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The Universal Thermal Climate Index (UTCI) applications for microclimatic analysis in urban thermal environments. Case study; Oasis University campus, Algeria

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Abstract. This work on outdoor thermal comfort tends to highlight and affirm the contribution of vegetation to outdoor thermal comfort in a climatically hostile environment by being very hot and dry, this effect of creating a more forgiving microclimate in terms of thermal atmosphere was highlighted by simulations and in situ measurements, in a semi-open public space with a set of mature ficus retusa trees that we cut later, in this way, it gives us an unexpected and important opportunity for an intangible conclusion on this thermal contribution by means of a comparison, within the same space, in other words, with the same morphological characteristics but in two different states; case "A" with the presence of trees and case "B" after these same trees have been cut. This led us to deduce the influence of persistent vegetation on thermal comfort in such an environment; the measurements were made before and just after cutting the trees. The comfort index (UTCI) was calculated from microclimatic factors, themselves dependent on morphological indices, the measurements carried out highlighted the variations in the comfort index, that is, an indicator of the thermal comfort in both cases. In the end, this confirms the great influence of the trees shade on the outdoor thermal comfort in a public space located at the university campus of Biskra.

Keywords. Vegetation, Outdoor Thermal Comfort, In Situ measures, Simulations, The comfort index (UTCI), Oasis university campus

1.Introduction

With steadily growing impacts of global warming, cities are increasingly struggling with new problems such as intensified urban heat island (UHI) effect (Taha and al., 1988; Oke, 1982). Owing to UHI effect, an urban area can be on average 1.0°C to 6.0 °C warmer than the nearby non-urban regions, it is reported that because of UHI effect, American cities experience 0.5°C to 4.0 °C higher daytime air temperatures and 1.0°C to 2.5 °C higher night-time air temperatures than the nearby rural areas (Dimoudi and al., 2013),. This phenomenon is also exacerbated by the growing size of the city dwelling human population and the increasing rate of energy consumption (Mirzaei, 2015; Battista and al., 2016). Research has shown that cities currently account for 60% to 80% of the world's total energy consumption (Kamal-Chaoui and Roberts, 2009). It was also indicated that distance from UHI is a key factor affecting heating and cooling loads and thus the effect of urbanization on energy demand (Kolokotroni and al., 2010). Since it has been estimated that the ratio of world urban population to total population is set to increase from 54% in 2016 to 60% in 2030 (UN, 2016), UHI can be expected to become a major challenge in the future urban life.

The majority of investigations into the effect of features and dimensions of urban green spaces (UGSs) on UHI have been conducted over the past ten years (Akbari and Dionysia, 2016). According to a review study published in 2010 (Bowler and al. 2010,), green infrastructure (trees, parks, forests, and green roofs) have a higher level of thermal comfort than other urban spaces. This is especially true for larger parks and urban forests (UGS), which can have up to 0.94 °C lower daytime temperatures. Another recent review study has shown that thermal comfort and the UHI reduction effect of a UGS depends on its size and shape. According to this study, the cooling effect of an UGS is directly correlated with its vegetation cover and tree shade area (Jamei and al., 2016). In a recent review paper by (Taleghani, 2018), among the strategies for reducing the effect of UHI, the role of effective UGS has been emphasized by taking six Urban Parks Studies (UGS) into account, it has also been demonstrated that these spaces play a major role in UHI reductions.

In general, the methods currently available for this purpose can be categorized into four groups: the use of vegetation cover like trees, shrubs and lawns at different scales (Gago and al., 2013; Mackey and al., 2012), the stack night ventilation (Kolokotroni and al., 2006), the use of waterbodies (Gunawardena and al., 2017; Moyer and Hawkins, 2017; Daniel and al., 2018), and the use of materials with high albedo rating for pavement and other ground surfaces (Pacheco-Torgal, 2015, Santamouris, 2013, Li and al. 2013. Taha and al, 1988).

2.Literature review

Since ancient times, man has tried to create a comfortable thermal environment, and this is clearly reflected in the architecture and town planning of the corresponding period (Givoni, 1978).

The evaluation of the impact of climate parameters on human beings has become the concern of several disciplines, namely: architecture, town planning, tourism and environmental medicine, recent studies aim to improve the thermal comfort of users in taking into account the climatic parameters in order to lead to projects that can be described as bioclimatic, and which will best meet the requirements of thermal comfort, particularly in outdoor spaces. This apprehension becomes a major concern which takes into consideration the vegetation in the city.

