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Transforming grey to green: Enhancing microclimates in hot arid regions with green open spaces

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Abstract: The utilization of parking lots, rubbish dumps, and other similar sites has led to an increase in the number of gray spaces in urban areas over the past several years. As a means of contributing to the improvement of the urban climate and ecology, it is necessary to propose solutions for these waste regions. The purpose of this study was to evaluate the impact that converting gray spaces into green spaces has on the microclimate and thermal comfort in an open environment associated with a hot and dry climate. Baghdad's Abu Nawas neighborhood was chosen as the location for one of the substreets that overlook Al-Saadoun Street. This neighborhood is characterized by its gray open space. A simulation technique that utilizes the program ENVI-met was employed to produce a green open space. Several factors, including air temperature, average radiant temperature, wind speed, and humidity, are included in the measurement of the microclimate factor. The findings demonstrated that greening open spaces has a positive impact on all microclimate characteristics, reduces the effects of urban heat islands, and makes these locations more sustainable and habitable overall. Additionally, the findings provide guidelines for legislators and urban planners to implement these improvements in regions that are hot and dry.

Keywords: *Green Open Space, Grey Open Space, Hot Arid Climate, Microclimate, Open Spaces.*

1. Introduction

Last century, there has been a progressive increase in rural-to-urban migration, which culminated in 2016 seeing Over half the world population reside in urban areas [1]. The area has become rapidly urbanized over the past few decades because of both population growth and the expanding number of urban people. Urban regions are characterized by dense populations, man-made surfaces, and

little vegetation [2].These elements mainly satisfied the needs of cities' walkability and practicality. However, the increased of grey spaces which refer to urban areas dominated by hard, impervious surfaces such as concrete, asphalt, and buildings. These spaces typically lack vegetation and greenery, contributing to urban heat islands, reduced air quality, and limited biodiversity. Examples of grey spaces include parking lots, rooftops, streets, and industrial zones. The concept contrasts with "green spaces," which are areas with natural vegetation that provide environmental and social benefits. Greening grey spaces involves introducing plants and green infrastructure to mitigate negative impacts and enhance urban livability of land under use has resulted in adverse environmental effects caused by humans, such as degradation of the quality of the soil, water, and air or a decline in biodiversity [3]. In addition, urban development increases energy consumption, creates new urban heat islands (UHI), and alters wind patterns locally [4]. Climate change simultaneously intensifies these stressors and raises the dangers to health and vulnerability [5]. Consequently, in order to address these issues, cities look for guidance for modifying urban planning regulations. One important subject is heating mitigation, which aims to reduce negative health effects and enhance population thermal comfort in densely populated

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places. Numerous urban cooling techniques exist, most of which target one or more facets of the lower atmosphere's energy balance [6]. For example- Cool urban materials, such as pervious or green alternative surfaces, or increased reflectivity/emissivity and thermal inertia, offset the detrimental effects of dark impervious surfaces [7, 8]. Energy-saving measures can also be encouraged, and metropolitan areas generally lack vegetation; however, this can be compensated for by using greening and watering cooling strategies [9].

Unquestionably, one of the most well-known and effective passive methods now in use for regulating the urban microclimate is urban greening [10-12]. Additionally, there are a plethora of additional benefits that come with urban greening, including Enhancing the quality of the soil and air [13]. Growing perceptions of the quality of life and local attractiveness [14]. Contributing to the protection of biodiversity [15].

open spaces are considered an influential element in the design of cities of all kinds, as they contribute to increasing the interdependence of their parts as well as facilitating the movement between their parts, and that afforestation and the addition of appropriate building materials will help in changing the temperatures, for the purpose of setting a plan for the development of the external spaces.

When it comes to enhancing the quality of the environment, the presence of water, trees, and plants in their many forms all play a significant role. The occurrence of this process is one of the most significant factors that contribute to the alteration of land cover, which might result in the undesirable phenomenon of hot air. Worlanyo and Jiangfeng [16] dust, high temperatures and reflections of sunlight.

The transition from open green public usage to grey spaces, which is one of the most widespread phenomena in Baghdad, is one of the elements that is impacting these phenomena. This shift in use is one of the factors that is affecting these phenomena. Consequently, the incorporation of flora and bodies of water into the interior of the building has the potential to enhance the thermal comfort of the infrastructure of the city [17]. Trees serve as a source of moisture, a temperature regulator, and an excellent barrier from the sun, radiation, wind, and tree shade. Trees also provide shade [18]. The rate of evaporation of water bodies is higher than that of vegetation, and the presence of water bodies inside the interior of an urban fabric has the potential to improve the thermal comfort of the urban fabric. The significance of water features in reducing the negative impacts of urban heat islands is described here. When the temperature is high during the summer, the presence of green spaces is the most effective cooling element in urban areas. The UHI results in a decrease in the temperature of the air in regions that are located above or close to the green spaces. Vegetation is the most effective heat absorber, and it can even remove heat from the environment [19].

Table 1.

Term	Definition or explanation
Open spaces	Areas that are open to the environment
Green open space	Open spaces with natural vegetation
Grey open space	Urban areas dominated by hard, impervious surfaces like concrete and asphalt
Microclimate	The climate of a small, specific place within an area as contrasted with the climate of the entire area
Hot arid climate	A climate characterized by hot temperatures and very low rainfall
Urban Heat Islands (UHI)	Urban areas that are significantly warmer than their rural surroundings due to human activities
ENVI-met	A software for simulating the microclimate of urban environments
MRT	Mean Radiant Temperature
PMV	Predicted Mean Vote, a thermal comfort index
PET	Physiological Equivalent Temperature, a thermal comfort index
UTCI	Universal Thermal Climate Index
Sky view factor (SVF)	The fraction of sky visible from a point on the ground
Flow V	Air movement or wind speed

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2. Literature Review

2.1. First Study

In the semi-arid city of Djelfa, Algeria, research is being conducted to determine the most effective method of greenery in order to guarantee appropriate thermal conditions. The goal of this research is to evaluate the effects that greening has on the metropolitan climate throughout the summertime. Using a computer model that was developed with the help of the ENVI-met tool and confirmed through measurements that were carried out in situ, four different scenarios are simulated, beginning with the current region and then modifying the vegetation practices. The outputs include a variety of things, including meteorological parameters and thermal comfort indices (PET and UTCI). The findings indicate that the green space has the ability to generate a cool island within the urban fabric, which ultimately leads to a drop in the peak daytime air temperature by approximately 4.75 degrees Celsius. When it comes to cooling, the density of vegetation in urban areas is superior to the greening of structures throughout the day with regard to performance. As the sun went down, the tree canopy became less dense, and the wind speed slowed down, which is the primary factor that contributes to the city's cooling during the overnight hours [20].

