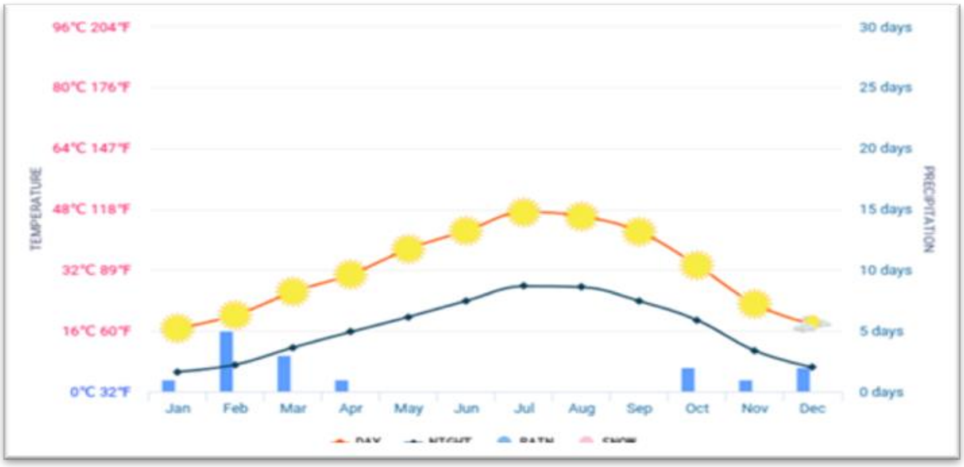

Figure 1. Climatic descriptions of the study area (4)

Model of envi-met

Specialized microclimate simulation program EnVI-met analyzes open spaces and their vulnerability to wind turbulence, vegetation, and neighboring urban structures. The calculations also consider structures, clouds, and humidity to determine how they affect microclimatic characteristics like pollutant dispersion, ecological impact, and bioclimatology. Data is input in a sequential manner at hourly, daily, or weekly intervals. This data will be processed according to program logic. ENVI-met's outside simulations have been shown accurate by several investigations. These tests show that the program's simulations match local meteorological data (18). Another study by Alitoudert & Mayer examined streetscapes for physiologically equivalent temperature (PET) and human thermal comfort to confirm the simulation's correctness. The researchers noted that the conclusion was somewhat exaggerated due to elevated radiation fluxes and a focus on wind velocities, but air temperatures verified the simulation. ENVI-met accurately predicted mean air temperatures and diurnal variation. In Baghdad, the ENVI-met technique accurately quantifies the effects of aspect ratio, symmetrical distribution, and vegetation policies on urban design and thermal comfort .

DATA of the study area entered into program: The data used to test the suggested model came from the IMOS. As we already said, the suggested models were simulated with highest temperatures of 51.80oC at 4 pm and minimum temperatures of 24.8oC at 6 am. According to IMOS, this temperature indicated the hottest day recorded in Karbala., which happened on July 28, 2020. So, the main conditions of the climatology settings were winds blowing from the southeast at 315o and at a speed of 3.90 m/s. In the morning at 6 am, the relative humidity was 36%, and at 4 pm, it was only 24%. The game went on for 24 hours. It was necessary to do some preliminary work on the area in AutoCAD before starting the work in ENVI-met. Applying a bitmap picture from AutoCAD data as a base, this program was able to rebuild the whole district. A grid having dimensions of 50 in the x-axis, 50 in the y-axis, and 20 in the z-axis were used to figure out the model area f. The sizes of this grid are shown in a grid cell by 10, 4, and 2 m for dx, dv, and dz. The model has been rotated 45 degrees due to modifications in structures and typical roads in an arid environment.

Configuration of models

The study area was picked because it is very important and draws in Numerous individuals annually, especially at religious periods. The city has changed a lot because of all the pilgrims and tourists. These changes have an effect on the weather, which in turn affects the comfort level outside (15). This work focuses on improving the comfort level outside for an area of 100,000 m2 by simulating an urban area in the main district of the holy city of Karbala on the hottest day of July. The two shrines and dome measure 12 m and 20 m in height, as well, as illustrated in Figure 7. Table 1 presents the specifications of the finishing materials utilized in the study area for the reality model (I) and the proposed model (II).