Trees improve the urban thermal environment in summer by shading surfaces and cooling the air, while providing adequate thermal comfort.

In arid climates, it is interesting to use local vegetation which consumes less water (Akbari and al. 1992), while the evapotranspiration of a tree can reach up to 400 liters per day, which represents a cooling action equivalent to that of 5 medium air conditioners for 20 hours in hot and dry climate (Huang and al. 1987).

According to (Vinet, 2000), the urban plants play the role of sun protection especially in very sunny regions, and it reduces the degree of openness to the sky (SVF). In view of the density of the foliage, which is a determining factor in permeability to solar radiation, this reduces the temperature of the ground and will reduce the reflected radiation and the effects of inertia on the ground.

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A study by (Bernatzky, A. 1982). in Frankfurt (Germany) has shown that a green urban square lowers the air temperature by 3°C to 3.5 ° C and increases the relative air humidity by 5% to 10%, ventilates polluted air and creates fresh air in the city center.

In his study, (Picot, 2004) has shown that tree growth can have an impact on user comfort. It shows that the physical appearance of trees can influence the character and atmosphere of microenvironments.

For their part, (Chatzidimitriou and al. 2006), found that shaded paved surfaces are 40% cooler than the same areas exposed to sunlight, and their surface temperatures are 21% lower than air temperature.

Compared to the study by (Jörg Spangenberg, 2008), made in Brazil (São Paulo) reveals that the cooling effect of the plot is 2 ° C on average compared to the open space with peaks going up to 6 ° C and this is due to the density of the plant cover in this plot, which is very important compared to one in close proximity.

A research team from (the ABC laboratory in Marseille, 1997) has found that the leaf mass of trees in the garden or in alignment keeps the temperature close to the air temperature. That is to say, the air temperature under a tree is given, as if the solar radiation was zero.

Utilizing a three-dimensional CFD model in Ljubljana in Slovenia by (Vidrih and Medved, 2013), the study indicated that the summertime cooling effect of different parts of a 1.96 ha park is depending on its leaf area index (LAI). They also reported that in areas where LAI of (planting density of 45 trees with an age of 50 years, per hectare) is 3.16, cooling effect intensity (CEI) reaches -4.8 °C, but in the extremities of the park, where LAI is 1.05, CEI reaches -1.2 °C.

According to a study conducted by (Park and al, 2017) in Seoul, small green spaces with an area of 300 m^2 can result in 1 °C temperature reduction and slightly larger parks with an area of 650 m2 can reduce the temperature by up to 2°C. This study found that the CEI of a park correlates with its size, and accurately predicted that a 1500 m^2 green space would reduce the temperature by up to 3.6 °C. This study also showed that polygonal lands with combined vegetation cover can reduce the temperature by up to 4 °C.

2.1 Outdoor thermal comfort evaluation

The average radiation temperature (Tmrt) is considered to be the most important factor affecting human thermal comfort in an outdoor urban area. The value of Tmrt is the sum of all the shortwave and long wave radiation fluxes absorbed by the human body which affect its energy balance and human thermal comfort. (Peng and al, 2012) confirmed that the average radiation temperature is a more precise indicator than air temperature for evaluating thermal comfort. (Thoreson and al. 2007) came to the same conclusion, stating that the average radiation temperature is the most important meteorological parameter governing the human energy balance and thermal comfort.

2.1.1Universal Thermal Climate Index (UTCI)

In the year 2000, the Universal Climate Thermal Index (UTCI) was developed by a commission created by the International Society for Biometeorology (ISB, 2004). Jendritzky and his commission have, as main objective, the creation of an index which is exact in all the climates, the seasons and the scales, and to be independent of the personal characteristics such as age, sex, specific activities and clothing (Walls and al, 2015) . For this reason, it is kept for use in this work.

This index indicates the thermal sensation (stress or comfort) felt by humans due to the combination of the ambient parameters: temperature, humidity or pressure of water vapor, wind speed and thermal radiation, by using a physiological model (Fiala and al. 2012), a clothing model and a reference condition (Bröde and al. 2012). More than an index, the UTCI represents a model with well distributed input parameters, expressed in° C. This index was used to determine the various types of atmosphere (comfortable, cold or warm) (Blazejczyk and al. 2013).

