The Use of Green Design Strategies for Achieving Thermal Comfort

(Applying PMV as a Measurement Tool)

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ABSTRACT

Improving outdoor thermal comfort is a key parameter in achieving the vitality and functionality of urban spaces. In order to build a thermally comfortable outdoor space, designers must consider suistainable urban, architectural, and landscape design solutions. The main problem is that most of recent developments in Egypt didn't consider the use of green design strategies which resulted in human outdoor thermal discomfort. In this research, a case study in Egypt, characterised by hot arid climate is used to discuss and quantify the impact of green design strategies on urban microclimate and human sense of thermal comfort. The methodology used is based on Envi-met simulation to measure the four climatic parameters and PMV index. The outcomes indicated that significant enhancement in thermal comfort was achieved with the trees coverage, Where Using the maximum tree coverage showed the best improvement in PMV values with a drop of 2.48 at peak hours when compared to the base case. The results showed that the use of trees is an important strategy to improve the micro-climatic conditions and human thermal comfort in open spaces due to the shading effect as they block out excessive solar radiation.

KEYWORDS: Green Design strategies, Microclimate, outdoor thermal comfort, Hot arid climate , Envi-met.

1. INTRODUCTION

A thermally comfortable environment is extremely important for people to enjoy the outdoor urban spaces. Thermal comfort has been shown to be the foundation of a vital and functional outdoor space. A suitable microclimate can increase pedestrian comfort, encourage walkability, and support sustainability. Some previous studies have pointed out the contribution of such outdoor spaces to the quality of life and the wellbeing of their users (Cheng, Ng, Chan, & Givoni, 2012). The government of Egypt is seeking to implement more city plans and residential projects, for new urban communities, to accommodate the overflow in the population and to solve the housing problem. In the last five years, social housing projects have been considered one of the most important national project for low and middle-income people. The prioritization of the outdoor thermal performance in such projects is signficantly an important issue. The major problem in developing these new projects is that they are all built with almost the same building prototype on both scales' architecture and urban scale. These projects are built without taking into consideration the use of green design strategies and the climate change problem causing heat stress and the built environment which result in human outdoor thermal discomfort.(Mahmoud, 2019). The benefits of green design startegies such as vegetation and water elements in urban areas are recognized by many authors. Where, vegetation can modify the microclimate and improve human thermal comfort.

The main purpose of this study is to discuss, investigate and quantify the effect of green design strategies on microclimate and human feeling of thermal comfort during the summer months in urban outdoor areas, with special reference to the Egyptian hot arid climate.For this paper to achieve its goals, its first part consists of a theoretical study, with review from the literature on the thermal comfort of humans in outdoor areas and thermal indices used to evaluate coldness and heat conditions in the outdoors, such as the predicted mean vote (PMV). In addition, it describes the use of green design strategies in the urban spaces and their impact on microclimate and human thermal comfort. As for the second part of this paper, it involves an emperical study that discusses the methodology which is based on presenting two different scenarios and comparing it to the base case which is located in Wadi El.Natroun in Egypt.

The proposed scenarios are adding vegetation and using water features. ENVI-met 4.4.4 is employed to measure the microclimatic parameters (air temperature (Ta), relative humidity (RH), wind speed (Ws) and mean radiant temperature (MRT)). It also employs the calculation of the PMV index to evaluate the human thermal comfort in outdoor areas for the the existing case and the two different proposed scenarios. The results of this analysis showed that green design strategies especially trees are important to improve the micro-climatic conditions and enhance human feeling of thermal comfort in open spaces.