2.2. Second Study

The aim of this research is to utilize the ENVI-met simulation to investigate the impact that increased green space has on the conditions of the microclimate. Within the confines of this study, a comparison was made between the current state of affairs and a hypothetical situation in which there was an increase in the amount of green space. In order to conduct an analysis of the amount of green space, the ENVI-met simulation tool was utilized. Temperature, humidity, wind direction, and wind speed were among the climatic variables that were utilized that were measured. In the situation where there was an increase in green space, the total green area decreased to 2,487 square meters and grew to 4,398 square meters. The simulation results provide insight into the significant influence that this augmentation has on the microclimate. The temperature range observed varies from 31.11 degrees Celsius to 33.04 degrees Celsius, suggesting that the growth of green spaces leads to a decrease in temperature and has a beneficial effect on the environment. In general, this results in a temperature reduction of 0.45 degrees Celsius throughout the entire region. This study highlights the positive impact that increasing green space can have on the circumstances of the microclimate, and it does so by utilizing the results of ENVI-met simulations. It sheds light on the ways in which this kind of rise could be beneficial to temperature regulation. Because of these findings, it is clear that it is of utmost significance to consciously incorporate green space into the processes of urban planning and design. This is because green space helps inform decisions that are beneficial to the preservation of the environment. Since this is the case, it is recommended that local governments give the expansion of green spaces a higher priority in their subsequent projects, while also taking into consideration the microclimate and the quality of the environment [21].

2.3. Third Study

This study investigates the influence that different shade patterns, water features, and vegetation cover have on the level of thermal comfort that pedestrians experience when they are outside at educational facilities. Aims and objectives: Based on the city of Babylon as an example, the purpose of this research is to determine the impact that urban characteristics have on the level of thermal comfort experienced outside on an educational campus that is located in an area with a hot and dry climate. Within the framework of the research methodology, the ENVI-met application is utilized to simulate the case study. Discoveries: In addition to reducing the mean radiant temperature by 8 degrees Celsius and the sky view factor (SVF) by, the data indicate that urban adaption elements, which are the soft components of the environment, have the potential to reduce the temperature by around 3 degrees Celsius. There are a variety of shade patterns, water bodies, and vegetation cover that are included in these aspects.

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Despite the rapid urbanization that has taken place in hot and arid countries, the preponderance of grey spaces, which are places that are dominated by impervious surfaces such as concrete and asphalt, has led to major environmental issues. These concerns include but are not limited to greater temperatures, lower air quality, and diminished biodiversity. In order to significantly improve microclimates, it is absolutely necessary to conduct research into the possible advantages of transforming these grey areas into green and vegetated areas [22].

Previous studies have shown the importance of greening in improving climatic conditions in arid regions. For example, a study conducted in Algeria found that increasing vegetation cover can reduce local temperatures by up to 4.75°C. In addition, another study in Babylon confirmed the role of water bodies and diverse vegetation in improving pedestrian thermal comfort by reducing average radiant temperatures by 8°C.

3. Methodology

We decided to go with a certain open area in Abu Nawas, which is located in Baghdad, Iraq. In the past, there was a structure on the land that had a garden attached to it. After that, the structure was demolished and converted into a parking lot that was open and grey in color. This transition had an effect on the surrounding community because of the heat that was generated by the automobiles, the noise that was produced, and the pollution that was present in the air. The location of the site in respect to Abu Nawas Street is depicted in Figure 1, along with the site plan, which is depicted as an open parking lot.

The alterations that took place at the location are detailed in Table 2, which includes a comparison of the site before and after the change. Prior to the modification, the location had a floor that was paved with concrete, the walls that surrounded the site were built of cement, and there were no trees or plants present under any circumstances. Moreover, the utilization of the location had a detrimental impact on the surrounding region, which was exemplified by a parking lot. After the modification, the location was transformed into grassy soil, which served to wet the area. The location features a body of water in the center of the space, in addition to trees that are dispersed across the site, including at the entrance and in other corners of the location. Bricks are used to cover the walls that surround the site, and green plant walls are used to depict a portion of the walls that surround the site. For it, the use was changed to that of a park. There is a park in the middle of the street that is green. The roadway and the surrounding neighborhood were the only places where the usage for the street was changed from public to private.

An investigation into the ways in which the characteristics and functions of the open space influence the climate in the surrounding area was carried out by the paper with the assistance of a piece of software. A comparison between the two scenarios was carried out with the help of ENVI-met, which was applied accordingly. For the purpose of creating two separate models through the use of simulation, it was fully finished. In the past, it had been utilized as a construction site; however, it has now been changed into a parking lot, just like the rest of the capital. The ENVI-met simulation's climatic variables were chosen for their significance in enhancing thermal comfort and reducing the heat island effect. These factors, which directly reflect the effects of turning grey areas into green, were wind speed, humidity, and air temperature. In order to concentrate the study on elements that have a bigger influence on the local climate, some variables, such direct radiation levels, were also eliminated.

The place that was selected was a big area that measured 20 square meters by 13 square meters. A total of nine sample output files are included in the simulations, with each file serving as an example in its own right. The second step was to collect data according to geography; more specifically, a thickly populated metropolitan district in Baghdad was chosen, despite the fact that the city is infamous for having a hot and dry atmosphere and ENVI-met. This was done in spite of the fact that the city did not meet the criteria for ENVI-met. It is characterized by summers that are hot and dry, and winters that are both brief and warm to cool. The region is characterized by these characteristics. It is generally agreed that the summer season lasts for around eight months. As a consequence of this, the high

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temperature in Baghdad is one of the most important aspects of the environment that surrounds these cities. During the summer, it is not out of the question for the average temperature to be higher than 44 degrees Celsius (111 degrees Fahrenheit). It is quite rare for temperatures to drop below 24 degrees Celsius (75 degrees Fahrenheit) throughout the summer months, and this is true even during the evening hours. Temperatures that are considered to be high during the summer months typically reach 52 degrees Celsius (125 degrees Fahr.). Over the course of the summer months, the humidity level is frequently lower than fifty percent. Because of this, the simulation was run with temperatures ranging from 23 to 50 degrees Celsius to accurately represent the environment. It was decided that the event would take place on July 21, which is generally considered to be one of the hottest days of the season.