Table 1. Finishing materials used in the area between the two shrines in Karbala

Explanation	Model I	Model II
1. Central courtyard situated between the two shrines	marble tiles	marble tiles
2. The roofs of the two shrines	Reinforced concrete	RC and glass in certain areas
2. Sheds	None	Steel
3. Courtyard flooring of the dual shrines	Marble tiles	Marble tiles
4. Roofs of the neighboring structures	Concrete tiles	Concrete tiles
5. Walls of the:		
Two holy shrines	Bricks	Bricks
neighboring structures	Bricks	Bricks
Central courtyard	Bricks	Bricks
6. Trees	Palm trees	Sephora japonica + Palm trees

Model I shows the current situation before adding the Sephora japonica tree.

Model II is the step that is recommended for making the thermal comfort area bigger by adding Sephora japonica tree in specific locations in the study area.

Figure 2. The area between the two shrines in Karbala in reality (up) and proposed model (down)[auther]

Review reality (model I) and proposed (model II) results: Most urban heat island indicator evaluations occur after 9:00 PM. Temperature, radiant heat, relative humidity and thermal comfort factor affect this phenomenon. Digital modeling was done on both models to see how the suggested fixes would change the UHI and the feeling of PMV in the chosen area. This is what the results were: (**model I** is reality model and **model II** is proposed model) The suggested model was looked at, judged, and compared to identify the optimal thermal comfort zone for the tow holy shrines area. In the study area, the first model shows reality situation . Adding trees to certain spots along the yard is part of the suggestion model. Tree evaporation changes both the balance of surface energy and the hydrological cycle of water vapor. between the hydrosphere and the atmosphere. Of course, this is also the main reason why trees have environmental benefits like cooling and humidifying .

1- Mean radiant temperature (TMRT)

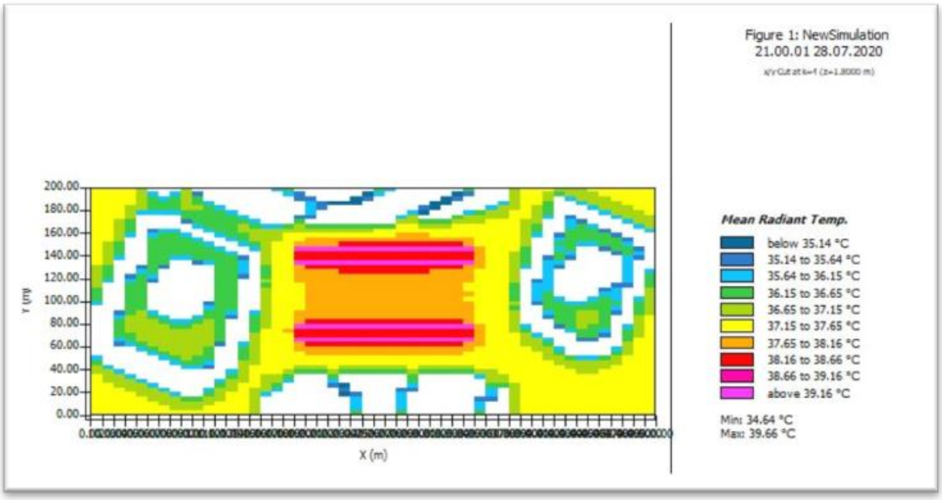

Figure 3. Model I (TMRT) [Extract from the program]

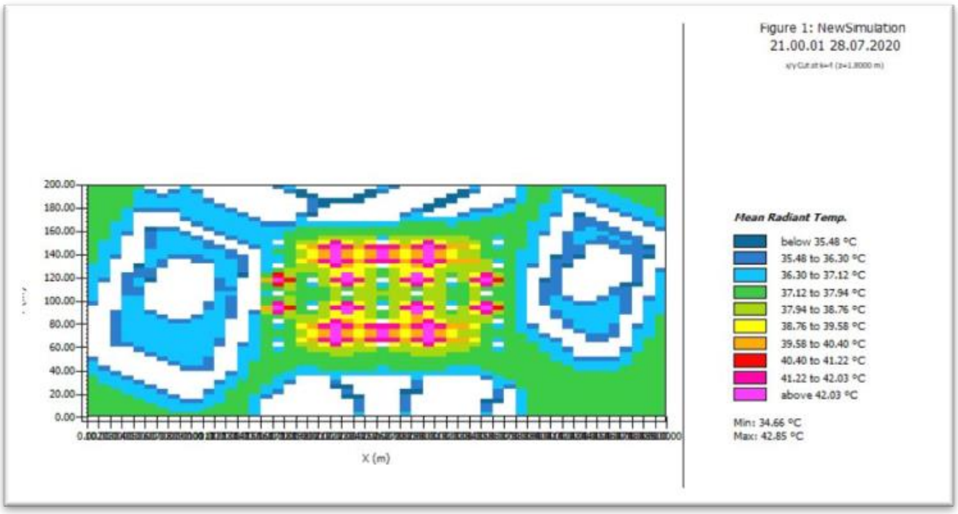

Figure 4. Model II (TMRT) [Extract from the program

- Planting trees in **model II** increased the amount of radiant heat from the surfaces

