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THE ROLE OF THE LANDSCAPE ELEMENTS TO IMPROVE THE URBAN SPACES ENVIRONMENTAL PERFORMANCE

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Structured Abstract

Objectives

The absence of environmentally compatible designs for urban spaces that consider the high-density usages is the most important urban problem under discussion. Attaining the thermal comfort for users of the urban spaces directly affects the usage efficiency and improves the quality of life for the residents. This research aims to improve the performance of urban spaces specially the environmental performance by using the various landscape elements to achieve the thermal comfort for its users.

Methodology

The methodology for achieving the goals can be represented via a theoretical part which spots the various performances of the landscape elements, and an analytical part in which, the Tanta Medical Campus is selected as a case study. A development proposal for the urban design of its urban spaces is presented by focusing on the environmental performance to achieve thermal comfort for users and thus to attain satisfaction within the space. Then an evaluation of the effect of the proposed design, to achieve the best environmental performance of the urban spaces, is done by the use of environmental simulation software “ENVI-MET”.

Results

This research outlines the results that prove the role of the landscape elements in enhancing the environmental performance such as decreasing air temperature, reducing MRT and reducing surface temperature. The thermal satisfaction for the users, as measured using PMV, has been improved during the daylight hours. The MRT under the shaded areas is reduced due to the proposed development.

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Originality

This paper introduces the redesign of the medical campus at Tanta University by using the various landscape elements considering the functional, Social, environmental and aesthetical needs. By using simulation, tool “ENVI-met” to evaluate the environmental effect of the proposed design, which confirms the distinguished effect of the landscape elements especially the vegetation to achieve the thermal comfort for campus users.

1. Introduction

The urban spaces are considered the most important elements of the urban context, there contains different human activities to deliver various human needs, as functional, aesthetic, economic and environmental needs. The most important objective of the planners and landscape architects is improving the performance of the urban spaces. The urban design have a great impact to provide a sustainable environment that is suitable for users' needs, comfort, well-being and the standard of living (Hwang *et al.,* 2009). So the main objectives of this research is improving the performance of urban spaces specially the environmental performance by using the various landscape elements to achieve the thermal comfort for its users.

The universities can be considered as a small city due to its large population size and various complex activities Throughout the 1990s, many universities started to raise environmental issues the case of the University of Northern Colorado that incorporates principles of sustainable design that conserve resources (Steiner, 2011). So, the research suggested proposal design of one of Egyptian universities campus (The Medical Campus of Tanta University) to improve the campus environmental performance using suitable landscape elements that have a great environmentally impact on it.

The research uses simulation tool “ENVI-met” as an urban simulation tool to evaluate the environmental effect of the proposed design to achieve thermal comfort for users, to create a better urban living environment. The main objective is developing the campus urban spaces, by using various landscape elements to improve the environmental performance, achieving the users’ thermal comfort.

The research entails the development of the urban spaces of the medical campus at tanta university through the uses of the landscape elements to achieve the main research objective. The methodology consists of four parts: first part is theoretical, which studies the various landscape elements and its role in improving the performance of spaces, and studies standards, which improve the environmental performance and thermal comfort inside the Urban Spaces. Second part is the case study, through which a development proposal for the urban design of the Tanta Medical Campus spaces was chosen as it represents a great importance within the city; and the development strategy includes development of circulation paths, entrances and parking lots by using of various elements of landscape to achieve the expecting goals. Third part is the evaluation of the effect of the proposed design to achieve the best environmental performance of the urban spaces and testing it by the use of environmental simulation software ENVI-MET. Finally, the results the recommendations of this study are formulated.

2. Landscape elements and its role in improving the performance of urban spaces

Landscape elements divided into hard and soft elements and can be classified as follows:

2.1 Soft landscape elements

2.1.1 Vegetation elements

They include the various types of trees, shrubs and ground cover, which have an important role in improving the performance of the urban spaces on several levels (Booth, 1989; Directorate General, 2013).

Functionality by routing, dividing and linking spaces of the paths for both cars and pedestrian, and used as block out the vision or to achieve visual privacy (Schutzki, 2005). Aesthetically by featuring attraction in the urban spaces designed to achieve the differences and diversity of colour, texture, scale, rhythm and others. Socially by enhancing sense of containment and intimacy within the Urban Spaces also, contribute to provision spaces, which enhance the community meeting (Simonds, 1983).

Economically by having, a significant impact on reducing energy costs in buildings for its improved climate of the spaces surrounding those buildings, beside the vegetation element. Environmentally: The vegetation is a modifying factor of the local climate, and a helper in improving urban microclimate in open spaces (Dimoudi *et al.,* 2003; de Abreu-Harbich *et al.,* 2015), by enhancing air temperature, reducing the effect of solar radiation and reducing the effect of urban heat island phenomena (Wong *et al.,* 2011; Oliveira *et al.,* 2011). Vegetated areas have lower surface temperatures than impervious ones (Chun *et al.,* 2014), (Srivanit, & Hokao, 2013) and it can control air movement and provide shaded areas. Hence, it works on mitigating the effects of climate changes and improving air quality. Moreover, it represents an effective tool in fighting against global warming and the mitigation of emissions and pollutant oxides to air. It also mitigates the heat island phenomenon. It also has an important role in noise reduction and glare.

2.1.2 Water elements

It includes the different types of dynamic and static elements, whose role is to improve the performance in urban spaces (Booth, 1989; Directorate General, 2013).

Functionally: by linking spaces together, or split it. In addition, it helps increase the functional performance of the spaces efficiently. Aesthetically: by determining as visual element and aesthetic point of attraction. Socially: by entertainment and helping to users gathering and establish social relations (American Society of Landscape Architects *et al.*, 2009). Economically: by using irrigation reservoirs reduces the consumption of drinking water. Environmentally: Water areas can help in improving the urban environment, as they help in the cooling process through the evaporation process. They represent one of the effective ways in passive cooling .Some studies showed that water areas lower the temperature of 2-6 c (Manteghi *et al.,* 2015). Hence, they can reduce the impact of the heat island phenomenon and cover the noise. In addition, it can keep rain for reuse.