2. Outdoor thermal comfort

In order to lead a good life, humans must feel thermally comfortable. "Human thermal comfort is defined as a condition of mind, which expresses satisfaction with the surrounding environment" (ANSI/ASHRAE, 2017). It's not easy to control the microclimate to achieve thermal comfort in hot arid regions climates, especially due to excessive summer heat. Compared to the indoors, outdoors are much less controllable and more complex due to the direct exposure to microclimate conditions (Ng, Chen, Wang, & Yuan, 2012). Generally, thermal comfort relies on equilibrating the human body's heat gain and loss to the environment aiming to stabilize its core temperature at 37˚C. Equilibrium with the environment is achieved through conduction, convection radiation ,and evaporation. When an individual feels neither too hot nor too cold, this state is referred to as the neutral temperature. (Johansson, 2006; Nikolopoulou, Baker, & Steemers, 2001). The most common indicator for human thermal comfort is the air temperature. However, air temperature solely is not a correct indicator of thermal comfort. There are critical factors for outdoor comfort that include environmental and personal parameters that must be taken into consideration. According to ASHRAE Standard 55-2010, the environmental parameters include air temperature Ta, mean radiant temperature MRT, wind speed Ws and relative humidity RH, while the personal parameters include activity level MET and clothing insulation CLO. (ANSI/ASHRAE, 2017).

2.1 Outdoor Thermal Indicies

To be able to determine the combined effects of the previously mentioned environmental and personal parameters, thermal indices are mathematically calculated. These indicies are provided to architects and urban designers to help them make better decisions during the design process. These thermal indices can evaluate both cold and hot outdoor conditions. They include a lot of indices but one of the most frequently and widely used is Predicted Mean Vote (PMV) which is used in this study, the PMV model was initially developed by Fanger in 1967 for the indoor spaces where a seven-point thermal sensation scale that runs from cold to hot in which zero at the mid point represents the neutral value of human thermal comfort (Fanger, 1967).In 1981, Jendritzky and Nübler modified the PMV model to adapt with outdoor climates (Jendritzky & Nübler, 1981).

3. Green design Stratigies

Green design strategies enhance the quality of the city environment and the life of its inhabitants. Green design strategies play a vital role in the wide range of benefits provided to humans in their urban spaces where it is urgent to consider the need for urban green coverages such as grass and trees as well as the use of water features (Brown & Gillespie, 1995).

3.1 Vegetation

One of the green design startegies frequently employed is the vegetation, which is a natural landscape element, It helps to achieve the two aims in this research (the improvement of the microclimate and human thermal comfort in the outdoors). There exist four main ways to modify the urban microclimate through vegetation, especially through the use of trees: firstly by modifying the solar radiation intensity, secondly by modifying the reflected radiation from the ground and other surfaces, thirdly by modifying the relative humidity and finally by modifying the wind. The main effect of vegetation on thermal comfort lies in its shading effect, where trees reduce thermal radiation by reflection and absorption, trees can block a great amount of incoming shortwaves as well as they reduce the longwave radiation because of the decrease in the surface temperature values. Accordingly, the significant characteristic of the trees is its shape, location, and leaf density (Lai, Liu, Gan, Liu, & Chen, 2019). Another principle that affects the microclimate is the humidification through the evapotranspiration process which is the sum of two evaporation process and transpiration process. Previous studies showed that, in a dry climate, vegetation has the ability to increase the local RH by 3% to 6% compared to spaces without vegetation (Louafi, Abdou, & Reiter, 2017).

Various studies have focused on the important effects achieved by the vegetations in the modification of the microclimate. In his simulation performed in the Mediterranean climate of spain, Gkatsopoulos, (2017)suggested that trees can lower air temperature under its canopy by 1.5˚ C relative to the surrounding area.

3.2 Water Features

Water features are also considered an important element used in green design strategies. Their importance stems from their ability to improve spatial perception within their location in the organization of spaces, as well as their ability to increase the quality of a place, and consequently its psychological effect on users. Research focusing on the effect of water surfaces on the microclimate are relatively less than those on vegetation, where using artificial lakes, water fountains and water features in outdoor spaces as a bioclimatic technique to improve the microclimate is an effective strategy in hot dry conditions(Manteghi, Bin Limit, & Remaz, 2015). Bodies of water act as good heat sinks, particularly, in the peak thermal stress periods of the day. The evaporation provided by the presence of water causes a lift in latent heat, which in turn leads to better cooling during the day. It can be said that these bodies of water are effectivley sources of cooling for the areas around them.The physical characteristics of the water features and their effect on microclimate include the area, depth, and shape. The expansion of the water features area can increase the evaporation area of the water surface, and then increase the latent heat exchange between water and the atmospheric environment. Certain researches have shown that added thermal improvement takes place, when wind blows more uniformely on an elongated body of water and is more aligned with it.(Syafii et al., 2017)