2- **Temperature (T)**

Figure 5. Model I (T) [Extract from the program]

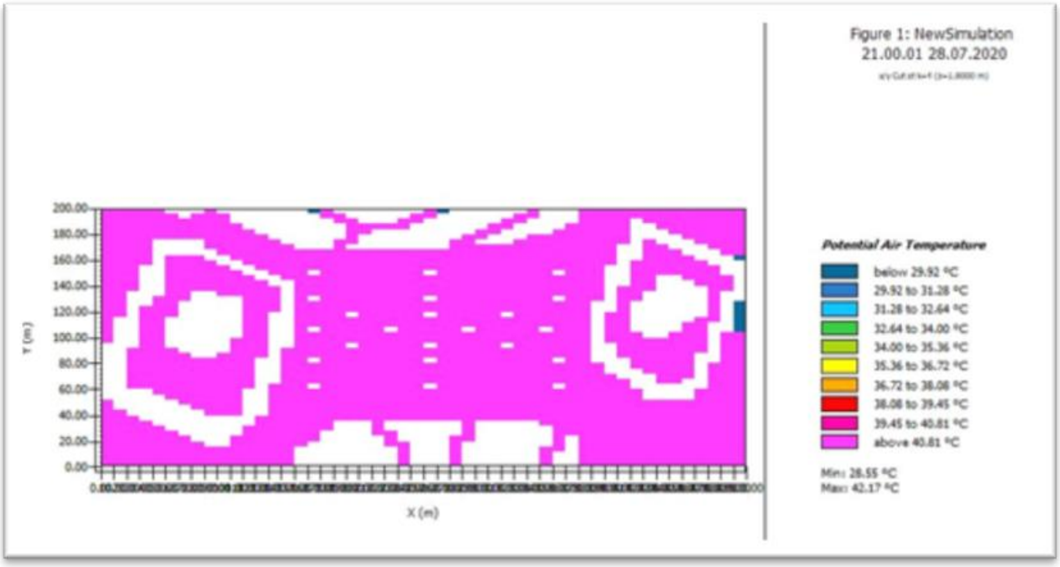

Figure 6. Model II (T) [Extract from the program]

- The greening technique increase air temperature in **model II**

3- Relative Humidity (RH)

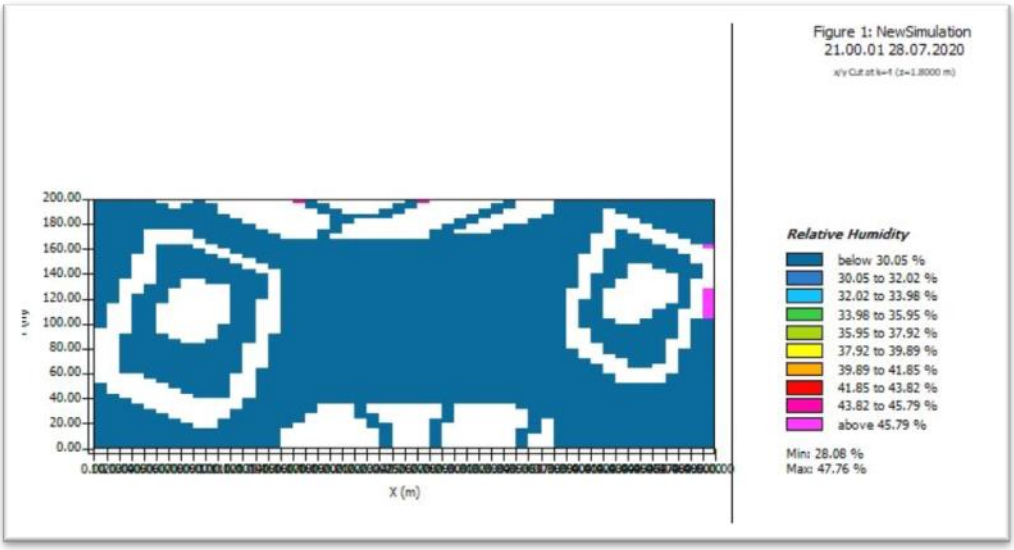

Figure 7. Model I (RH) [Extract from the program]