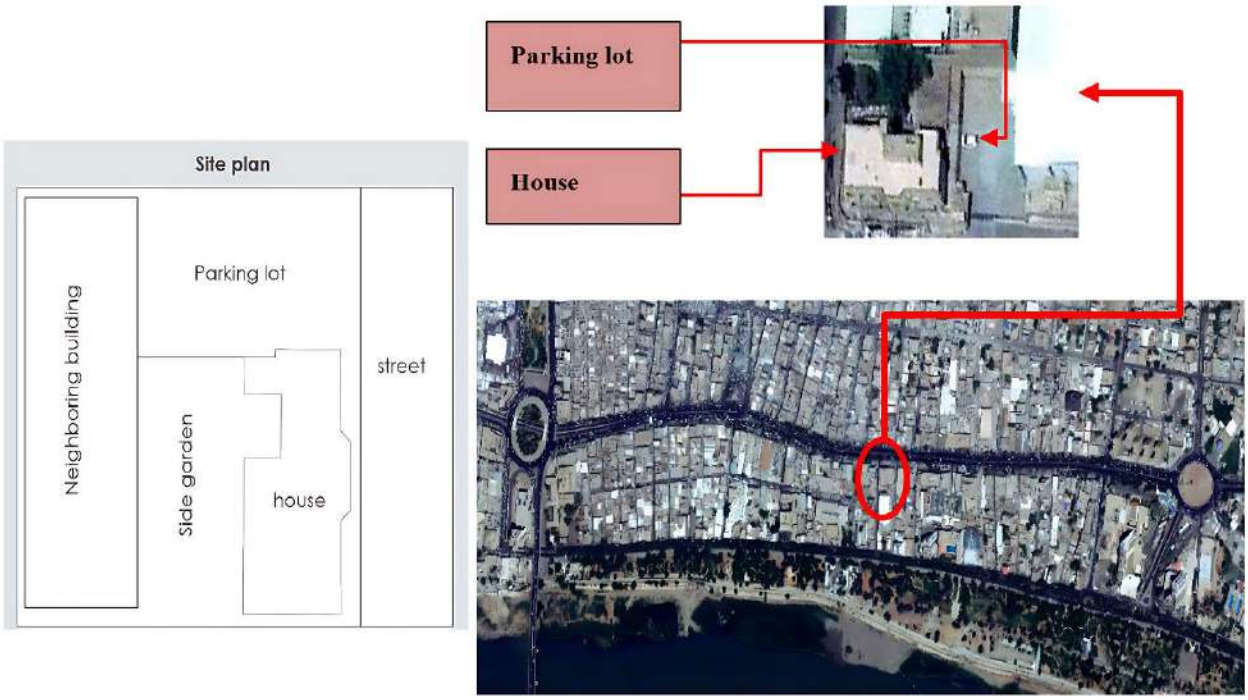

Figure 1.
Location of the site in relation to Abu Nawas Street and the site plan.

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Table 2.
Describes the changes that occurred to the site.

After change	Before change
The floor of the property contains grassy soil, which helps to keep the area moist. The location features a body of water in the center of the space, in addition to trees that are dispersed across the site, including at the entrance and in other corners of the location. Bricks are used to cover the walls that surround the site, and green plant walls are used to depict a portion of the walls that surround the site. It was converted into a park with a large expanse of land. At the center of the street, there is a green. The roadway and the surrounding area are the only places where the usage has been designated as private, having previously been public.	A concrete surface has been laid out on the land, and the walls that surround it are constructed out of cement. There are no trees or vegetation present at any point. In addition, the usage of the site has had a negative impact on the surrounding neighborhood. This is exemplified by the presence of a parking lot, which has led to the pollution of the air, noise, and dust. Additionally, the street has been converted from private to public use, and those who are not familiar with the region have also used the site.
	 

4. Results

Table 3 below lists the results obtained from a comparative analysis of two cases before and after changing the characteristics of the open space and its function, showing the effect of changing the vegetation cover, adding water bodies and changing the materials of the buildings surrounding the open space. It appears in the first and second. The results can be as follows:-

4.1. In Scenario 1

Concrete paving was used as a surface for the street. Compared with other roofs, it had the highest temperature indicators, as well as the yard is paved with concrete that has a high heat absorption capacity, and the walls surrounding the building are represented by cement and iron materials, in addition to the function of the yard as a parking lot.

4.2. In Scenario 2

The concrete paving was painted with white paint The concrete floor was replaced with grass and moist soil, a water body was added, the materials surrounding the building were changed, trees were added to the place, and the walls were covered with climbing plants that reduce heat absorption.

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Table 3.
Results obtained from a comparative analysis of two cases before and after changing the characteristics of the square and its function.

Open space	Parameter	Min.	Max.
Befor change	Air temp. (C°)	19.85	54.08
	MRT (C°)	50.63	58.52
	Wind speed(MPF)	1.22	3.22
	Relative humidity %	27.69	28.46
Aftter change	Air temp. (C°)	33.81	34.15
	MRT (C°)	45.85	52.10
	Wind speed(MPF)	3.00	3.88
	Relative humidity %	27.08	27.33
Befor change	Building & Vegetation	37.29	37.29
	Leaft Temperture	22.67	34.30
	Temperture For soil	19.85	45.07
	Temperature For Surface	19.85	54.08
	Sky view Factor	0.22	0.97
Aftter change	Building & Vegetation	35.08	35.88
	Leaft Temperture	19.93	36.29
	Temperture For soil	19.85	42.72
	Temperature For Surface	19.85	47.25
	Sky view Factor	0.20	0.96

In Table 4 the Minimum temperature 33.81 ℃ Maximum temperature 34.15 ℃ the temperature decreased by two degrees, which indicates the effect of changing the characteristics of the arena on the temperature. Minor temperature is 35.88 ℃. The maximum temperature is 35.08 ℃. The temperature decreased by two degrees, which notes the effect of changing the properties of the building and plants in relation to the temperature Aerodynamic movement 10.00 m/s Large, which forms air movement that helps to change the temperature and cooling the atmosphere minimum temperature 33.61℃. Great 34.15℃ two-degree drop in temperature. Minimum temperature the temperature is 37.03℃, the maximum temperature is 19.93℃ the temperature has decreased by three degrees, which notices the effect of a change in the heat emitted. Minimum temperature 19.93℃ and max temperature 36.29℃ the temperature has decreased by three degrees, which indicates the effect of changing plants on the temperature .Aerodynamic movement 10.00 m/s Large, which forms air movement that helps to change the temperature. Minimum temperature 19.85℃. Maximum Temperature 42.72 ℃. The temperature has decreased by two degrees to the maximum temperature, which notices the effect of changing the characteristics on the temperature, as the open space has a temperature of less than 22.14 ℃, which indicate the effect of the water surface, and the temperature in it ranges at this point due to the availability of different soil represented by the grass cover. Minimum temperature 19.85℃. Maximum temperature 47.25℃. The temperature decreased by seven degrees to the maximum temperature, which indicates the effect of changing the characteristics of the surfaces surrounding the open space on the temperature, as became with a temperature of less than 22.14℃.

This study offers a useful illustration of how to improve the local climate in arid, hot cities. This strategy might be broadly applicable to other cities in other regions of the world, such Dubai and Riyadh. These cities deal with comparable issues, such as growing urbanization and water scarcity. If natural variations like soil type, water supplies, and native plants that are adapted to the temperature are taken into consideration, greening initiatives can help lessen the urban heat island effect.

One of the main obstacles to putting green transformations into practice is sustainability. To guarantee long-term benefits in hot, arid climates, water conservation and routine plant care are crucial. Research suggests that using drought-resistant native plants and smart irrigation techniques can significantly reduce water needs, making these initiatives more sustainable in the face of climate change."

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Although the study demonstrated improvements in wind flow, a more thorough examination of the function of green space design—including the positioning of trees and water features—could greatly enhance wind dynamics. Trees can serve as obstacles that favorably channel airflow, improving local cooling. The efficiency of evaporative cooling can also be increased by positioning bodies of water in the direction of the wind.