2.2 Hard landscape elements

2.2.1 Pavement

The Paving acts as a base of the spaces, which affect by their different properties the performance of the spaces therein (Booth, 1989; Directorate General, 2013): Functionality: By paving used as an important element of the definition and spatial division, it is also used to identify directions within the spaces, and to give a distinctive character of spaces. Socially: by using paving materials with suitable properties for the activities within the spaces, enhances the use of spaces and encourages social relations. Aesthetically: By making a visual link between spaces, also it represents a magnet. Economically: By using of recyclable and re-use, paving materials, the use of environmental and natural materials, which not need a large maintenance, reduces the cost. Environmentally: Use of compatible materials with the environment, lowers the emission factor and reduces the solar radiation (Guan, 2011) and the reflection; and it leads to an urban space with a microclimate that is suitable to achieve thermal comfort for users. In addition, the use of cool pavements results in absorbing less solar radiation, and reducing the strength of heat island performance (Santamouris *et al.,* 2012).

2.2.2 Furnishing elements and complementary elements

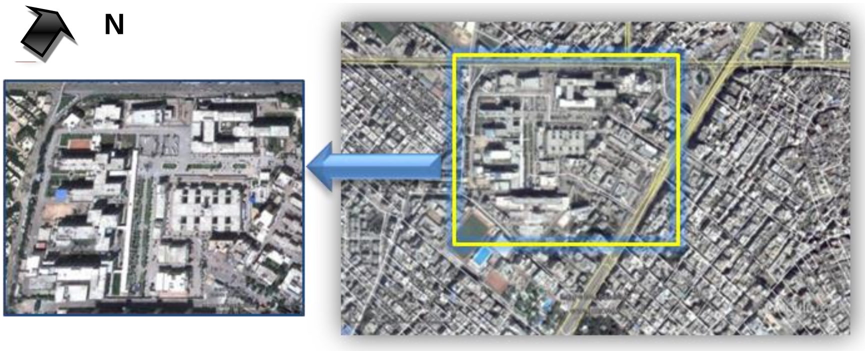
It is one of the most important elements that directly affect the activities set up in the spaces (Booth, 1989; Directorate General, 2013): Functionality: by designing the furniture elements to suite the activities in the urban spaces and promotes the activation and the interaction of users with the spaces. These include many elements such as the seats, light elements, signs. The complementary elements work efficiently, whether partially or totally separated from each other. Aesthetically: by working as visual elements and distinctive attraction points within the spaces as sculptures elements. Socially: by encouraging social interaction, and achieving safety and clarity in spaces; this achieves better interaction for users with spaces. Economically: by using local and natural materials that lead to reducing energy consumption and reduce long-term maintenance costs. Environmentally: the natural materials of the furnishing elements help in providing sustainability. For example, elements like umbrellas and pergolas, which provide shading areas to reduce the impact of solar radiation and provide thermal comfort; they reduce the pollution, emissions, and the heat island phenomenon as well.

3. The case study

The Medical Campus of Tanta University can be considered the largest community of students and researchers In Gharbia Governorate, one of the Central Delta governorates. The campus is located on the major movement path within the city of Tanta, with its cultural activities. It contains several buildings, such as a huge conference hall, Information and Technology Centre and the Main Library, which qualifies the campus to play the social, scientific and cultural role that is important to that central region of the Delta.

The case study is selected to achieve the study objective. One important area is the Medical Campus of Tanta University. The Campus occupies an area of 70 acres (including faculties, education centres and hospitals) at latitude 30° 47' north and longitude 30° 59' to the east and rises about 22 metres above sea level at the hot zone, where the movement is located in the heart of the city, at the intersection of “Albahr” Street with “Tanta-Alex.” Highway.

Figure 1. **Medical Campus in Tanta University**



Source: Google Earth image

The research objective can be achieved via an improvement strategy for enhancing environmental performance and achieving thermal comfort inside the selected urban space. The performance is then tested using the microclimate simulator "ENVI-met" to compare the efficiency of that urban space and user satisfaction in current and improved status. Figure 1 spots the selected urban area.

4. The Proposed Development Plan of the Medical Campus of Tanta University

4.1.1 Current Status

The current state of the area is determined to find out the status within the campus' urban spaces as shown in Figure 2, and to recognize their strengths, weaknesses, determinants, possibilities and obstacles that might impede the development process. It includes:

Figure 2. **Medical Campus (before development)**

Source: Engineering Management Office -Tanta University

4.1.2 The problems (weaknesses)

- *Movement Paths (Circulation)*

- Interference of movement paths for both vehicles and pedestrians is noticed, so that the mechanism movement despot to pedestrian movement.
- The pedestrian paths are inappropriate for their functions in terms of width, and quality of materials, with insufficient shaded spaces.
- Overuse of vehicles causes air pollution as well as noise.
- Excessive use of the asphalt material in the paths of vehicular movement, which has negative environmental and aesthetical effect.
- The design of facilities does not take in account the users with special needs in their use; especially at the Pedestrian crossing.
- The lack of plant elements (limited in Fichus trees and palms) at the movement paths that produces very few shaded areas.
- Lack of complementary elements such as lighting poles at the movement paths.

- *Open Spaces*

- The absence of grouped places for playgrounds and various sports activities.
- The misuse of open spaces and the existence of many unused marginal spaces.
- The area and capacity of the Campus are specific, and there is no extra space for future expansions or to place parking and the possibility growth is limited.
- The lack of special urban character of the Campus open spaces and entrances.
- Lack of plant elements whether trees, shrubs or grass which cover about 50% of the area of open spaces, that effect negatively; environmentally by increasing of air pollution, socially causing absence of social relationship and aesthetically causing visual pollution of the campus.
- Materials used in the pavement (interlock tiles) are environmentally unsustainable.
- The design of facilities is not considering the users with special needs in their use especially at the entrances of the buildings.
- Lack of complementary elements such as lighting poles, trash baskets and guiding signs within the appropriate quality and quantity at the open spaces.