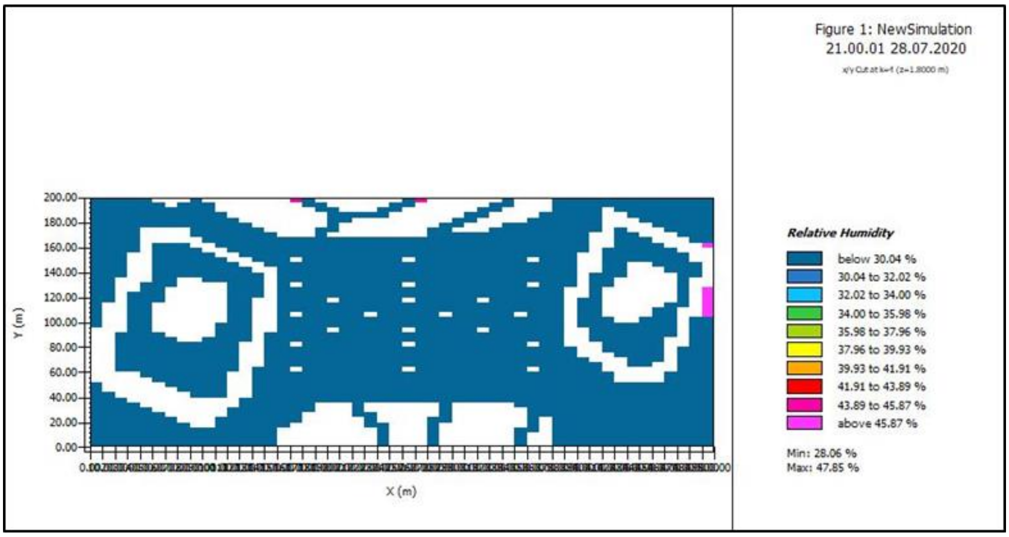

Figure 8. Model II (RH) [Extract from the program]

- The greening technique did not result in any observable change in relative humidity in **model II**

4- Thermal comfort indicator (PMV)

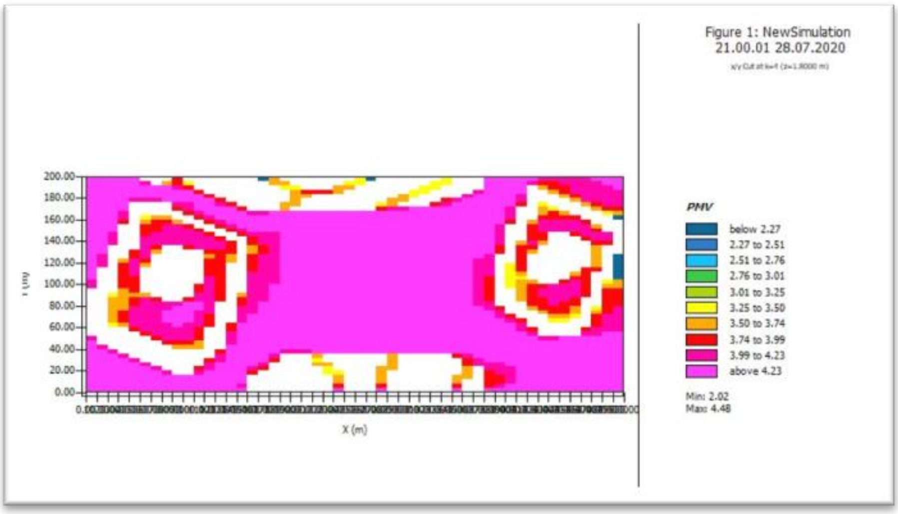

Figure 9. Model I (pmv) [Extract from the program]