The Universal Thermal Climate Index (UTCI) is expressed in an equivalent ambient temperature (°C) of a reference environment providing the same physiological response of a reference person as the real environment (Walls and al, 2015), according to *Table 1.*

UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
0 to +9	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress

Table1. *The scale of UTCI and the degree of comfort. Source: Blazejczyk et al. 2013*

3.Objectives of the study

In the cities of southern Algeria with hot and arid climate, the dissatisfaction of the population is to avoid the solar rays while seeking shade and freshness (by the vegetation and the buildings) during these periods when the temperature is very high, reaching peaks of 50 °C, pushes the desertification of outdoor public spaces, assailed all day by a hot and burning sun, towards shaded spaces and especially towards air-conditioned interior spaces. (In this period considered to be the longest of the year, which can last up to 07 months), in our case.

The concern of our work is the role and influence of vegetation (urban vegetation) on thermal comfort, this work consists in verifying whether vegetation has an impact on the urban climate in an arid region of southern Algeria, in this case, it is a green space within the University of Biskra, it is retained following an observation of grouping of students under the shade of its trees during the hottest periods of the year.

The objective of this research is to confirm through field work and simulations the effect of urban vegetation and shade on the microclimate and thermal comfort in a semi open public space in a southern Algerian city with hot and arid climate (the city of Biskra)

It is also to confirm the impact of trees' shade (Ficus retusa) on the microclimate and the thermal comfort in this space by a comparison of two situations; plot with dense trees, being the first case, which we call "A" and the same plot following the cutting of its trees, being the second case, which we call "B". We deal with the quantitative aspect of thermal comfort and

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assess the thermal environment from an objective point of view based on real measurements in situ.

4.Trees canopies and radiation modification

In general, microclimate consists of six components that affect the condition of small outdoor spaces. The components are solar radiation, terrestrial radiation, wind, air temperature, humidity, and precipitation which are the important elements in creating comfortable thermal surroundings (Brown, R. D., Gillespie, T. J. ,1995).

Physically, the components can be modified by elements in landscape. Generally, there are four main ways to modify the microclimatic environment through landscape elements, especially green structures. First of all, through wind modification, then through modifying relative humidity, after that, through modifying incoming solar radiation, and finally through modifying terrestrial radiation from the ground and other surfaces [(Brown, R. D., Gillespie, T. J. ,1995) & (Kotzen, B.,2003)].

Trees can have some effects on all modifications, but in the arid zones, are most important in modifying solar radiation and terrestrial radiation from the ground through the creation of trees' shades.

According to (Robinette, 1968), one significant usage of plant in climatic control is radiation control. Deciduous plants in full leaf are the best solar radiation control devices when the sun's rays are most oppressive in temperate climates. Therefore, he added in his study that in tropical climate, evergreen trees are more suitable because of the leaf density and the leaves are alive on year-round basis. Hence, the performance of trees in giving the best shadow and filtering the radiation is according to the form and solidity of the canopy (Robinette, G. O., 1968). The character depends on tree canopy form and tree structure that is influenced by two major elements, namely, (i) branching and twigs; and (ii) leaf covers. These two elements may influence the overall character of tree shape and density [(Brown, R. D., Gillespie, T. J. ,1995) & (Picot, X. 2004)].According to (Brown and Gillespie , 1995), a single layer of leaves will generally absorb 80% of incoming visible radiation, whilst reflecting 10% and transmitting 10%. Approximately 20% of infrared is absorbed with 50% being reflected and 30% is transmitted. More layers of leaves will be more efficient at reducing solar radiation under a tree. Therefore, the percentage for these two radiations absorbed is approximately about 50%; reflected 30% and only 20% is transmitted. *Figure 1.*

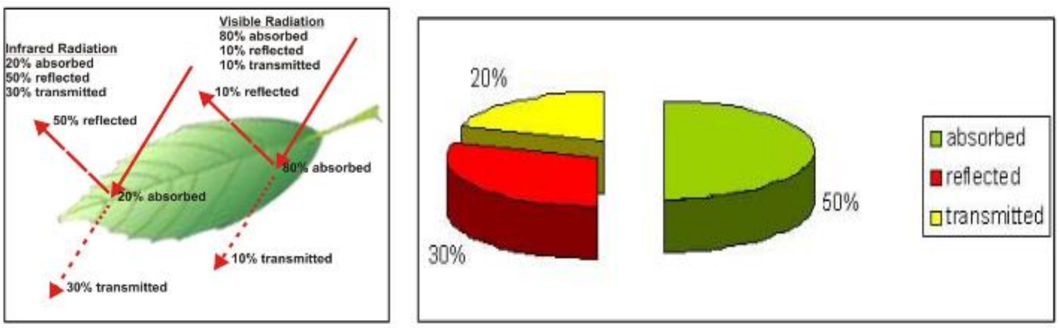

Figure 1. *Leaf absorption, transmission and reflection, (modified from Brown and Gillespie, 1995.*

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In addition, all trees can filter approximately 80% - 90% depending on leaf density, arrangement and types of leaves (Fairuz, M. S., & Mustafa, K. M. S. 2005).