The results of this study can be compared to comparable studies carried out in hot and arid regions like Algeria and Abu Dhabi, even though it concentrated on a particular situation in the Abu Nawas neighborhood of Baghdad. For instance, a research conducted in Algeria discovered that adding plants to urban areas reduced the temperature by 4.75°C. These analogies offer a more comprehensive framework for implementing the

5. Conclusion

It is possible to observe in Table 5 that the utilization of vegetation, in contrast to the utilization of a concrete surface, results in an improvement in the level of heat, as it diminishes by three degrees. This observation highlights. the impact that the utilization of different plants has on the temperature Table 5. The addition of trees and a body of water resulted in an improvement in the levels of temperature that were observed in the situation when the temperature was changing. These findings were more readily apparent in the scenario in which climbing plants were used to cover the surface of the built environment. The findings of the study suggest that grey open spaces within urban areas in a hot and dry climate should be replaced with green spaces that soften the atmosphere of the surrounding areas. This is because the precise and relatively small effect of the specific characteristics and function of the areas on the microclimate of the area necessitates the use of green spaces rather than heat-raising vehicles such as car parks, which pollute the areas.

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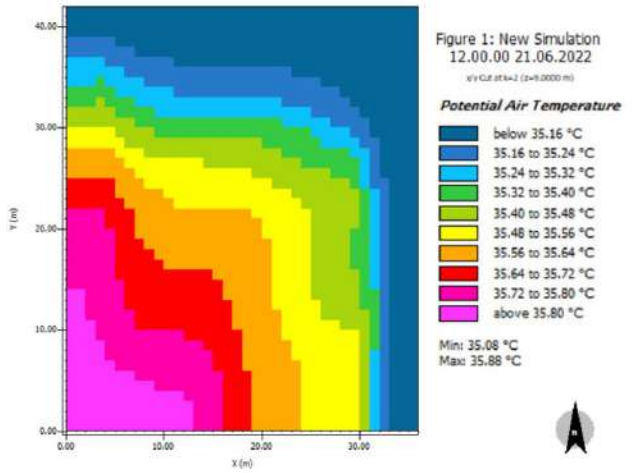
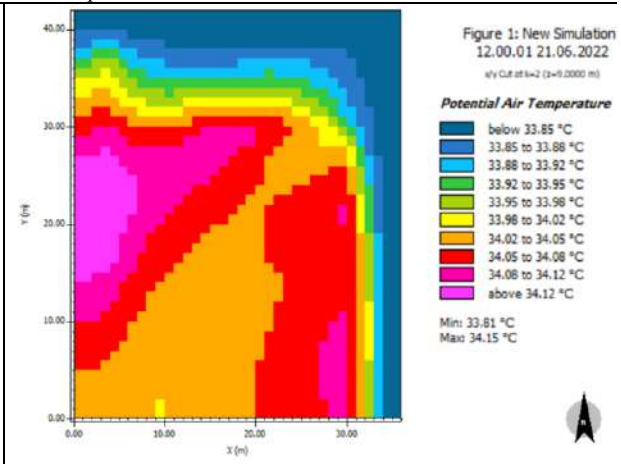
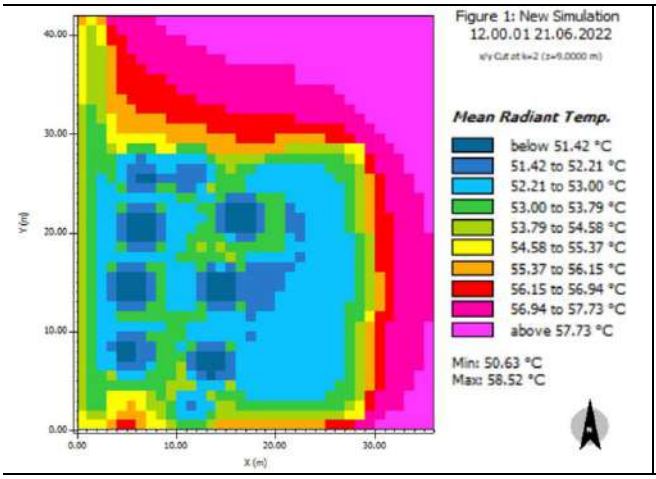
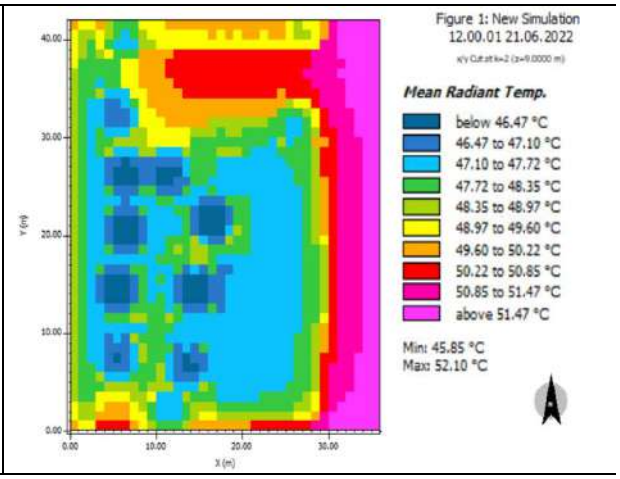
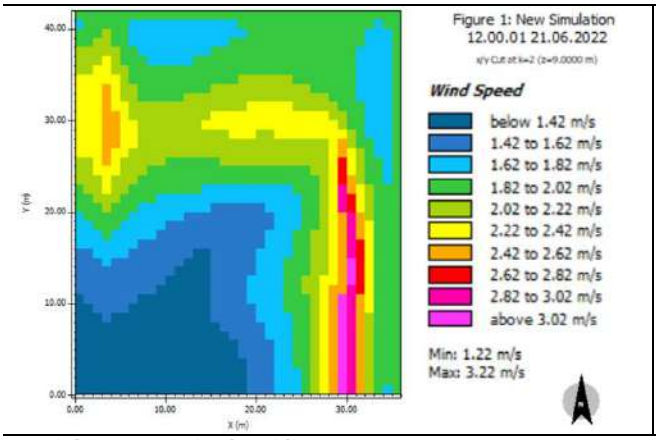
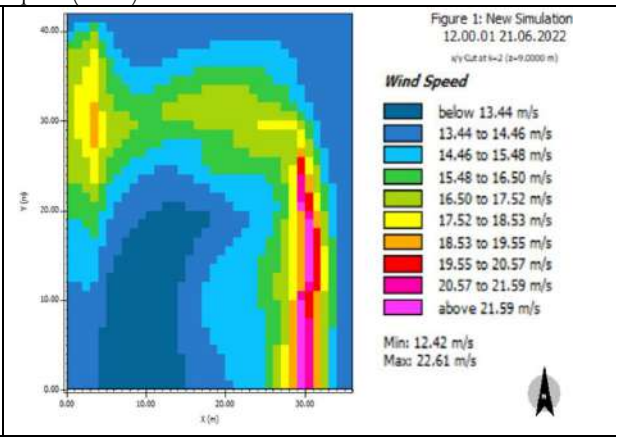
Table 4.
The variations in the microclimate before and after the modification.