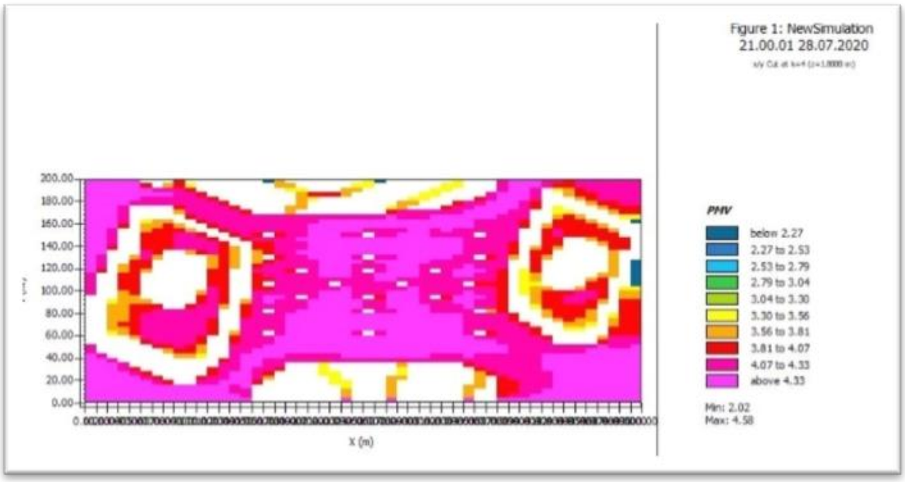

Figure 10. Model II (pmv) [Extract from the program]

- Planting trees in **model II** decreased the value of PMV index.

Practical framework summary: The heat maps derived from the input processing of both the reality and suggested models indicated an important change in PMV index, resulting in an improved feeling of thermal comfort due to greening suggested in **model II** through the following:

• Increase in radiant heat
• Increase in temperature
• Stability in relative humidity
• Decrease in PMV index

Table (2) summarizes the results extracted from **model I** and **model II** as follows:

Table 2. The simulation results of the two models[auther]

Model Name	Highest Radiative Heat (°C)	Lowest Radiative Heat (°C)	Highest Temperature (°C)	Lowest Temperature (°C)	Highest Relative Humidity (%)	Lowest Radiative Humidity (%)	Highest Thermal Comfort	Lowest Thermal Comfort
reality model I	39.6	34.6	40.8	29.9	47.7	28	4.5	2
Proposed Model II	42.9	34.6	42.8	29.9	47.8	28	4	2

RESULT AND DISCUSSION

According to the results reviewed in table 2, the following was observed:

- A noticeable **increase in the radiant temperature of the study area in the proposed model reaches 3°C with an increase in the distribution area ratio as shown in figures 11&12,** resulting from increased shading, which helps reduce thermal absorption of surfaces during the day and thus increases thermal radiation in the early evening hours.

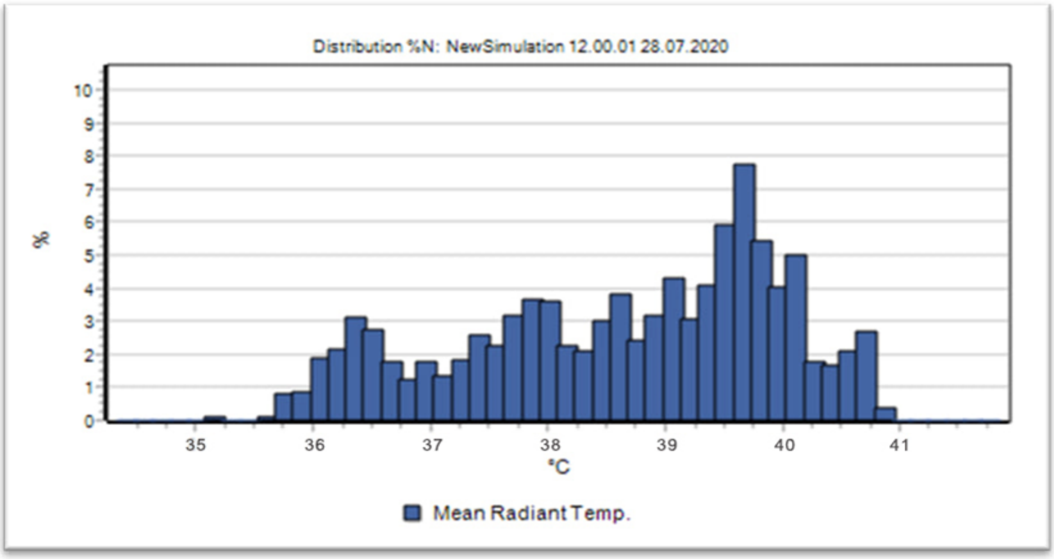

Figure 11. Percentage distribution of radiant heat values in Model I Extract from the program]