- *Parking lots*

- Materials used in the pavement (asphalt) are environmentally unsustainable.
- Absence of plant elements (trees) at the parking lots with no enough shaded areas.
- Lack of complementary elements, such as lighting poles, trash baskets within the appropriate quality and quantity at the parking lots.

4.1.3 The available facilities (strengths)

- Unique location for the Campus at the centre of a major movement path in Tanta.
- Availability of space within the Campus spaces, which can be designed to make use of them either functionally, environmentally and aesthetically, including improved performance for Campus urban spaces.
- The presence of some plant components that can be employed within the new urban design proposal such as palm trees as focal point and shrubs as locating paths.

4.1.4 The proposed development strategy

The authors suggest a development strategy for the urban spaces of a vital project as the university campus, because it is considered as a large urban project, which has a great impact on society. Adopted development strategy aims to reach urban design resolution, which helps to raise the satisfaction of the users with their various functional needs; especially to improve environmental performance to implement environmental needs by achieving thermal comfort for users of spaces, conserve energy and urban sustainability. The achievement of the development strategy can be attained through:

4.1.5 Design considerations

- Re-planning the movement paths: firstly, by reducing the vehicles paths' area with the realization of the function. Secondly, encouraging cars alternatives by adding bikes paths. Thirdly, redesign of pedestrian paths with its width according to the use population density, and considering the separation of different movements, identifying the crossing areas and the selection of the appropriate quality of pavements.
- Redesigning the parking lots to be near the main entrances of the Campus to reduce car traffic density inside the Campus, taking into account the use of elements of landscape, such as trees, to shade the lots that ease the design of parking.
- Providing open spaces, such as seating areas, for students to do social, scientific and intellectual activities; and a combined area for sports activities, along with designing both with the provision of appropriate services and easy access, using the appropriate complementary elements to ensure that these activities efficiently during different periods of the day.

4.1.6 Visual and aesthetic consideration

- Determining central grouped spaces in the centre of the Campus and confirming it through the development of distinct signs, which work as attractive points.
- Achieving unified general character of urban spaces using unified elements, whether in the type of pavements, plants or elements of furniture and complementary elements within the spaces, in addition to increasing green colour that gives a comfort sense for users
- Determining paths with pavements or plant elements to identify the vision, and taking into account the achievement of visual sequence through a systematic rhythm by using the vegetation element and lighting poles.
- Redesigning the entrances of the Campus to conform the image of the university and redesigning the Campus borders (walls and entrances) in an attractive style where it gives the initial impression, which is important for visitors from various directions.
- Making an inventory and assessment of existing vegetation elements by developing guiding principles for protecting existing trees or replacing and renovating existing trees, with labelling and identifying it, as well as shrubs and flowers as a way to educate.

4.1.7 Economic considerations

- Using environmental materials and components, which are available in the local environment with less cost and low maintenance cost.
- Conserving the plants on the site as an economic value.
- Using reduced-energy consumption elements by using materials that attain sustainability, for example solar powered lighting systems.

- Encouraging pedestrian traffic is the most important source of energy conservation.

4.1.8 Environmental considerations

- *Vegetation element*
- Increasing the vegetation elements of the urban spaces covered by about 39%, to reduce the impact of solar radiation and the temperature of urban spaces, besides improving air quality and reducing the proportion of oxides and harmful emissions.
- The use of evergreen spread trees with height 9-12 meters to allow shading required for paths, parking lots and open areas.

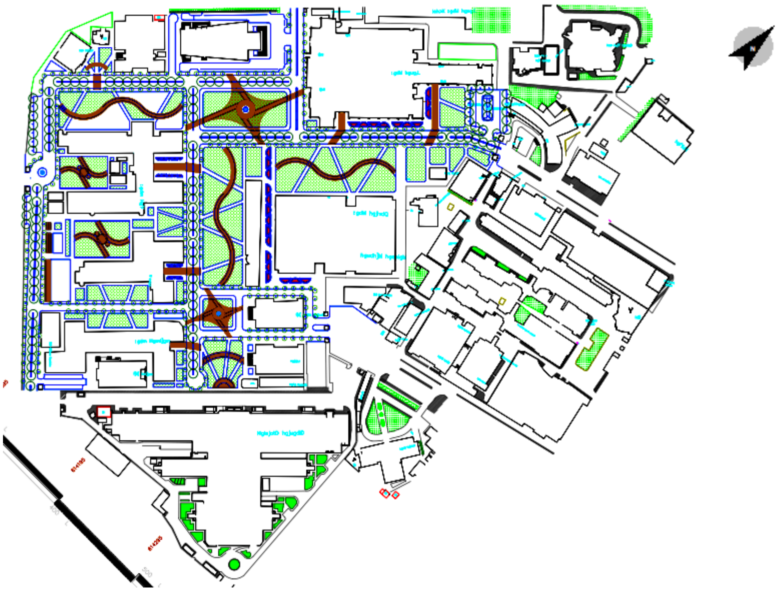
- *Pavement*
- Reducing asphalt surfaces for roads and parking lots by about 30%, by using the yellow brick as pavement for pedestrian's paths to reduce surface temperature, which affects the air temperature in urban spaces.

- *Complementary elements*
- Using Shading elements and benches made from natural non-polluting materials.
- Using mechanism process to collect and separate waste that allows recycling.
- Re-using rain wastewater for irrigation process at the Campus.

4.2 Environmental testing for the proposed development

The study is based on an environmental simulation of the proposed development of the Medical Campus spaces; through the use of the "ENVI-met" software (Fahmy *et al.,* 2011).of the study measured the thermal behaviour for the Campus in its current state, and after the re-design of spaces and developing the elements of the landscape as Figure 3.