Before change	After change
Variable1: Potential air Temperature	
	
Variable 2: MRT	
	
Variable 3: Wind speed (MPF)	
	
Variable 4: Relative humidity	

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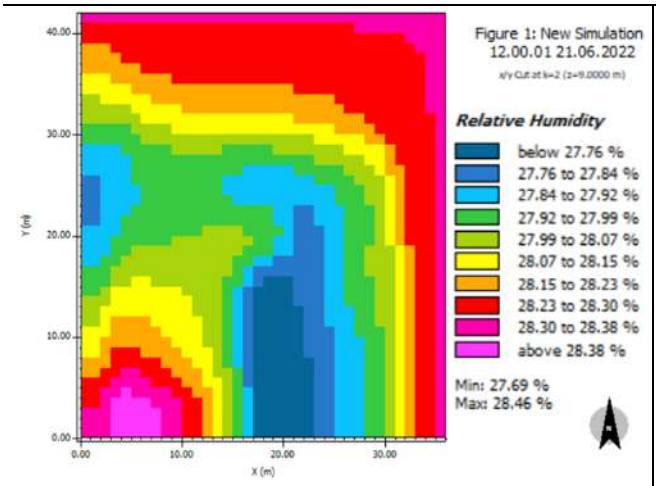
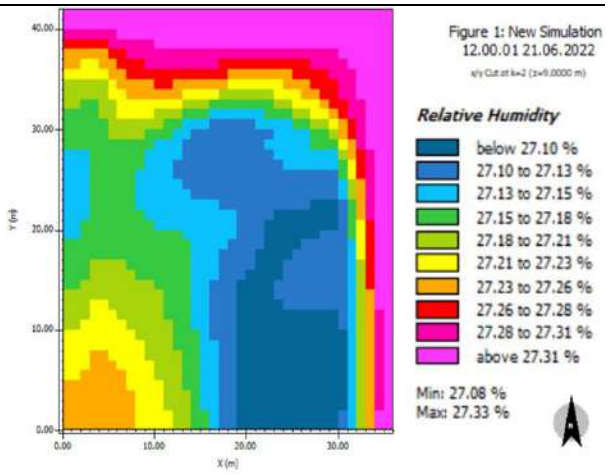
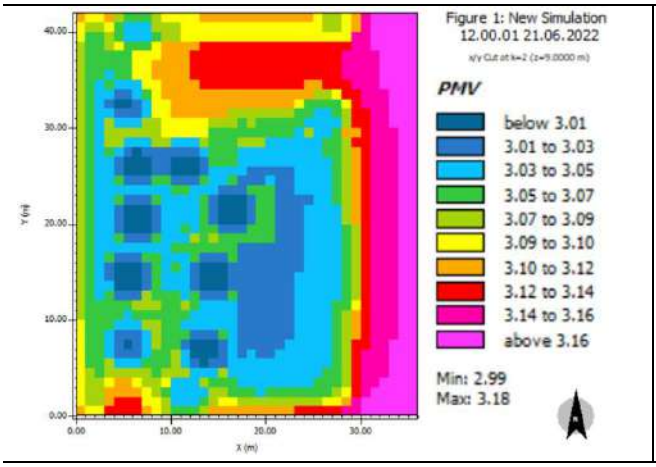
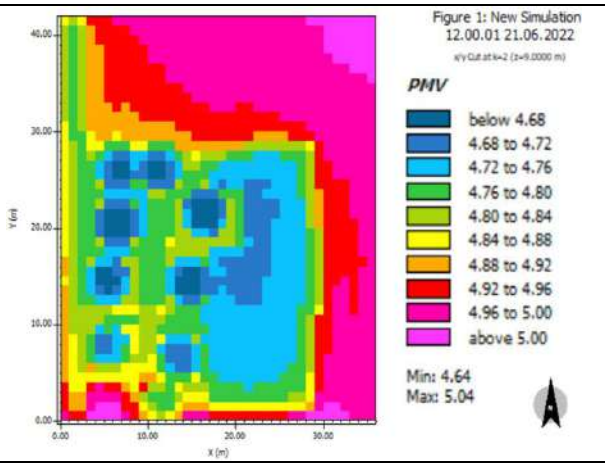