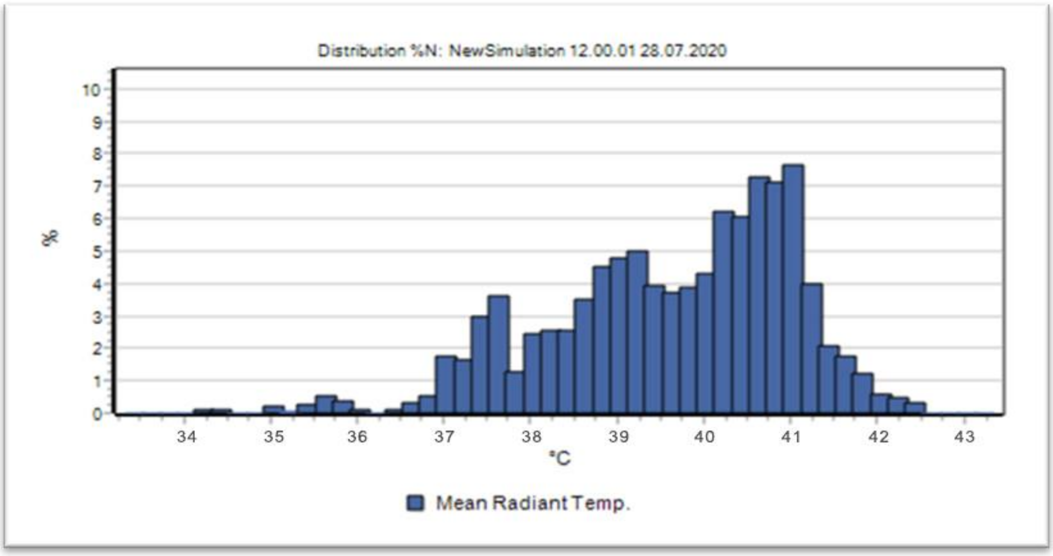

Figure 12. Percentage distribution of radiant heat values in Model II [Extract from the program]

- An important **increase in temperature by 1°C with an increase in the distribution area ratio as shown in figures 13&14,** as a result of the increase in radiant heat from surfaces in the study area for the proposed model.

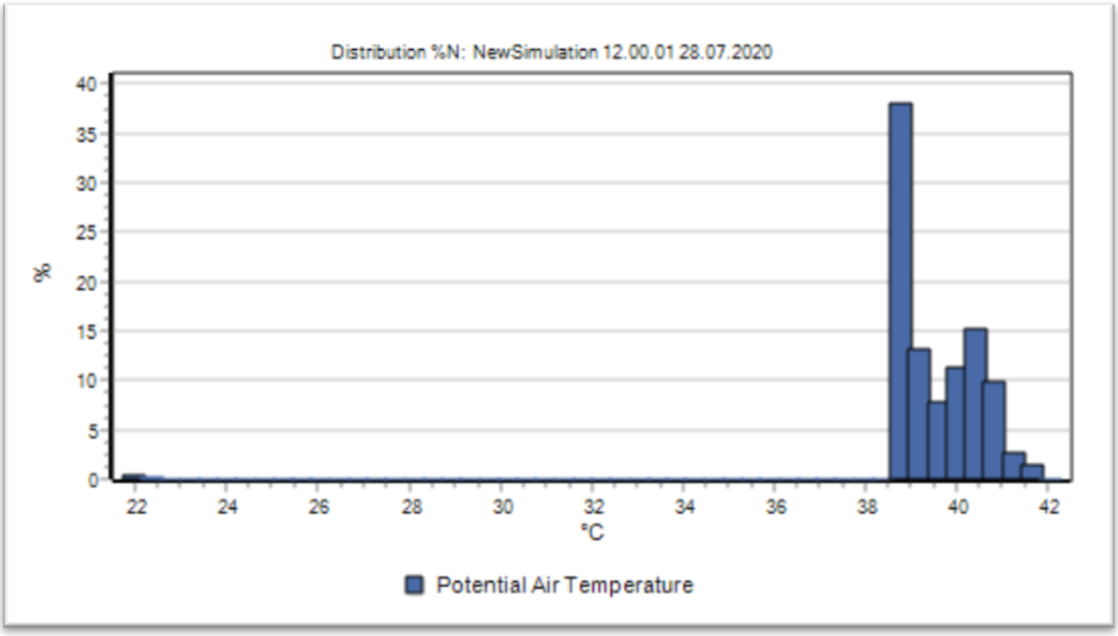

Figure 13. Percentage distribution of tempreture values in model I Extract from the program]