Figure 3. **Medical Campus (after development)**



Source: Engineering Management Office -Tanta University

4.2.1 Simulation Tool Description

ENVI-met is a simulation program that is developed by Michael Burse (ENVI-met 3.1 Manual). It is characterized by several interfaces and each one of them is important for a reliable simulation or the reading of output data. The software presents three main components furnishing the required inputs, while the interface for the simulation examines globally the data by applying the calculation models. It has various capabilities including 3D microclimate modelling, calculating and simulating climate in urban areas with a resolution ranging from 0.5 to 10 metres and as low as 10 seconds time intervals. It integrates the laws of thermo-dynamics and fluid mechanics. ENVI-met uses an orthogonal Arakawa C-grid to represent its environment and the Finite Difference Method to solve the multitude of partial differential equations. This software has been used in many studies to evaluate, in terms of biometeorological conditions, the urban layout. Some parameters examined are transpiration, evaporation and the sensible heat flux flowing from the vegetation to the air while performing a complete simulation of every physical parameter of the plant (as the photosynthesis rate). (ENVI-met 3.1 Manual). It can calculate the microclimate wind-speed and direction, air temperature, humidity, turbulence, fluxes of different gases and particles and pollutant dispersion.

It is able to examine even the heat and mass exchanges related to the surfaces: for example, a parameter which is taken into consideration is the amount of water absorbed by the plant in the soil balance. (Salata, *et al.,* 2016) It enables simulating surface vegetation, building, and atmospheric processes. Moreover, it can be configured and adjust its setting parameters to the geographical area under study (Ozkeresteci *et al.,* 2003).

4.2.2 The experiment Description

The purpose of the re-design as the Figure 4 is to suit the needs of students, compatibility with the function of the place, and to achieve thermal comfort for users. Moreover, it aims to improving the thermal performance in this urban space, through the study of simulated environment of the campus. The simulation is performed by using the ENVI-met microclimate simulator (Abdel-Aleem, 2012). It was used in measuring the thermal behaviour of the area in the current state and after the redesign of spaces and processing elements of the landscape. The program is able to measure the Mean Radiant Temperature (MRT), and the air temperature (T_{air}), the surface temperature ($T_{surface}$), and the thermal comfort (PMV).

PMV is a model to simulate the average pedestrians' rate on the thermal performance of the scale of the study area. The measurement depends on the extent of balance of the energy exchange between the human body and the surrounding environment. The grading scale starts at -4, which expresses the (very cool) to +4, which means (very hot), while 0 expresses the thermal balance and thermal comfort check.

The closer the PMV to zero the better is the balance in the energy and thermal comfort exchange. It is known that the PMV is a function of different factors including MRT, air temperature and the surface temperature that directly affects the air temperature. During daylight hours (9-11-13-15-17), the Campus is simulated in two cases: firstly, before the treatment as shown in Figure 4, and secondly, the Urban spaces with development and re-designed is implemented using elements of landscaping and site coordination through the use of ENVI-met program as the Figure 5.

Figure4. Medical Campus as plotted the Envi-met editor (before improvement)

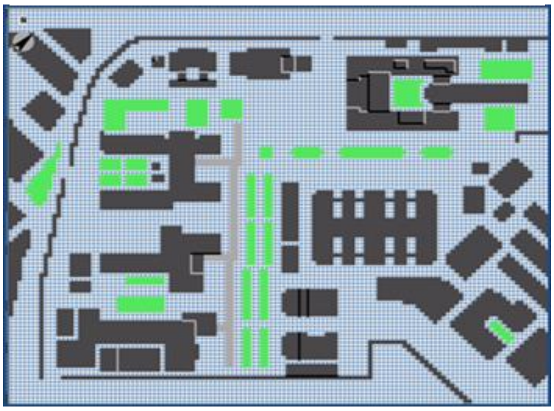


Figure5. Medical Campus as plotted the Envi-met editor (after improvement)

Source: By authors

The study sample properties, patterns treatment using landscaping elements which using in the ENVI-met program is representing in the following Table 1.

Table 1. **The study sample properties**

Total study area	**200,000 m2 = 48 acres**
Grid size	125 x 100 x 20; X-Y grid spacing, 4m; Z grid spacing, 3m
Date, time of simulation	1-7-2014
	Start Simulation at Time (HH:MM:SS) = 9
	Total Simulation Time in Hours: = 9
	Save Model State each min = 60
Boundary conditions	Initial Temperature Atmosphere [K] = 301.8
	Relative Humidity in 2m [%] = 59
	Wind Speed in 10 m ab. Ground [m/s] = 3.5
	Wind Direction (0: N.90: E.180: S.270: W.) = 0
Places shading	on height of 4 meters
Plants	Trees: Ds: Tree 10 m dense, distinct crown layer sk: tree 15 m very dense, distinct crown Bushes H2: 0.63 cm Grass trip around campus Lg: luzeme 18 cm