Approximately half of this energy is visible light and the other half is solar infrared (Brown, R. D., Gillespie, T. J. ,1995). This energy that reaches the ground is absorbed, transmitted or reflected by the ground. Radiation that is reflected will affect energy budgets and thermal comfort as will the absorbed radiation. The amount of absorbed energy, which is the emitted, as terrestrial radiation, is a function of the temperature of the object. By blocking solar radiation, the branches and leaves of a tree directly reduce the energy reaching the ground, thereby reducing temperature and long-wave radiation from the ground (Kotzen, B. ,2003).

4.1. Tree Physical Characteristics and Solar Radiation

Filtration tree physical characteristics play an important role in filtering solar radiation. Landscape elements, especially trees that have the following characteristics that affect solar radiation [(Brown, R. D., Gillespie, T. J. ,1995), & (Scudo, G. (2002)]:

1. Individual leaves that allow some radiation to be transmitted through them (normally about 20%), absorb some radiation (normally about 50%), and reflect some radiation (normally about 30%);
2. The maximum height of the plant;
3. The transmissivity of the canopy in different seasons (a combination of the characteristics of the leaves, twigs, branches, dates, and size);
4. Multiple layers canopy structure;

5. Presentation of the study context

The city of Biskra is located in the southeast of Algeria at a latitude of 34.51 ° North and a longitude of 5.43 ° East. *Figure 3.*

Biskra belongs to an arid classified region where a hot and dry climate prevails with cold winters and hot summers. The maximum temperature exceeds 50 °C during the month of July and the minimum temperature decreases to 7C ° in winter during the month of January. The average annual temperature is 21.7 ° C while the average annual humidity is 46%. Very low rainfall is recorded with a maximum of 20mm / year, and an annual average of about 8.8mm / year. The prevailing wind directions is North in winter, South in summer at a speed of 4 to 10 m / s. In this study, we will therefore limit ourselves to presenting the results obtained during the hot period.

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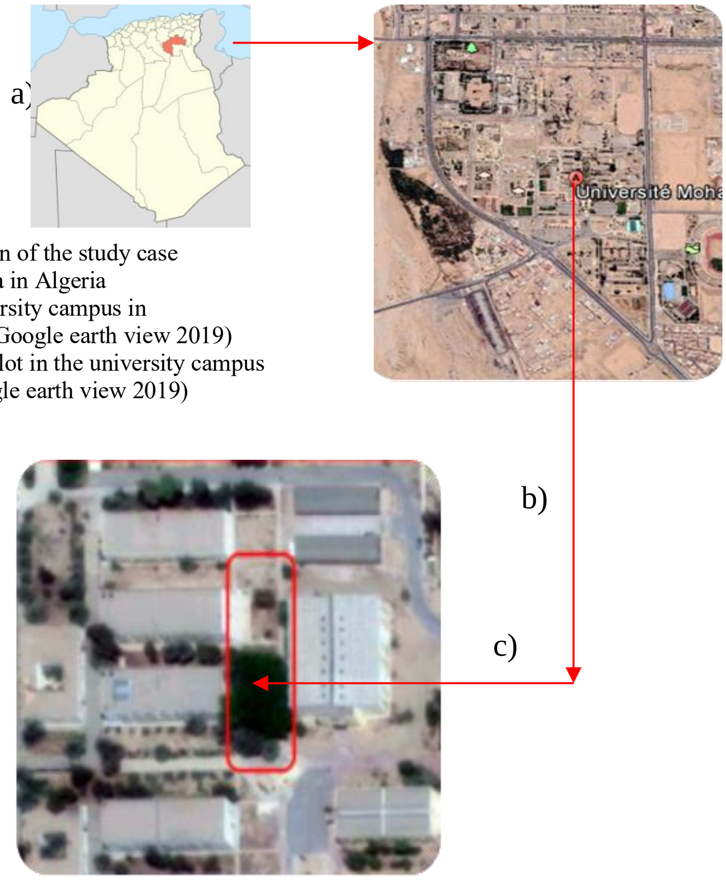