According to a study in Singapore, it was found that air temperatures near water features, like ponds, pools and water walls, were found cooler by up to 1.8°C as compared to surrounding urban built up areas during sunny, clear days(Syafii et al., 2017). Moreover, a study in Japan by(Kimoto, Iyota, Nishimura, & Nomura, 1998) showed that air temperature above an urban water pond was 1°C to 2°C lower as compared to the surrounding park during the daytime. However, there was an increase in the levels of humidity, as the evaporation process took place, with its cooling effect which could have a moderation impact in hot arid regions. The use of water as a Strategy of mitigation, should be sensitive to the problem of water scarcity in our region, which should not be ignored. Thus, the use of the gray water system, as a mitigation strategy, could be one of the practical solutions.

4. Methodology

To achieve the peviously mentioned aim of this study, the ENVI-met V.4 simulation software was used to investigate and quantify the effects of the application of green strategies on feelings of thermal comfort in outdoor areas in a location characterized by its hot arid climate.. The objective was to explore the difference between the existing case and a comparative scenario after adding vegetation and water features.

4.1. Simulation with ENVI-met

Various simulation softwares are used to estimate the evaluation of human thermal comfort in outdoor spaces, such as Envi-met, Rayman, Autodesk Computational Fluid Dynamics (CFD), and two plug-ins used in Grasshopper for Rhino, namely Lady Bug and Honey Bee. In this study, Envi-met, the three dimensional model, was used. The simulation process of the model was performed at three main levels, as shown in figure 1. Firstly, in the (Area Input File Editor), the urban environment is designed (building masses, streets, pavements, vegetation, etc.) and the respective structural materials with their thermophysical properties were defined. Secondly in the (the Configuration File Editor), data related to climate were fed into the system (Air temperature, relative humidity, wind speed and direction, turbulence model, time steps, etc) and the simulation limitations were defined. Finally, start the Envimet, the calculations were conducted based on the two aforesaid data files. Interpretation and visualization of the results were carried out through using the LEONARDO application. The Output files of the simulation were imported in BIOMET application, a tool inside the Envi-met software, in order to calculate the thermal comfort index (PMV). Body parameters were defined, as per the standard human. The selected height for the calculations was defined at 1.8m. ENVI-met data output was extracted for the neighborhood area using microsoft excel 2019 where the average of Ta, RH, Va, and MRT were calculated.