Source: By authors

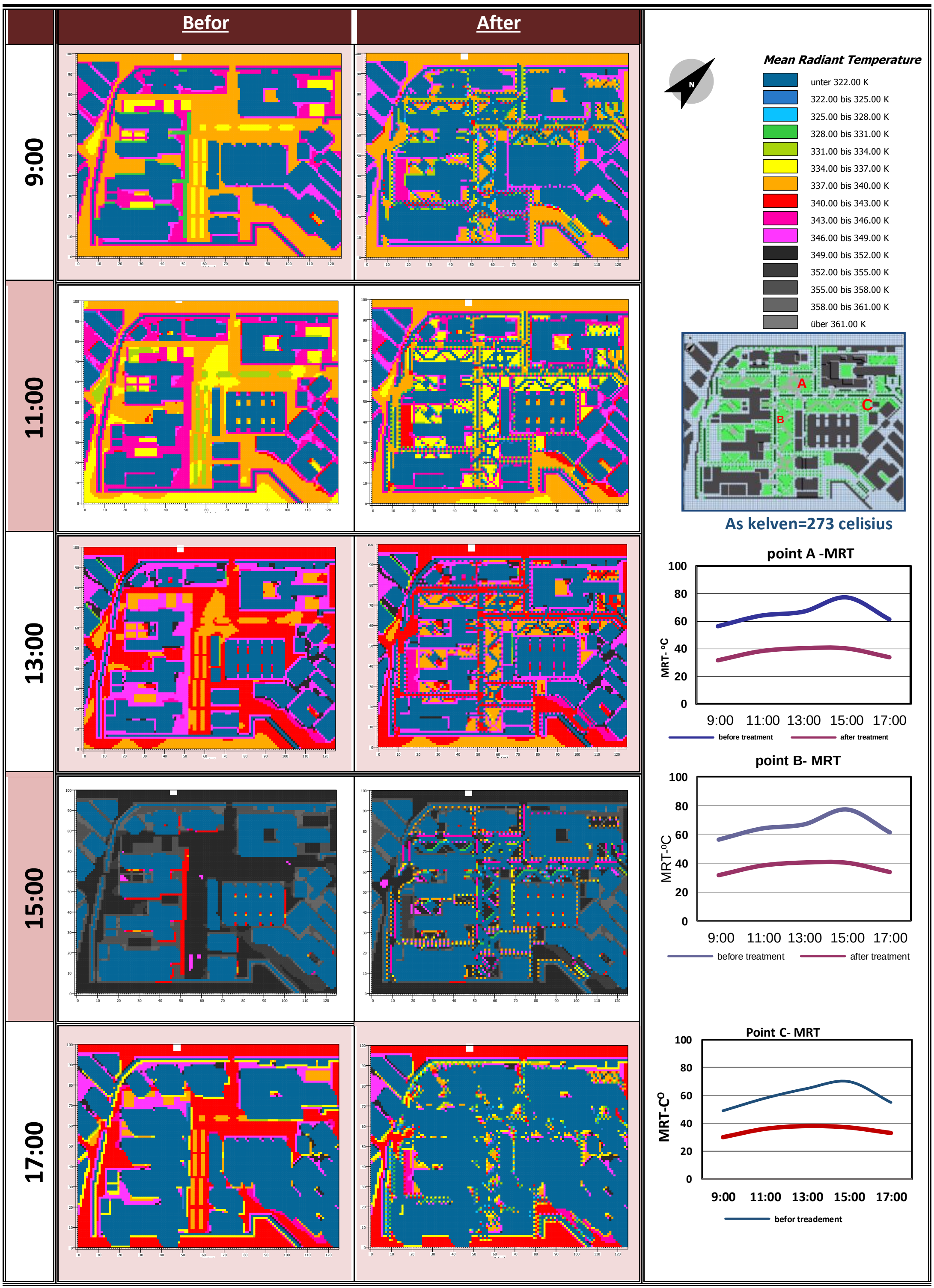
The MRT, surface temperature, air temperature, and PMV are measured in the Medical Campus of Tanta University. Specifically in three points: A, B, and C. The point A is located in the middle of the main square under shaded grass area. Point B is located in the main street, which is in the North West – South East direction, while point C is chosen on paved sidewalk of the street that is perpendicular to the former street.

5. Results of the Simulation

Next figures show the main results of the simulation before and after treatment.