Figure 3. Location of the study case
a) Biskra in Algeria
b) University campus in Biskra (Google earth view 2019)
c) The plot in the university campus (Google earth view 2019)

5.1. Presentation of the investigation site

During our prospecting, we noticed a space within the university, main pole, located in the eastern development of the city of Biskra, on the road leading to Sidi Okba, and above all, having the characteristics of vegetation we are looking for; This represents a place of attraction for crowds of students under the shade of its trees during the hot days of late spring and early fall, as noted by all passing nearby

Case A: The plot with built environment and dense ficus trees estimated at 90% plant cover

The geometry of our case study is rectangular, dimension 25m * 30m, is a clear space with H / L = 0.25. The dominant orientation is North - South. The air flow is of the isolated roughness type, the plot has bare natural soil, covered with a set of persistent ficus retusa type trees with an approximate height of 10m with very dense canopies, which ensures substantial shade estimated at 90% plant cover. *Figure 4.*

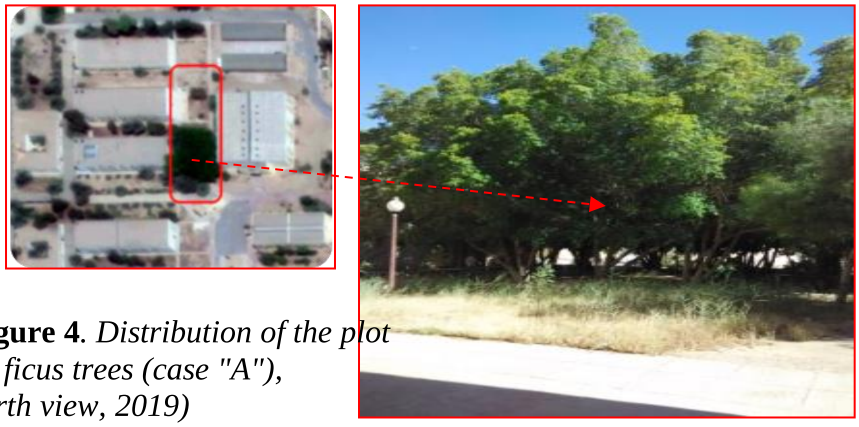

Figure 4. *Distribution of the plot with dense ficus trees (case "A"), (Google earth view, 2019) (Right) view during the summer period. (Source. Author 2019*)

Case B: the plot with built environment and cut ficus trees estimated at 0% plant cover
It is the same space therefore the same morphology and the same environment, except that the trees have been cut and that the ground is grassed, consequently, the effect of shading is eliminated and the contribution of the grass remains neglected. In this way, the verification of the contribution of trees in terms of thermal comfort by comparison between the two cases will be tangible. *Figure 5.*

Figure 5. *Distribution of the plot with cut trees (case "B") (Google earth view 2019) (Right) View during the summer period. (Source: Author, 2019)*

The morphological characteristics of the plot in the two cases are summarized in the *table 2* below, knowing that:

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Morphological indicators of the plot	The Placette with dense ficus trees Case "A"	The Placette with cut ficus trees Case "B"
H /L	0.24	0.24
SVF	0.06	0.43
Albedo « a »	Wall=0.45	Wall =0.45
	Ground=0.2	Ground =0.26
Orientation	North /South	North /South
Vegetation	90%	0%
The Views		
The Fish eye photos		
Characteristics	The presence of the sun mask of the surrounding buildings and a very dense vegetation , the earth bare. Case "A"	The presence of the sun mask of the surrounding buildings without trees, the lawn soil, no trees sun mask. Case "B"

Table 2. The morphological characteristics of the plot in both cases (Source: Author, 2019)

The morphological indicators chosen for this study are calculated according to the mathematical process, they are very suitable for determining the irradiative and thermal exchanges in the plot:

A) - the H / L Ratio prospect. According to (F, Fouad. Ahmed. Ouameur, 2007). The mathematical calculation of the H / L ratio depends on the horizontal and vertical dimensions of the space,

B) - Average albedo of surfaces (a.)

Is calculated according to a visual analysis of the percentage of occupation of each material in the facade and floor covering (F, Fouad, Ahmed Ouameur. 2007).

C) - Opening factor to the sky (SVF)

The Sky view factor (SVF) allows researchers to assess the heat exchange by radiation between the space studied and the sky. The latter can be obtained by calculation (formula) or by simulation. Its value is between 0 and 1. If the value of the SVF = 1, then the space studied is isolated; this means that the view of the sky is free of any obstruction (building, tree, street furniture ... etc.) no obstacle prevents the view and if the value of the SVF <1, means that the space is obstructed. On the other hand, an SVF of 0 expresses that the view of the sky is completely obstructed.