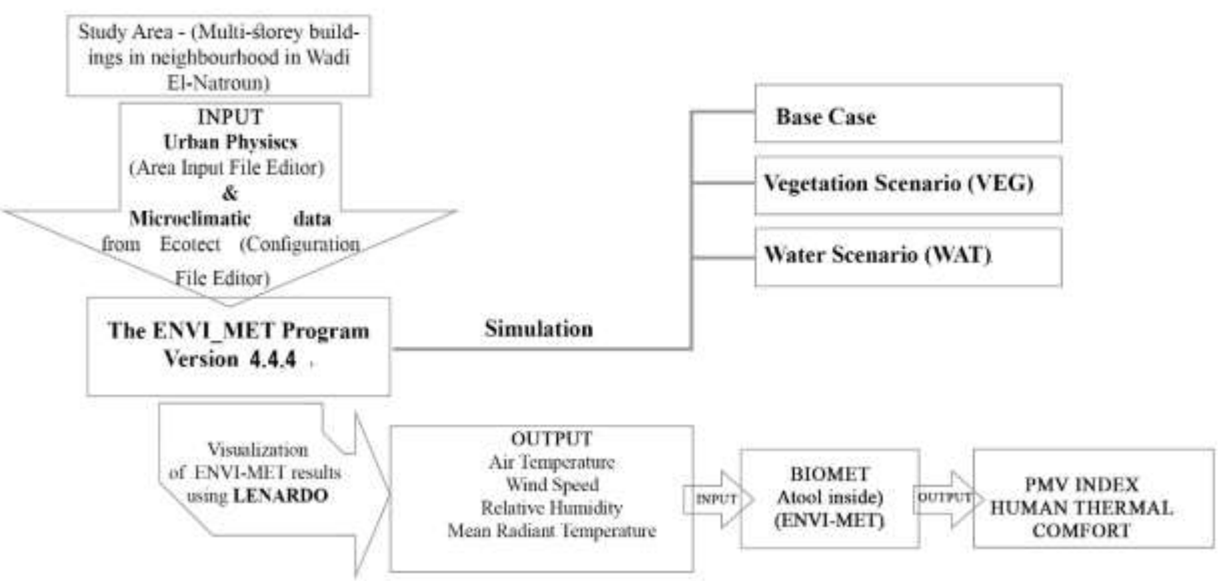

Figure 1 Flow chart Showing Results visualization and analysis strategy

4.2. ENVI-met Validation and Limaitation

In many research studies, ENVI-met has proven its success in performing thermal simulations for outdoor areas. (M. Fahmy, Mahmoud, Elwy, & Mahmoud, 2020; Gehl Jan, 1996; Yang et al., 2011; Yilmaz, Mutlu, & Yilmaz, 2018;Nasrollahi, Ghosouri, Khodakarami, & Taleghani, 2020).These studies confirmed an agreement between the measured data (from the field measurements or observed data at the local meteorological stations) and simulated air temperatures. Envi-met has the capability to simulate the microclimate of any location all over the world. (Tsoka, Tsikaloudaki, & Theodosiou, 2018).

However, Envi-met simulation tool has some certain limitations. The free version can simulate a limited areas of 50*50 m. Also, the tools available in this software to create the urban environment are only limited to the buildings, soil, pavement materials, and vegetation. There are no tools available to create any other objects such as shading structures that are independent from the building blocks. Another important limitation includes the oversimplification of buildings facades with a single mean heat transmission value for all buildings with in the model. Moreover, ENVI-met software cannot simulate water turbulent mixing so water strategies is only limited to still water bodies. Therfore, water bodies are inputted as a type of soil, and the process is limited to the transmission and absorption of the shortwave radiations. (Nasrollahi et al., 2020)

4.3. Study Area

A site located in Wadi El.Natroun was selected. This site is within the periphery of El Bahira governorate in Egypt and is located in a desert area. Wadi El.Natroun is the largest district in the governorate. It is specifically located at the eastern boundary of the Egyptian Western desert adjacent to the Nile Delta, just west of the Cairo-Alexandria Desert Road located approximately 110 km from Alexandria and 90 km from Cairo .It is about 10 km west of the entrance to Sadat City. The selected neighborhood's geographical position is on longitudes 30°05'–30°36'E and latitudes 30°29'–30°17'N as shown in figure 2 (King & Salem, 2013).

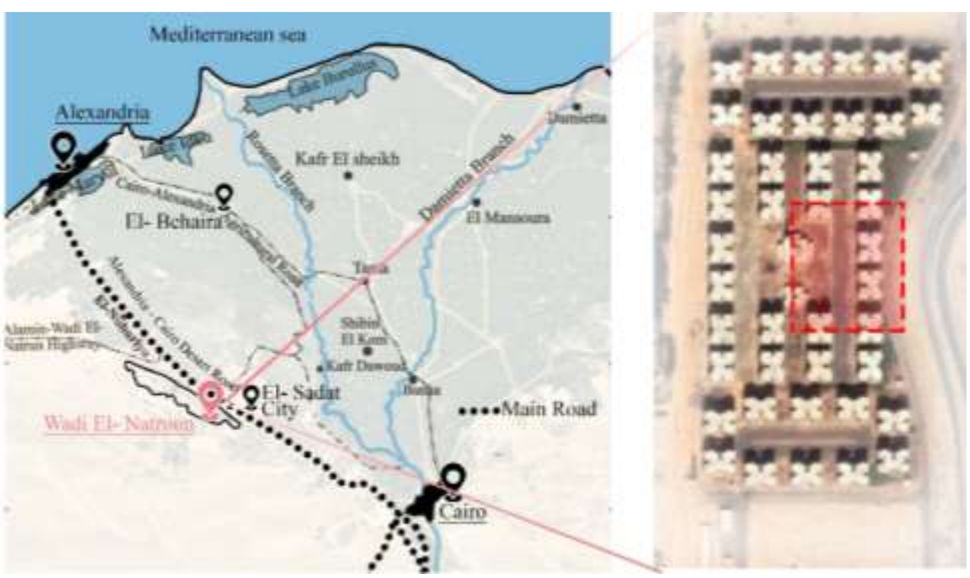

Figure 2 On the left: Map showing the location of Wadi El Natroun with in Egypt . On the Right: showing the neighborhood with in Wadi el Natroun, , Source: (Google Earth, 2021), Edited by the Researcher