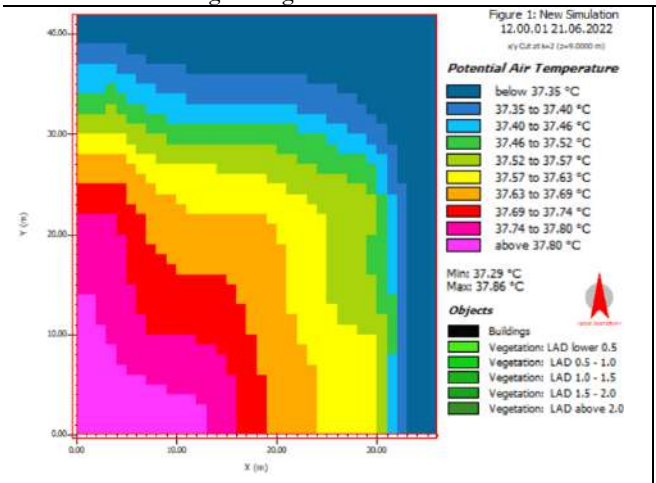


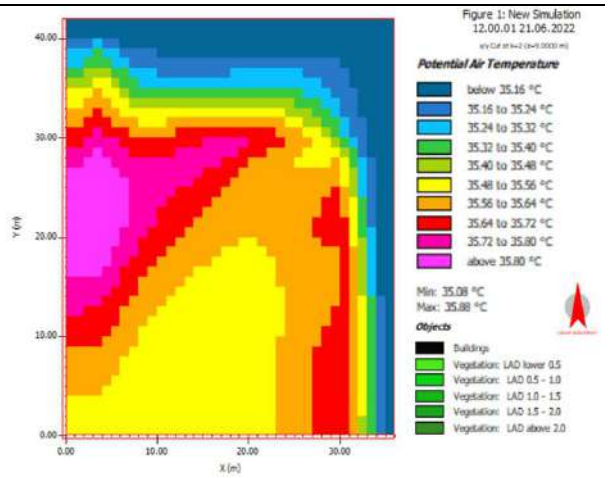
Variable 5: PMV





Variable 6: Buildings & vegetation





Variable 7: Flow V

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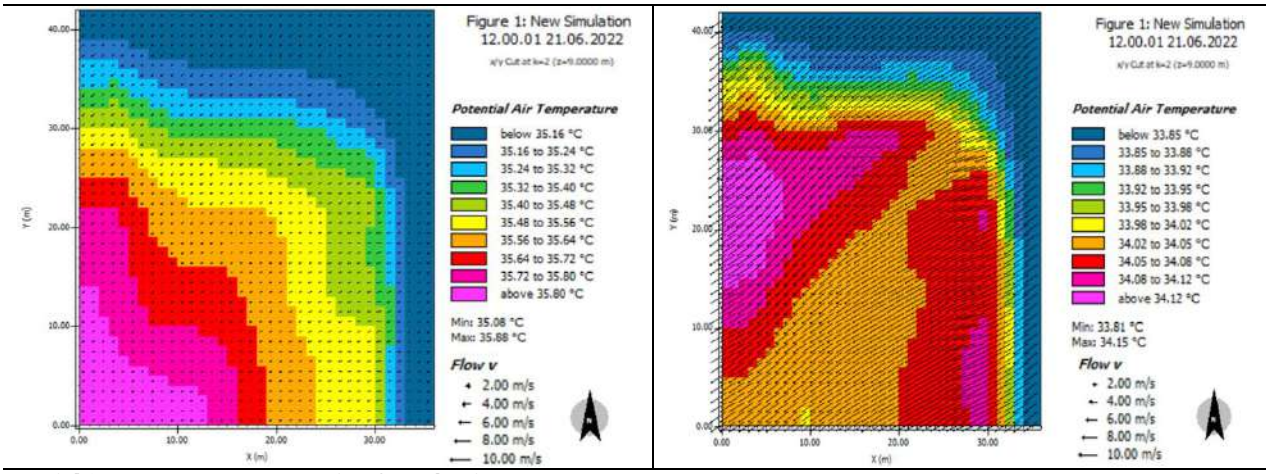
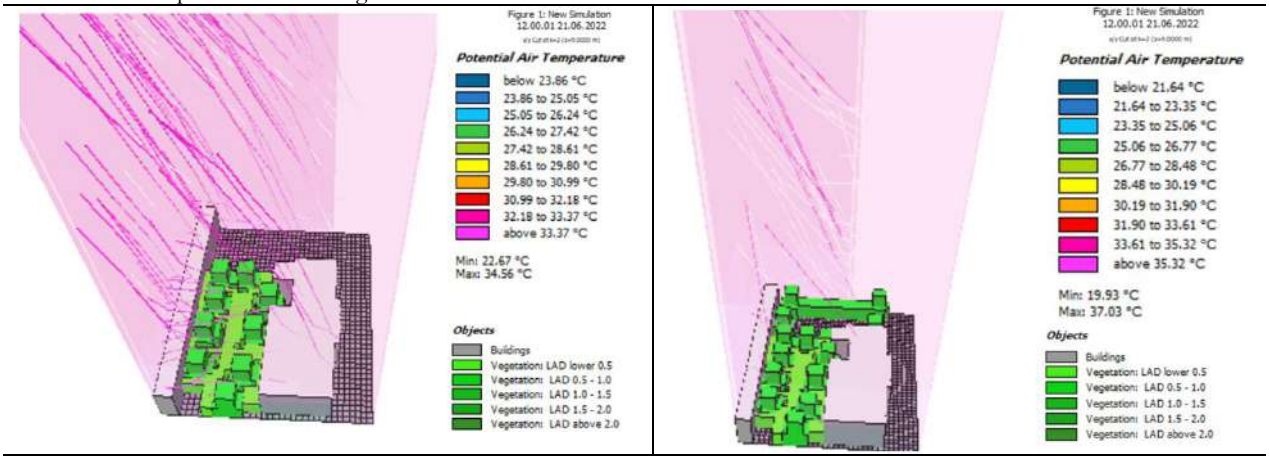
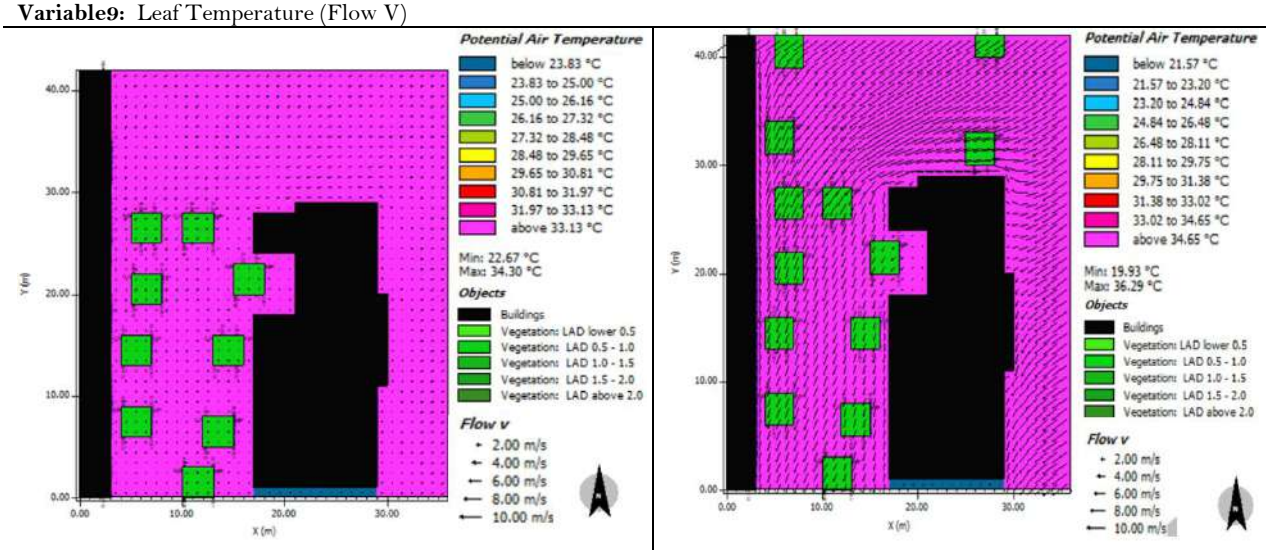


Variable8: Temperature emanating from the site.



Variable9: Leaf Temperature (Flow V)