This factor is considered to be an important and essential morphological factor in the impact on the microclimate.

6. Material and method

In order to assess outdoor thermal comfort, the work is based on an inductive experimental approach; itself based on the in situ measurement companions, whereas for the calculation of solar radiation (in its different forms; direct, diffuse and global) we used simulation using Envi-met software, version 4.4.3.

The measurements were taken on the hottest days of the year, in other words "typical summer days", based on the choice of average daily temperatures over a decade from the meteorological station of the city. This highlights that the period of July is when the thermal stress reaches its maximum values.

The measurements are taken by the instrument: "TESTO data logger 480", during the month of July 2019 (03-07-2019), (with the presence of trees) at the beginning of the month and with cut trees, towards the end of the same month (27-07-2019), where the different measurements are taken at two hour intervals; from 8 a.m. to 6 p.m. for both cases, during the activity period.

This allowed us to measure the air temperature (Ta), air speed (Va), relative humidity (Hr); at the height of 1.5 m, retained as the height of the center of gravity of the human body, according to European standards. We also used the same means “TESTO data logger 480” inserted in a blackened ball 5 cm in diameter for the measurement of the globe temperature.

In order to assess thermal comfort by the UTCI thermal index we adopt the following mathematical formula. (Medeouk and al, 2015). (Dohssi, Khadidja and al,2022). (Djamila Djaghrouri and al,2022) .

$$\mathbf{UTCI = 3.21 + 0.872\ Ta + 0.245\ Tmrt - 2.507\ Va - 0.0176\ HR \quad (1)}$$

With Ta: Air temperature (in ° C)
Tmrt: average radiant temperature (in ° C)
Va: wind speed at 10 m above the ground (in ms-1)
RH: Relative humidity of the air (in %)

Which was calculated using the MATLAB R2011 software, the comfort index was evaluated at two hours intervals, starting at 08h: 00.

This first requires the calculation of the mean radiant temperature (Tmrt) by method B described by (Thorsson and al. 2007), based on the previously measured climatic variables and the global temperature, according to the following formula:

$$\mathbf{Tmrt = [(Tg + 237)\ 4 + 2.5 \times 108 \times Va0,\ 6 \times (Tg\text{-}Ta)]]\ 1/4 - 273} \quad \mathbf{(2)}$$

With Tg: Globe temperature in ° C
Va: wind speed at 10 m above the ground (in ms-1)
Ta: air temperature (in ° C)

7. Presentation and discussion of the investigation results

7.1.Discussion of the simulated results

The investigation is based on a three-dimensional model ENVI-met which simulates the microclimate conditions in an urban environment. It is a 3D simulation model developed for numerical modeling of urban microclimate and again the majority of atmospheric processes that affect the microclimate (Michael, Bruse. 2019). The impact of vegetation can be quantified at different levels. Indeed, the consequences of this presence in the plant reflect microclimatic scale in terms of: quantity of transmitted radiation, air temperature, leaf temperature, humidity of the air and wind speed.

To define the height and the shape of a plant, the model uses standard normalized functions (Leaf area density profile LAD, Root area density profile RAD) which can be applied for grassy surface as well as for huge trees. The gas and heat exchange between the vegetation and the atmosphere is controlled by the local energy balance steering the leaf temperature and by the stomata conductance controlling the gas exchange (vapor and CO2). The actual stomata conductance of a plant is a complex function depending on external meteorological conditions (air temperature, available solar radiation and many others) as well as on the plants physiological processes (Photosynthesis rate, CO2 demand, CO2 fixation...). ENVI-met uses a sophisticated model to simulate the stomata behavior of the vegetation. *Figure 6 and figure 7.*

Figure. 6. 2D view of the plot: Case A, with trees left, Case B, with cut trees right. Designed in a file. In. Source: ENVI-met 4.4.3.