As can be seen in Figure 3, the main areas of the site are hard and impermeable, while very little areas are permeable. The lack of shading and cooling elements make the site overheated during the months of summer. The green cover looks poor with only one kind of vegetation including deteriorated grass. There are no interactive landscape components or even enough interesting pedestrian routes, which makes the place thermally uncomafortable and leaves it looking like an abandoned desert. The highlighted area in figure 2 and 3 is the simulated area on the Envi-met program and this is due to the programs area limitation. This area is specifically selected due to its high exposure to solar radiation.

Figure 3 Images showing the site's study area taken with a Canon camera and an Iphone x Source: The Researcher

Table 1 Showing the physical characteristics of the study area

Building				
Function	**Roof Material**	**Façade Material**	**Height**	**Albedo Value**
Residential building	Mosaic	Plaster	18 m	0.45
Mosque	Mosaic	Plaster	7m	0.4
Nursery	Mosaic	Plaster	5m	0.4
Surfaces				
Function	**Material**		**Albedo Value**	
Roads	Asphalt		0.20	
Pavements	Red Interlock concrete		0.3	

New Developments such as the selected neighbourhood in Wadi El.Natroun were planned for social housing to accommodate the huge increase in the population and solve the housing problem. These areas were developed for the purpose of controlling growth in major cities and establishing smaller cities with a more balanced social and economic growth. Wadi El Natroun is classified as hot arid area. According to Koopen, the whole Egyptian climate could be classified as a hot dessert climate (BWh). (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). The climatic conditions of Wadi El-Natrun area are those characterizing the desert areas of Egypt. According to 30 years of meteorological data from the World Meteorological Organization (WMO's) the area experiences four seasons throughout the year, the summer season has extremely hot temperature which was recorded in July and August, while in the winter season has cold temperature which was recorded in January. The average maximum temperature of the year is 27.9, while the minimum temperature is 13.4 °C. The area is mainly characterized by a hot rainless summer, receiving approximately 31.5 mm of precipitation per year, recording the highest value 9 mm was which was recorded in January as well as recording zero mm in

July and August. . In this study, the climatic data for the simulations were obtained from the weather data file from Ecotect.

4.3.1 Model Description

The study focused on the summer period specially in July which is known to be the hottest month of the year. During this time of the year, the site is exposed to direct solar radiation that directly affects the air temperature, micro-climate conditions and consequently affects the thermal comfort in the space. In order to assess site microclimatic conditions against the different strategy scenarios used, simulations were held for the peak solar radiation periods on the 19 of July as a representation for a typical summer day. As the inputs for the model description and meteorological data is shown in the table 2 as well as the personal data concerning the human body such as the age, gender, height, weight, clothing insulation and metabolic rate is also elaborated in table 2.

Table 2 Input parameter for the case study

General Simulation Settings	
Parameters	**Input Values**
Position	
Location	Wadi El Natroun
Geographical Position	Latitude:(30 24’34 .09 N) Longitude :(30 21’ 28.07 E)
Model Dimensions	
Area of the Study Model	78*78
Number of Grid Cells (X,Y,Z)	50*50*40
Size of Grid cell (X,Y,Z)	2*2*2
Nesting Grids (X,Y,Z)	11*11*11
Soil profile for all grids (main, nesting)	Sandy soil
Model Rotation out of grid north	45
Simulation Data and Time	19^{th} July
Initial Meteorological Conditions	
Initial Atmosphere Temperature (C)	27
Air Velocity (m/s)	3.7 m/s
Wind Direction (degrees)	North west
Relative Humidity (%)	55
Roughness length	0.01
Sky Cover	Clear sky
Human Parameters	
Metabolic rate (W)	80 W (walking)
Clothing Insulation (clo)	0.5 – Summer Clothing
Weight	75
Height	1.75
Age	35
Gender	Male

4.3.2 Current Simulation and Proposed scenarios

Ta, Ws, RH, and PMV were recored for the three cases tested (base case and two different scenarios) to enable the understanding of the effect of the different strategies employed. The urban morphology regarding (the street orientation, aspect ratio, sky view factor, and building envelop form) has been fixed in the model area for all the scenarios as well as building materials have also been fixed in all models.