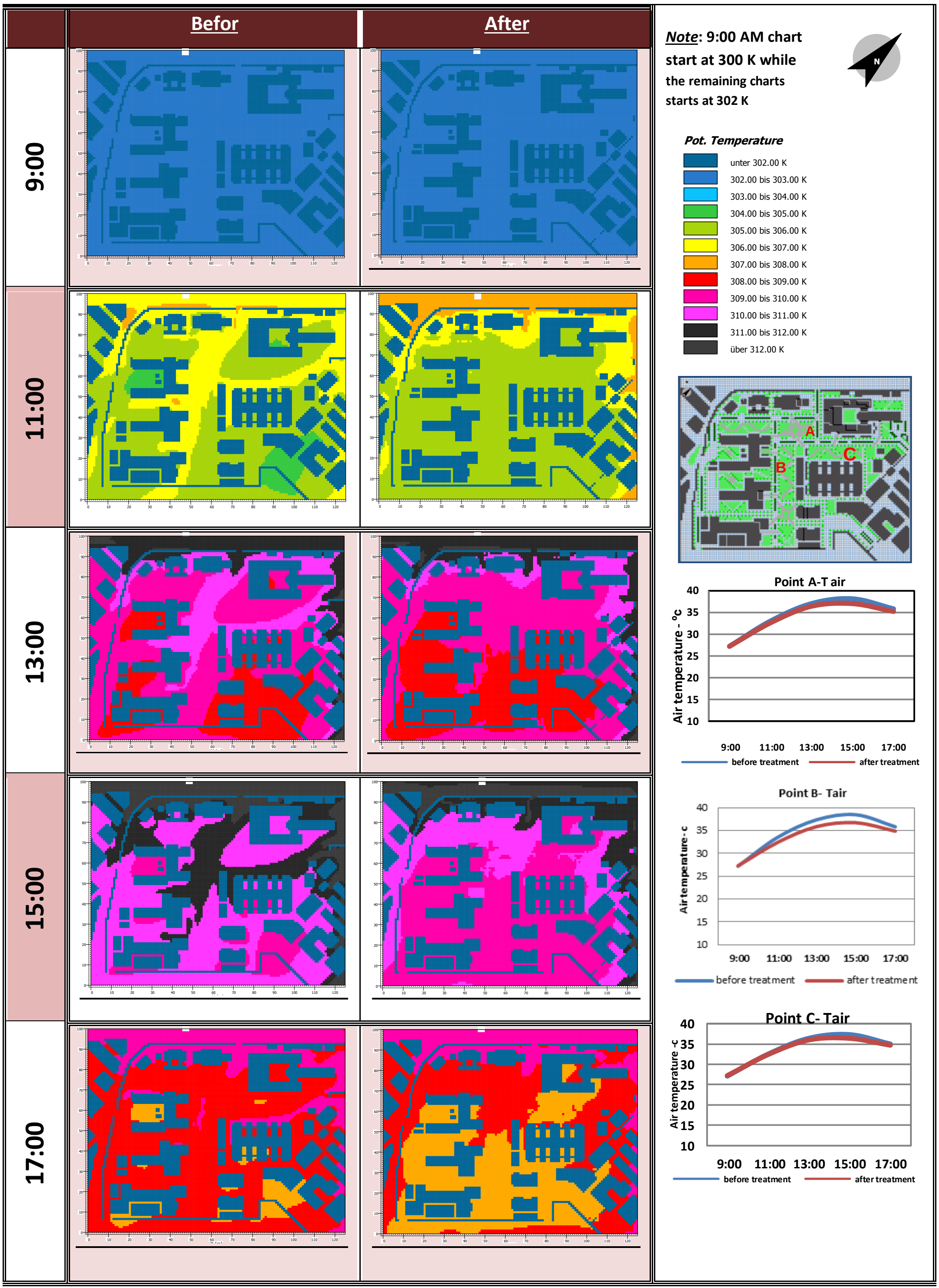
5.1 *Mean Radiant Temperature (MRT)*

Figure 6. **Mean Radiant Temperature (MRT) before and after treatment**



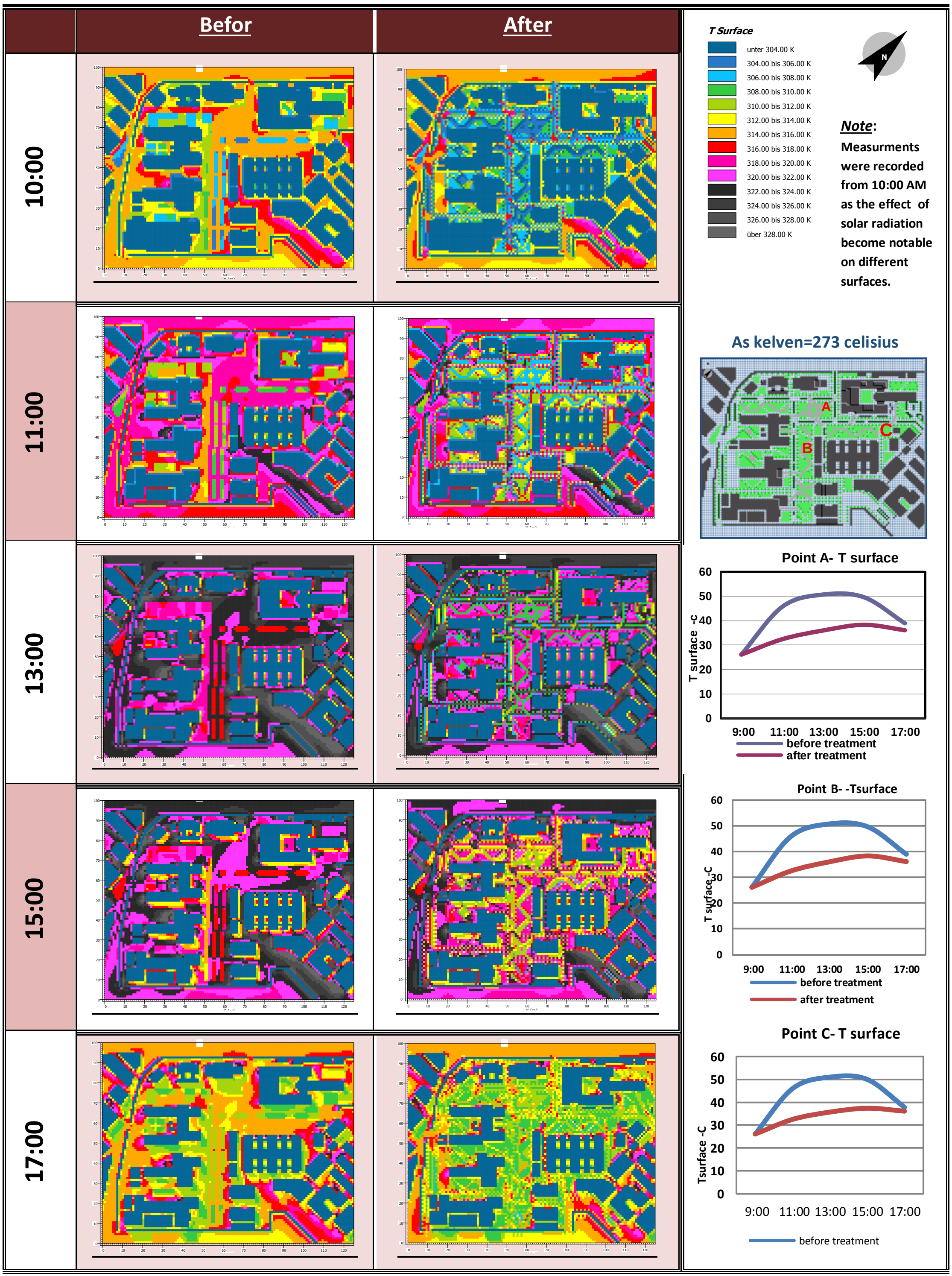
5.2 The air temperature T_{air}

Figure 7. **The air temperature T_{air} before and after treatment**



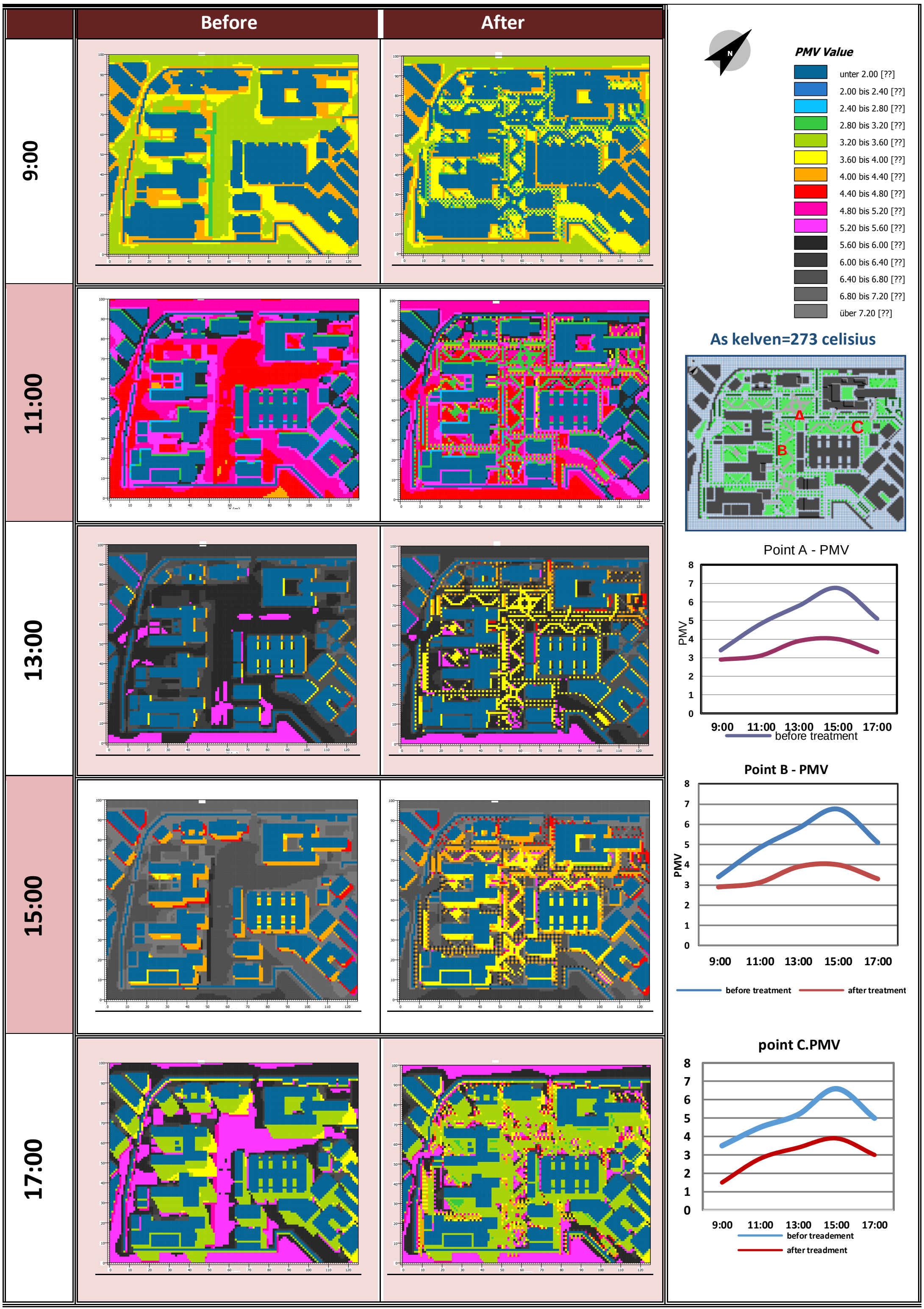
5.3 Surface temperature $T_{surface}$

Figure 8. **Surface temperature $T_{surface}$ before and after treatment**



5.4 The thermal comfort PMV

Figure 9. **The thermal comfort PMV before and after treatment**



6. Analysis of the simulation results

After making the proposed development (increasing the size of green area, the number of trees, shaded area, pergolas, tents, and water elements. Replacement asphalt with grass and break pavement). Noticed the behaviour of the Campus area has been monitored from 9:00 to 17:00, with two hours intervals. The following discussion highlights the apparent change of behaviour during that period.

6.1 By measuring the MRT before and after the development, the following notable results are reported

Using the various elements of landscape helps to reduce the MRT in the spaces and paths during daylight hours, which are typically the hours for student presence as shown in Figure 6. The difference in the MRT reduced is after using planting and shading to about 15-18 °C, while it is beyond 50ºC at 9:00 at those areas before the development. At 11:00, it is noticed that the difference in the MRT reduced to about 18-25°C so reached to 36°C which affects largely the thermal behaviour of these spaces and paths. At 13:00 a thermal peak is reached, and is considered as one of the most daylight hours subject to direct solar radiation. The MRT drops down in urban spaces after development by about 20-27°C, where it drops to about 38ºC This means that the direct exposure of solar radiation before development affects the thermal behaviour of those spaces while the suggested developments can achieve the required thermal comfort.

At 15:00, which representing the period, during which the highest thermal acquisition occurs, the spaces have gained its fully thermal energy from the solar radiation and are in turn begins to re-radiate that energy (thermal emission). MRT of the urban spaces at current state reaches about 77ºC After the development, the MRT is reduced greatly to about 28-39°C, which significantly affects the thermal feeling of students during the summer months. At 17:00, when the solar presence begins to decrease then the MRT, which represents about 67ºC at the urban space before development, is reduced in the proposed design about 18-33°C. It clearly shows the impact of the landscape elements on how much exposure to solar radiation and the high impact on the MRT.

6.2 Air temperature, T_{air}, for the medical campus before and after the development leads to the following

The results of measuring air temperature using the ENVI-met program of the current status of the campus and after a redesign of urban spaces using landscaping elements are presented in the following section. The impact on the temperature of the air in the urban spaces during daylight hours can be found in Figure 7. At9:00 the temperature is still the within the comfort temperature range in both cases, which is about 27ºC.

At 11:00, it is found that the air temperature decreases at the proposed urban design of campus about one degree compared to the current situation, especially for the space in the main square, which has been developed using shades, and planting trees in the main paths to achieve shading.