Figure 7. 3D view of the plot: Case A, with trees left, Case B, with cut trees right. Designed in a file. In. Source: Leonardo 4.4.3

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7.2. The transmitted radiation

The calculation of direct and diffuse solar flux and global radiation in the "B" case (with cut trees) and the "A" case (with trees) in a condition of clear sky is possible for the period (from 8.00 to 16. 00). The global radiation values obtained by simulation allow us then to establish the following graph: *Figure. 8.*

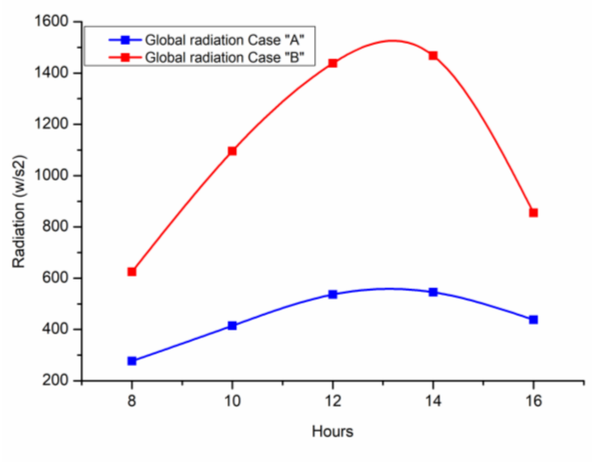

Figure. 8. Incident solar flux transmitted, in both cases. Source: ENVI-met 4.4.3.
Read by Leonardo 4.4. 3

The densification of the vegetation causing profound changes regarding the incident solar radiation transmitted to the ground level. The differences in global radiation are high between the case "B" (Cut trees) and the "A" case (with trees); the incident solar flux transmitted into the case"B" is very high compared to the "A" case. In the plot with cut trees the incident solar flux transmitted may exceed 1000 W/m2 compared with the situation of case "A"(plot with trees) (at 8h: 00). Direct action due to the shade of trees results in a decrease in surface temperature, an indirect effect of district cooling can occur while increasing vegetation cover (Sailor, D. J.1989) The impact of trees on the microclimate is one that causes the greatest impact on characterization of thermal conditions in outside space. Indeed, and according to the simulation, the calculations show that: global radiation in case "B" is about 1600 W/m^2 at 13h: 00. Global radiation in the "A" case is about 600 W/m^2 at 13h: 00. Similarly, the global radiation in the case "B" is much higher than that of case "A" at 15h: 00 (1200 W/m2 against 450 W/m2).

7.3. Effects of trees on air temperature

With regard to the air temperatures in the plot at 1.5 m above the ground, we can see that the air temperatures in case "A" plot with dense trees are less important than that situations of the plot with cut trees, the differences vary from 7 ° C to 9 ° C, with a minimum difference of 5 ° C around 4:00 p.m. This is explained by the fact that in the situation of the plot with cut trees (case "B"), the plot is more exposed to solar radiation compared to the situation with dense trees (case "A").

Consequently, the corresponding temperature values are higher as well as the convective exchanges between the surfaces and the ambient air. We also observe that air temperatures are influenced by surface temperatures which are higher for sunny areas than for shaded ones. *Figure 9.*

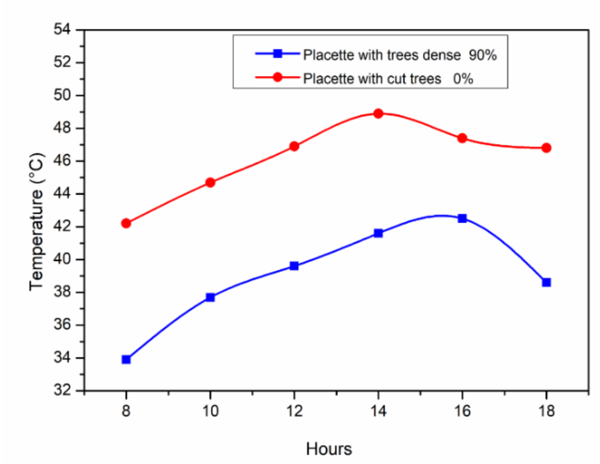

Figure. 9. The air temperatures in the plot at 1.5m from the ground in both cases, (Source author 2019)

7.4. Effects of trees on humidity

The humidity curves are homogeneous, in both cases, they are maximum at the start of the day, around 8:00 am, with a difference to the profile of the case with trees, so the shade allows a higher percentage of humidity which is well distinguished around 2 p.m., when the heat reaches its peak, there we notice the big difference between the two cases. From 2h:00 p.m., the relative humidity remains constant in case "B", that is to say in the case of cut trees, while in the other case, it decreases until 4 p.m., while being higher in case "B" to grow then overnight. Finally, we can deduce that shading has a significant impact on the relative humidity due to its protection and its evapotranspiration process. *Figure 10.*