The base case simulation has been taken as a point of reference for comparison with the scenarios that include the new strategies interventions. The base case ground surface materials were asphalt with a low albedo of 0.20, representing streets in the neighbourhood with width 11 m and red interlock with a middle albedo 0.30 representing the side walk pavement with width 1.0 m, infront of buildings, as well as it was used in the central area surrounding the mosque and the nursery.

The output data results as shown in table 3 simulated on the 19th of July revealed specific micro-climatic problems that the case study is currently experiencing. These problems can be observed by the human eye and experience. Values from the results affirm and validate these observations. These problems is that the study area has high percentage of asphalt as well as it lacks shading and suffer from strong solar radiations that leads to rising surface temperature and consequently rising air temperature. Therefore, in this area there is thermal discomfort during certain times of the day.

The applied scenarios were inspired by the literature review. Two scenarios with different green design strategies interventions were proposed to tackle the problems of the site and try to present some solutions. These scenarioes concentrate on heat mitigation and the improvement of human thermal comfort. Their basis were two physical principles: (1) decreasing solar absorption in the urban environment and (2) increasing evapotranspiration and evaporation by using greenery and water.

Figure 4 2D plan and 3D showing the base case (BC), Vegetation (VEG) Scenario and Water Scenario, Source: The researcher

The first scenario is an attempt to investigate the effect of adding vegetation (VEG) on the microclimate and the human thermal comfort. Since solar radiation is the main problem therefore, using trees and grass with certain characteristics must be introduced to the study site, as a green design strategy for heat mitigation and thermal comfort improvement. In this Scenario, the hard surfaces will be limited, while the permeable surfaces will be increased. Street width is reduced to be 7m instead of 11 m to to decrease the surface area of asphalt, increase the area of green spaces and to provide a pedestrian path. The trees used in this scenario are the Delonix Regia (Poinciana), the most popular shade tree in Egypt during the summer. It’s very native to Egypt and very popular with the people. It’s a fast-growing deciduous tree that provides shade during summer and sun exposure during wintertime.

The selected tree is characterized by a wide horizontal canopy forming an umbrella that spreads up to 15 m at maturity It also has a relatively middle height of 8-15 m at maturity which makes it more effective on the pedestrian level. This tree is also heat and drought tolerant, with a relatively moderate need of water, which fits with the site's characteristics. In the central area, trees will be located on grass area this means that the interlock pavements will be replaced by green areas (5 cm of grass). These trees will be also located to provide almost 100% coverage for the central area where people usually use this area, also a row in front of the building will be located on the pavement to provide shade for pedestrians walking in front of the building as shown in figure 4.

The Second Scenario attempts to improve the microclimate and the human thermal comfort and liveability of urban open spaces during the hottest months of the summer by implementing water features (WAT) as a cooling system, where evaporative cooling is an environmentally friendly air conditioning system that operates using induced processes of heat and mass transfer, where water and air are the working fluids. The water feature used in this strategy is a four rectangular strips shape pool with an area of 5*30 each and a depth of 0.3 m in the central area as shown in figure 4. As per the recommendation of the literature reviw, the shape of the water features is elongated and lies in the same direction as the prevailing wind for maximum benefits. Due to water sacristy and water problems, which is one of the most serious environmental challenges we are facing nowadays in the whole world and especially in our country, the gray water system will used in this strategy instead of fresh water. In this system, gray water tanks will be used to treat water collected from baths, showers, bathroom basins and laundry in corresponding neighborhoods. This gray water will then be directed in pipes towards the water bodies suggested in this study.

4.3.3 Results and Discussions

The following results were deduced after running the scenarios through the Envi-met program. The simulation patterns were performed on the neighbourhood and were extracted by using an excel sheets with raw output data from the case study, where various changes were observed in the values.