Variable10: Temperature For soil

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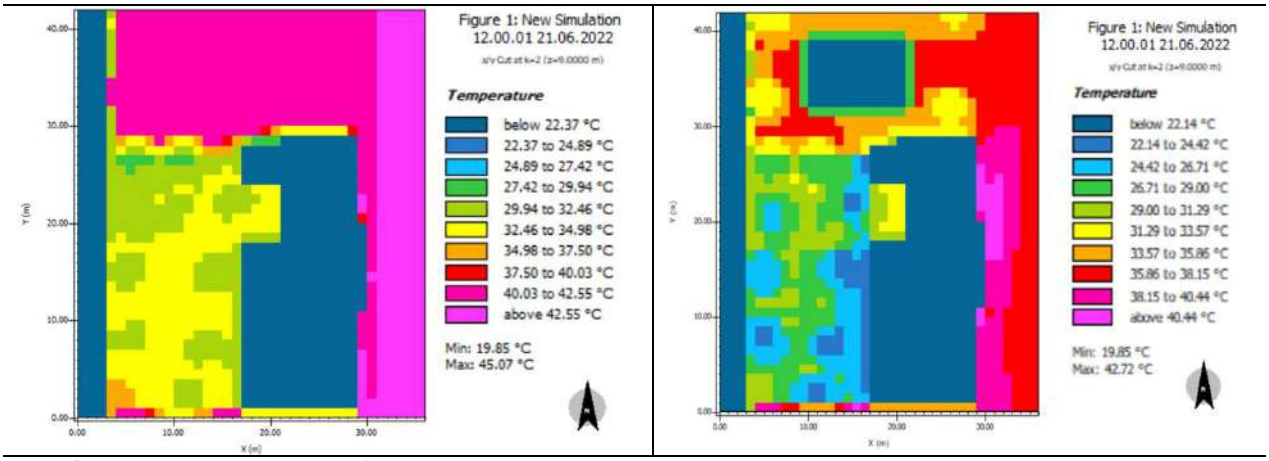
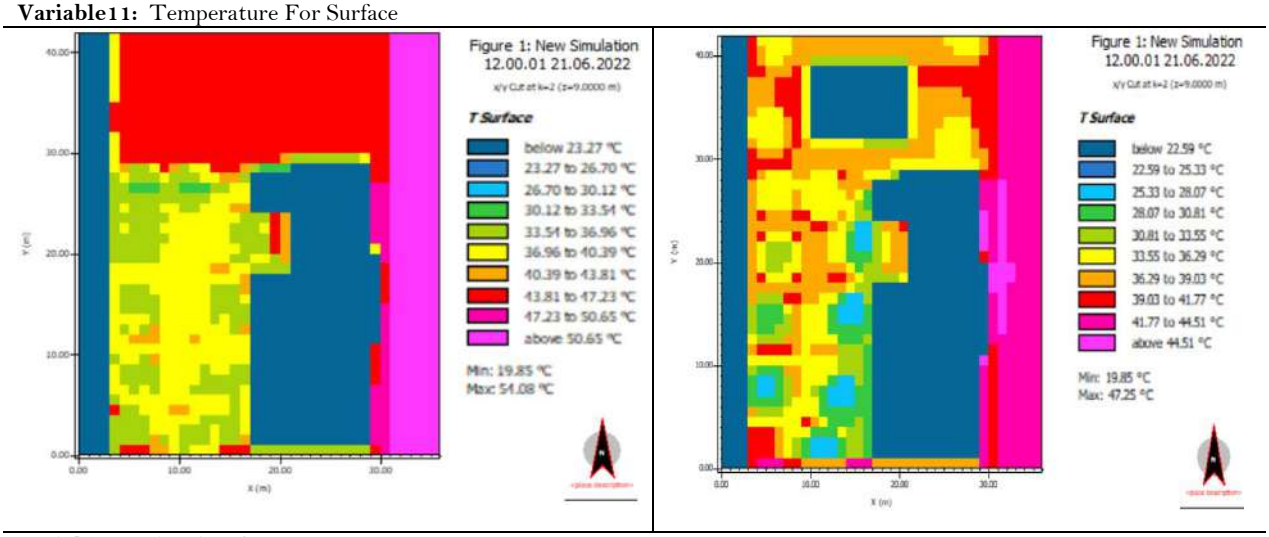
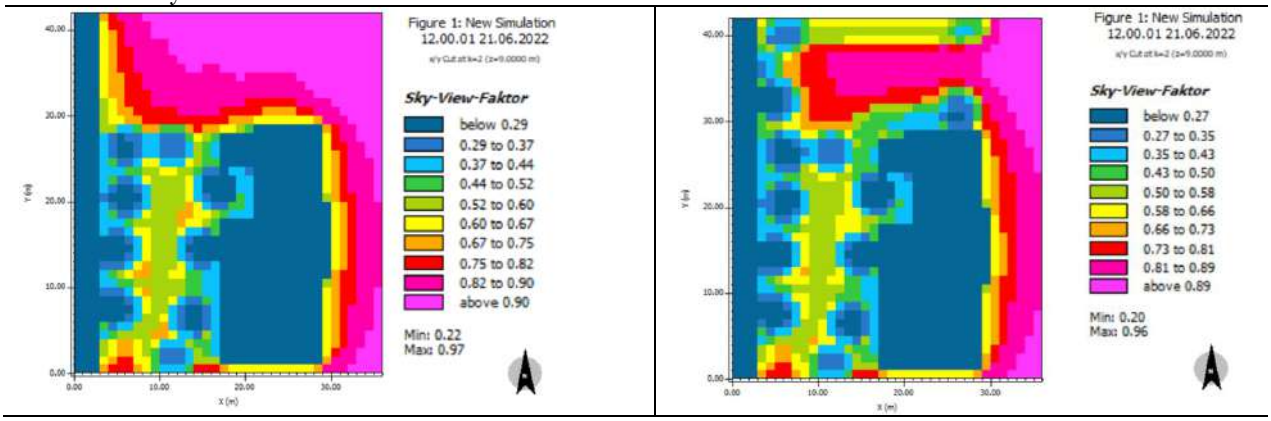


Variable11: Temperature For Surface



Variable12: Sky view factor



The usage of simulation software is an important phase in the process of identifying the pleasant circumstances for the setting throughout the process of urban planning design. This step involves predicting the thermal feeling of the occupants of the setting being designed.

The findings show that because of their high rates of evaporation, bodies of water have a considerable cooling effect. In comparison to regions with simply vegetation, temperatures were found

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to drop by an additional three degrees Celsius in scenarios where water bodies were introduced. This disparity highlights how crucial water use is as a design feature for lowering temperatures and improving thermal comfort in cities.

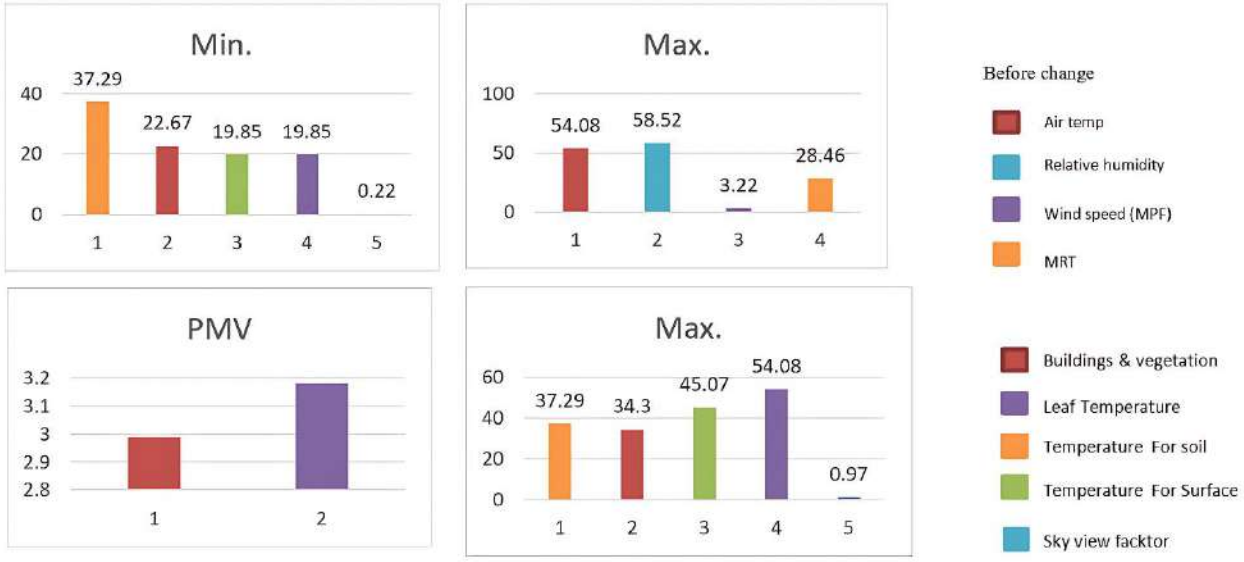

Figure 2.
The comparison illustrates the effect of vegetation and water bodies on local temperatures.