At 13:00, the air temperature in the campus for current statues is around 37.5ºC while it is found that it decreases in the proposed design to about (36-35.5)ºC, it is the hottest period of the day at 15:00 due to the accumulated thermal absorption, especially at summer. It is found that the air temperature decreases of those urban spaces from 39°C to about 36.5°C, which shows the influence of the elements of the landscape for the campus urban spaces in reducing air temperature. Finally, at 17:00, the air temperature in the absence of direct solar radiation in the current statues of campus is about 36°C, while in the proposed urban design it decreases to around 35°C, which highlights the impact of the elements of the landscape in reducing the temperature of the air and reduce heat stress, especially during the summer.

6.3 Surface temperature analysis of medical campus before and after the development it reaches the following

At 9:00, the surface temperature in both cases is the same. After that, it begins to differ on the various surfaces according to their materials, properties and amount of exposure to solar radiation. The surface temperature reduction in the proposed re-design of the Campus compared to the current statue becomes apparent after 10:00 the surface temperature at 10:00 is 40°C for the asphalt road, which is exposed to the solar radiation inside the campus before the development. The surface temperature of the paved surface reaches about 38°C, and ranges between 32-33°C for green areas. The surface temperature at 11:00 is 45°C for the asphalt road, which is exposed to the solar radiation inside the campus before the development. The surface temperature of the paved surface reaches about 41 °C, and ranges between 37-39°C for green areas, while it decrease to 33-35°C under the shaded areas, that is about 10-12°C lower than the exposed asphalt road, as shown in Figure 8.

At 13:00, the direct presence of solar radiation causes the temperature of the asphalt roads and the paths that is found in most of the space of the current status of the campus to reach 51°C, except for some minor green areas which reach the heat degree of the surface the to 47°C. The design of the new proposed landscape works to reduce the surface temperature greatly, especially under the shaded areas where the surface temperature becomes 35-36°C, while it reach to about 42°C for the open green spaces, and for the paved to about 45°C.

At 15:00, the materials' surfaces can absorb a lot of heat through direct exposure to solar radiation causing the thermal emission of them. It is found that the temperature degrees of asphalt surfaces, which cover most of Campus urban spaces in campus, are 53-56°C. In the urban spaces that have been developed by the use of the proposed elements of the landscape that are compatible materials, it is found that the temperature of surfaces ranging from 37-39 °C under shaded areas and about 45°C for open green surfaces, and for paved about 48°C.

At 17:00, the impact of the elements of landscape on the temperature degree of floors surface is clear. The surface temperature begins to decrease due to the buildings shading effect on the floor surface. It is noticed that the surface temperature of asphalt at current status is ranging 39-41°C, while the surface temperature of the proposed design by using elements of the landscape is reduced to 35 °C at most of the urban spaces. This means that the surface temperature decreases about 6 degrees, which show greatly the impact of the use of elements of the landscape in reducing the floors temperature, which affects in turn the temperature and thermal behaviour.

6.4 The level of satisfaction or the Predicted Mean Vote (PMV) for the medical campus before and after the development

PMV represents a model to simulate the average vote scale for users on the thermal performance of the urban spaces. PMV is collected all over the campus area using ENVI-met in the current and after redesign using elements of the landscape. It helps to estimate the thermal behaviour of that urban space, which can show the impact clearly on the thermal satisfaction, as shown in Figure 9.

The measured PMV values reach about 8 in some hours in the study area before development. This indicates the high dissatisfaction reported by the simulator because the PMV reaches higher values than the normal scale of it, which is -4 to +4. It also indicates that the dissatisfaction is due to hot climate. This is evident at the measurement points A, B and C in Figure 8. Hence the dissatisfaction of users increases.

At 9:00, the PMV decreased in the proposed design for the status to 1.6 while it was 4.3 before the use of any elements of the landscape. This indicates an increase of thermal comfort and approach the thermal satisfaction. Moreover, the PMV at 11:00 decreased from 4.7 to 3.At 13:00, the PMV reduction clearly highlighted the impact of the elements of the landscape in reducing it and approaching the thermal comfort as it decreased from 5.6 to about 3.8.

15:00 is representing the hour with the highest-heat stress on the streets and paths in the summer. The measure of PMV indicates a decrease of about 2.7 (6.6 decreased to 3.9), which clarifies the role of the plant element in achieving thermal comfort and improve the thermal performance of urban spaces.

PMV at 17:00 clearly shows the difference in how much satisfaction is achieved in urban spaces in the campus with status and after developing it using elements of the landscape. The value of PMV decreases from 5.5 to about 3.3, which highlights the improved thermal performance of proposed urban spaces design in order to achieve thermal comfort especially for students during summer classes in the current situation.

Conclusions

This research outlines several benefits of elements of the landscape such as social, environmental, aesthetic and economic benefits.

The case study has been conducted to show the role of landscape elements to improve the environmental performance of urban spaces, by using ENVI-MET simulation; the simulation results show the effects of using the various landscape elements to achieve the users thermal comfort in urban spaces such as:

- During the different day times the PMV after the proposed development doesn’t break value 4 even in thermal peak.

- Noticed that using vegetation and shading elements have the greatest impact for implementing thermal comfort.
- Reduction of the surface temperature within the urban spaces by the proposed development compared to the current status by 17-19°C under the shaded areas in the beak.
- Reducing the MRT in urban spaces due to the proposed development of the current status by 38-39 ° C under the shaded areas in the beak.
- The air temperature inside the urban spaces is decreased through redesign using landscape elements of the campus by 1-2 ° C under shaded areas.
- Achieving thermal satisfaction PMV for students by 35-53% during daylight hours under shaded areas.

Recommendations

- The need for good understanding of the principles of climate and environmental design, which helps improving the environmental performance of designed projects. This will be positively reflected on solving environmental problems in cities, and designing a comfortable, healthy and clean environment.
- It’s important to make good use of the elements of the landscape within the urban spaces to improve its environmental performance and improve air quality.
- The need to develop the knowledge about the importance of urban climate is not only among planners, but also is for the decision-makers and the public.
- Designing the urban spaces of the university campus must consider the integration between outdoor and indoor to achieve sustainability by using for elements of the landscape.

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