Table 3 Simulation values during the simulated hours for Ta, Ts, Ws, RH, MRT and PMV Source: Researcher

Time (hours)	Ta ˚C			Ws m/s			RH%			MRT˚C			PMV		
	BC	VEG	WAT	BC	VEG	WAT	BC	VEG	WAT	BC	VEG	WAT	BC	VEG	WAT
12:00	29.85	28.91	29.43	1.84	1.82	1.84	54.73	56.73	57.04	57.48	50.3	55.2	3.62	2.57	3.09
13:00	31.17	30.04	30.58	1.87	1.85	1.87	52.67	54.59	54.57	62.82	52.03	60.52	4.16	3.07	3.93
14:00	32.09	30.92	31.57	1.88	1.86	1.88	51.19	53.31	53.27	67.64	52.89	65.54	5.04	3.40	4.76
15:00	32.80	31.56	32.28	1.89	1.87	1.89	50.29	51.95	52.35	70.62	49.54	69.11	5.64	3.47	5.29
16:00	33.26	32.10	32.86	1.89	1.87	1.90	49.09	50.77	50.77	70.78	48.44	69.63	5.92	3.44	5.59
17:00	32.80	31.63	32.4	1.90	1.88	1.90	50.58	52.30	51.56	65.41	41.75	64.61	3.90	2.54	3.65

When comparing the base case to the applied vegetation scenario the simulated Ta at height 1.8 m decreased and reached a range between 28.91 ˚C and 32.10 ˚C, therefore a noticed drop occurred by 1.0 ˚C. Relative humidity increased by approximately 2 % during the simulated hours, due to the transpiration process. This increase in RH leads to better human comfort conditions, as the optimal levels 40%–60%. The Ws showed a slight decrease in its values. As for MRT, it witnessed a major decrease and its values ranged between 7.18 ˚C and 23.66 ˚C after simulation. The use of trees and soft materials, such as grass on the ground surfaces within the outdoor area, helped to improve the PMV values with varying effects, where the delta decrease ranged from 1.05 to 2.48 which contributes to a great improvement in the human thermal comfort, with the maximum improvement occurring hours of 15:00 and 16:00. It's clear through the thermal maps that the highest drops occurred specifically in the areas where trees existed due to the tree canopy shading.Trees have the ability to protect the pedestrians from the direct sunlight by reflection and absorption, it is well proven that trees can remove a great amount of incoming short-wave solar radiation causing the shading effect. Additionally, to blocking short-wave radiation, trees can reduce long-wave radiation because of the decrease in surface temperature. Also, the whole evapotranspiration process effect plays a significant role in cooling in the case of all types of vegetation.

In the second scenario with the addition of the water features, compared to the base case, the simulated Ta values ranged between 29.43 ˚C and 32.86 ˚C. Thus, a noticed drop 0.5 ˚C occurred. These results show that air temperatures above an urban water feature was 0.75°C lower compared to the surrounding site during daytime. Ws were not affected by the presence of the water feature, while the average RH values was found to increase by 2% due to the evaporation of water which contributes to increasing the humidity in the air, which is helpful in hot arid weather. A for MRT, it showed a noticeable decrease in its values by 2 ˚C due to the decrease in the long wave radiation. Moreover, the use of water feature in the outdoor central area had a moderate improvement effect on PMV, where an enhancement of 0.35 was clearly seen in comparison with the base case. The water element has a significant impact on Ta and RH just within 2-6 meters distance from the water body. It can, therefore, be concluded that the cooling effect of evaporation from the on water body is strongly impacted nearby spaces.