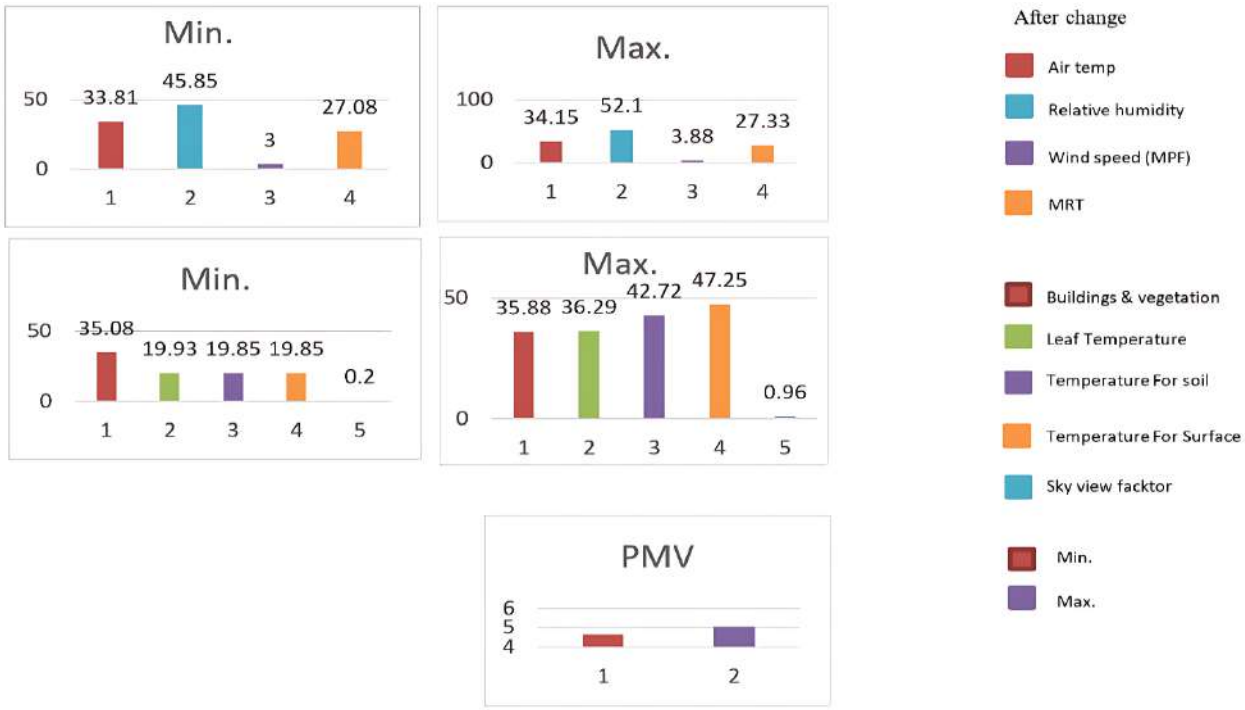

Figure 3.
Shows differences in wind speed and humidity between scenarios.

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Table 5.
The variations in the site's climate before and after the use of vegetation.

Variables	Before change	After change
Potential air Temperature	Minimum temperature: 35.08 Maximum temperature: 35.88 The temperature is relatively high	The minimum temperature is 33.81. The maximum temperature is 34.15. The temperature decreased by two degrees, which notes the effect of changing the characteristics of the arena on the temperature.
Buildings & vegetation	Minimum temperature 37.29C Maximum temperature 37.86C The temperature is relatively high	A temperature of 35.08 degrees Celsius is allowed. The highest temperature that may be reached is 35.88 degrees Celsius. The temperature reduced by two degrees, which notices the effect of modifying the characteristics of the building and plants in connection to the temperature.
Flow V	2.00 m/s Air movement is almost non-existent and its consequences lie in not affecting the temperature of the place. Minimum temperature is 35.08C. Maximum temperature is 35.88C.	10 meters per second As a result of the substantial air movement, air movement is formed, which contributes to the alteration of temperature and the cooling of the atmosphere. This temperature is 33.61 degrees Celsius. The highest temperature is 34.15 degrees Celsius. a two-degree drop in temperature from the previous reading.
Temperature emanating from the site.	Minimum temperature 22.67C Maximum temperature 34.56C The temperature emitted is relatively high and has an effect on the neighborhoods.	19.93 degrees Celsius is the lowest temperature. Total temperature: 37.03 degrees Celsius: The temperature dropped by three degrees, which indicates that there was a shift in the amount of heat that was emitted after the change.
Leaf Temperature	Minimum temperature 22.67C Maximum temperature 34.30C The temperature is relatively high due to the lack of plant influence.	It is 19.93 degrees Celsius at its lowest point. The extreme temperature is 36.29 degrees Celsius. Because of the effect that different plants have on temperature, the temperature dropped by three degrees, which is a significant change.
Leaf Temperature Flow V	2.00 m/s Air movement is almost non-existent.	10.00 m/s The air movement is large, which forms air movement that helps change the temperature.
Temperature For soil	Minimum temperature: 19.85 Maximum temperature: 45.07 The temperature is high, especially in the square, because of the material used for the floor, which is asphalt and concrete, and its absence of plant elements.	At its lowest point, the temperature is 19.85. The highest temperature that may be reached is 42.72 degrees. A two-degree drop in temperature was seen in comparison to the highest temperature during the period. Given that the square's temperature dropped to a level that was lower than 22.14 degrees Celsius, this demonstrates the impact that the modification of the square's properties had on the temperature. The body of water is responsible for this, and the temperature in it varies at this point as a result of the availability of varied soil, which is represented by the cover. Plant-based.
Temperature For Surface	Minimum temperature: 19.85. Maximum temperature: 54.08 C. The temperature is high, especially in the square, due to the surface material, which is concrete and cement, and its absence of plant elements.	At its lowest point, the temperature is 19.85. The highest temperature that may be reached is 47.25 degrees Celsius. The temperature dropped by seven degrees in comparison to the highest temperature that was recorded. This demonstrates that the temperature of the arena decreased to a level that was lower than 22.14 degrees Celsius as a result of the alteration of the features of the surfaces immediately surrounding the arena. The body of water is responsible for this, and the temperature in it varies at this point to provide surfaces that are suitable for growing vegetables as well as a variety of materials that are like bricks.
Sky view factor	Min 0.22 Max 0.97	Min 0.20 Max 0.96

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Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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