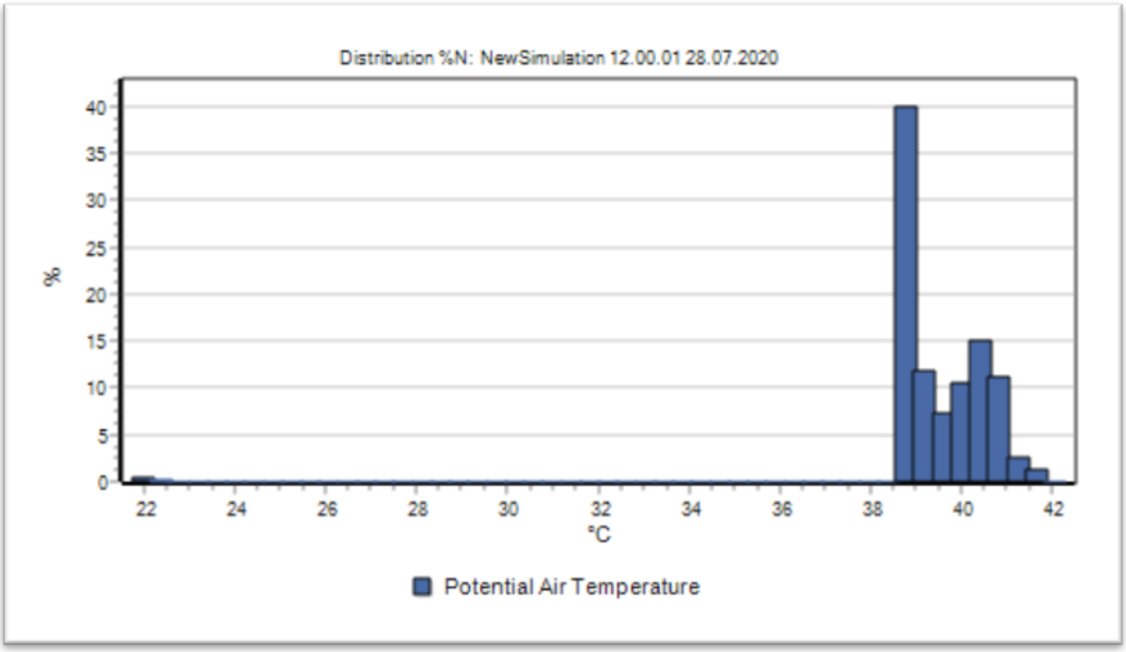

Figure 14. Percentage distribution of tempreture values in model II [Extract from the program]

- **Stability in the relative humidity ratio** because of the balance resulting from trees transpiration.
- because of previous indicators, the value of thermal comfort feeling in the planting area of the proposed model **decreased (when the value decrease, the feeling of thermal comfort increase) with an increase in the distribution area ratio as shown in figures 15&16.**