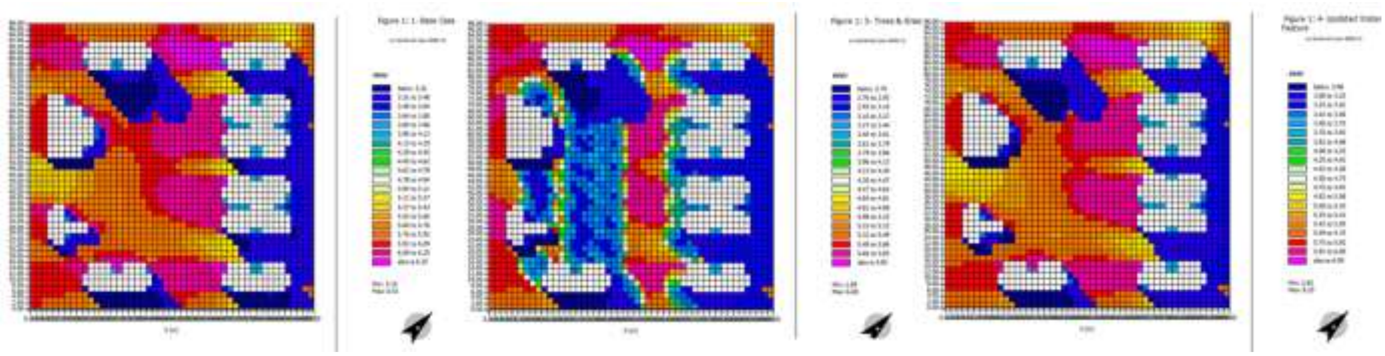

Figure 5 showing LEONARDO maps of PMV distribution at human height 1.8m for BC, VEG and WAT Scenario the 19th of July , source: The researcher

The scenario of using vegetation is usually better, providing more improved results than the scenario of using a water body, as the latter does not block direct solar radiation.

5. Conclusion

Green design strategies have demonstrated their ability to greatly affect human thermal comfort, as they can improve microclimatic factors. This improvement was proven by Envi-met simulation in hot-arid climates. The results of this study well-proved that the most influential parameter on the microclimate specially when dealing with the summer heat in wadi el Natroun is the direct solar radiation. This parameter affects especially air temperature and mean radiant temperature. This was clearly seen in the first scenario, where trees with their large canopies provided a more significant improvement in human thermal comfort, seen in PMV values in outdoor areas. The advantages of vegetation in hot arid climate are the reduction of incoming solar radiation and value of air temperature expressed by their shading effect and evapotranspiration process. However, the vegetation scenario improvement couldn't drive the PMV index to reach the comfort zone, but helped to improve the PMV values where the delta decrease ranged from 1.05 to 2.48.

The higher improvement in the PMV values when using vegetation especially shade trees rather than water surfaces agrees with previous results in the literature.This paper findings are limited to hot arid climates and canot to be generalized for other climatic conditions. In future research, it is suggested to test out other scenarios, that focus on different parameters in the built area, including building layout and height to width ratio, in order to compare the impact of different scenarios versus the original design in the early design stages.

Acknowlegment

The support of Dr. Samar Allam is gratefully acknowledged for helping with the understanding of Envi-met simulation Program.

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استخدام استراتيجيات التصميم الأخضر لتحقيق الراحة الحرارية

(تطبيق PMV كأداة قياس)

تحسين الراحة الحرارية هو العامل الرئيسي في تحقيق حيوية ووظائف المناطق الحضرية. من أجل تحقيق منطقه مريحة حراريا ، يجب على المصممين النظر في حلول تصميم المناطق الحضرية والمعمارية والمناظر الطبيعية المناسبة. المشكلة الرئيسية هي أن معظم التطورات الأخيرة في مصر لم تنظر في استخدام استراتيجيات التصميم الملائم للبيئه مما أدى إلى عدم الراحة الحرارية للانسان. تناقش هذه الدراسة و تحدد كميا تأثير تدخلات استراتيجيات التصميم الأخضر على دراسة حالة محلية تقع في مصر (المنطقة الحاره جافه) وتأثيرها على المناخ الحضري والراحة الحرارية للانسان. وتستند المنهجية المستخدمة إلى محاكاة Envi-met لقياس المعلمات المناخية الأربعة ومؤشر.PMV وأشارت النتائج إلى أن تعزيز كبير في الراحة الحرارية مع تغطية الأشجار، حيث باستخدام الحد الأقصى لتغطية الأشجار أظهرت أفضل تحسن في قيم PMV مع انخفاض قدره 2.48 في ساعات الذروة بالمقارنة مع حالة الأساس.وأظهرت النتائج أن الأشجار هي استراتيجية هامة لتحسين الظروف المناخية الدقيقة والراحة الحرارية البشرية في الأماكن المفتوحة بسبب تأثير التظليل حيث تمنع الأشجار الإشعاع الشمسي المباشر.