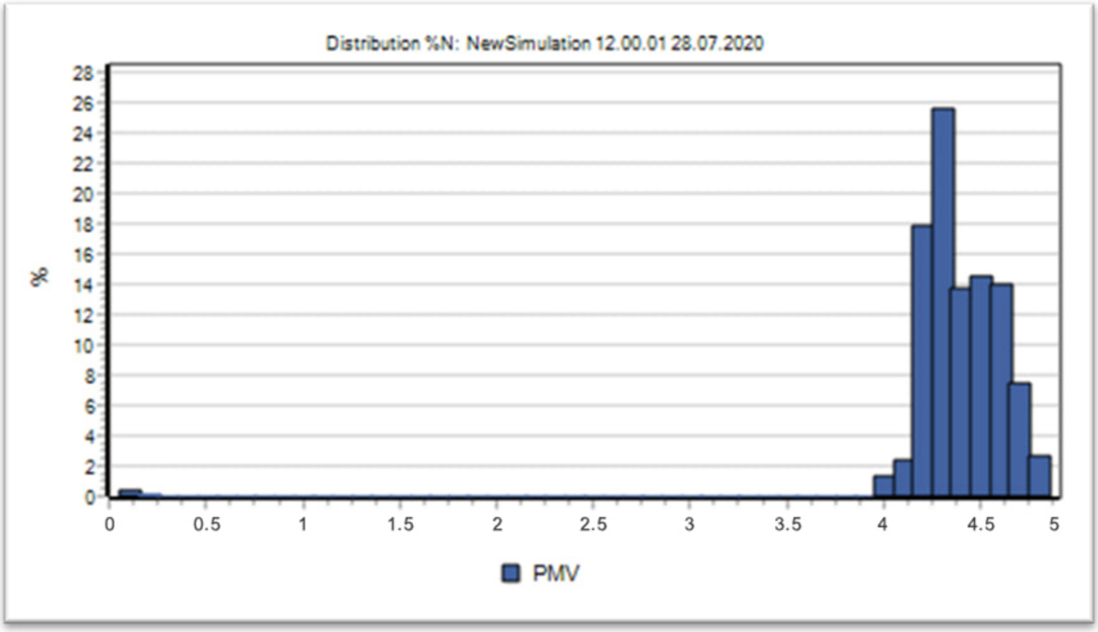

Figure 15. Percentage distribution of PMV values in model I [Extract from the program]

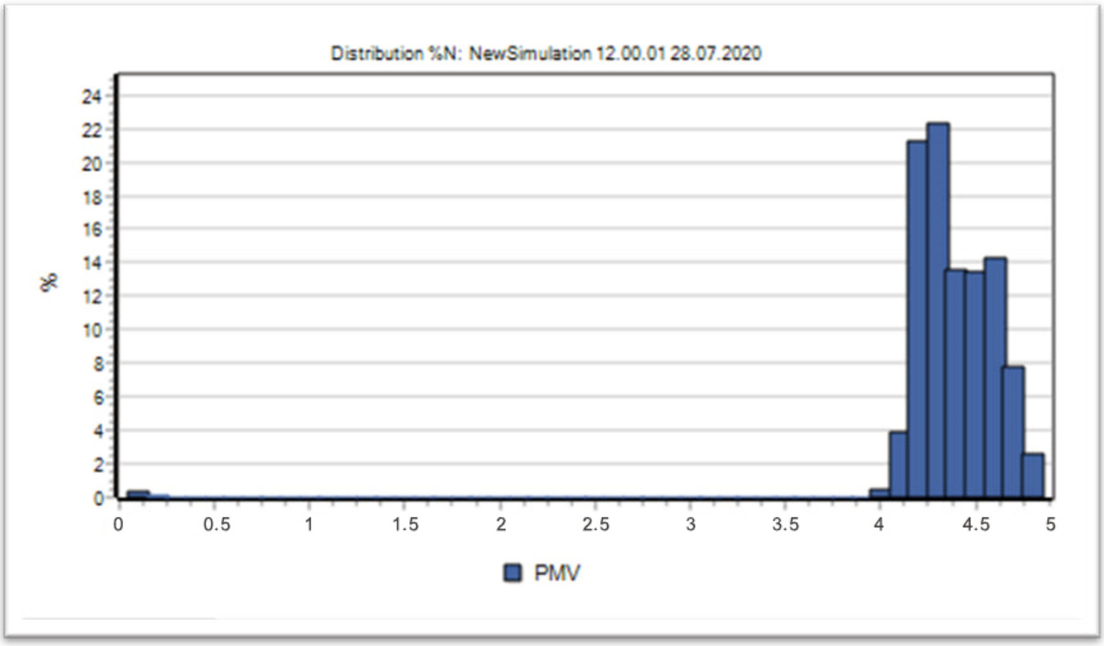

Figure 16. Percentage distribution of PMV values in model II [Extract from the program]

The research concluded that adopting umbrelled trees with a wide shading area contributes to:

1- Reducing the heat gain of surfaces during the day due to reducing the area exposed to sunlight On the other hand, there is an increase in thermal radiation during the early evening hours as a result of the shading process

2- Balance in the relative humidity rate because radiant heat accelerates the evaporation of excess moisture resulting from the evaporation process issued by planted trees.

3- The previous three parameters are the most influential on the feeling of thermal comfort, and this appears in the results extracted from the proposed model, where an increase in the thermal comfort factor was recorded

4- The thermal comfort factor is the indicator used to measure the severity of the urban heat island phenomenon, and the low values of this factor in the proposed model are evidence of its success in reducing this phenomenon. Therefore, the research recommends adopting the principle of urban afforestation to provide adequate shading in areas that suffer from a high rate of the urban heat island phenomenon as an environmentally friendly solution that eliminates the use of manufactured building materials, which may have negative effects in the future.

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