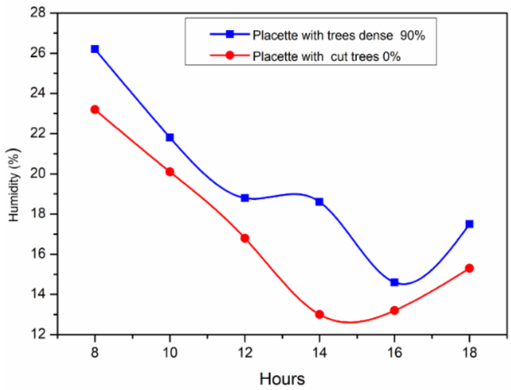

Figure 10. Relative humidity in the plot at 1,5m from the ground in both cases, (Source Author 2019

7.5.Effects of trees on wind speed

The wind speed in case “A” with trees is much lower than in the case “B”. It may be noteworthy that in the former case the wind speed reductions are observed when vegetation appears, though the plot is oriented north - south, exactly in the prevailing wind direction which comes from the North. Other factors may help the spread of freshness created by vegetation, including wind. In our study we recorded a value of 0.50 m/s between 12h: 00 and 14h: 00 in case “B” compared to case “A” where there was a value of 0.20 m/s at 12h: 00 and 0,10 m/s at 14h: 00. *Figure.11.*

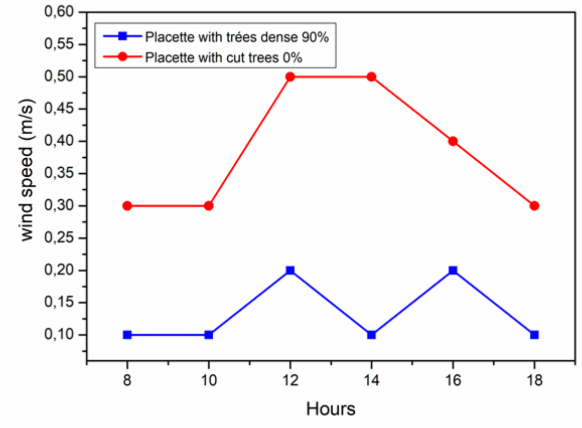

Figure. 11. The wind speed in the plot at 1.5m from the ground, in both cases, (Source author 2019)

7.6.Impacts of ficus trees on average radiant temperatures (Tmrt)

The average radiant temperature is the parameter most affected by the shading of trees under heat radiation, at the start of the day the values of the two cases are identical which begin to grow with time and the intensification of solar radiation, with increasing differences between the two cases (the values in case "B" are greater compared to case "A", with a difference of 19 ° C maximum around 2:00 pm hence the substantial effect of shading on the mean radiant temperature, the peak of the two cases is reached around 4:00 p.m., with a difference of 13 ° C, and then decreases with different intensities for the two cases. *Figure 12.*

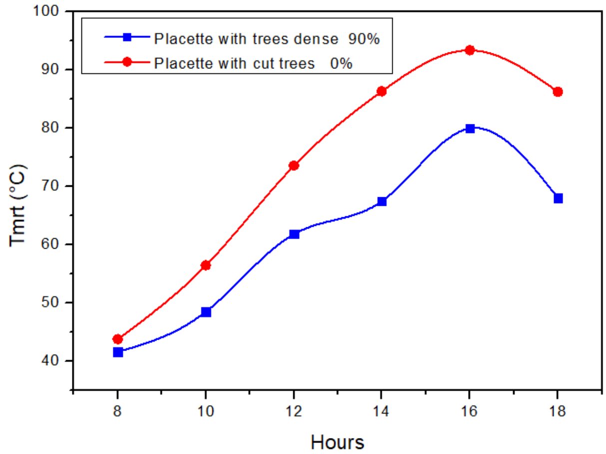

Figure 12. Average radiant air temperatures in the plot at 1.5 m from the ground , in both cases, (Source author 2019)

7.7.Impacts of ficus trees on the Universal thermal Climate index –UTCI-

UTCI has a great potential to be a useful tool for analyzing outdoor thermal environments in various studies of landscape, urban planning and design.

Though e are working in an area during the hottest period, the zone with cut trees is outside the very strong heat stress which stands between + 38 ° C and + 46 ° C whereas the place with trees stands in that interval till 10h00 in the morning, otherwise it over pass the limit of very strong heat stress, furthermore, even in that situation, it is clear that in the case of shading trees the values are always lower than in the case of cut trees. *Figure 13.*

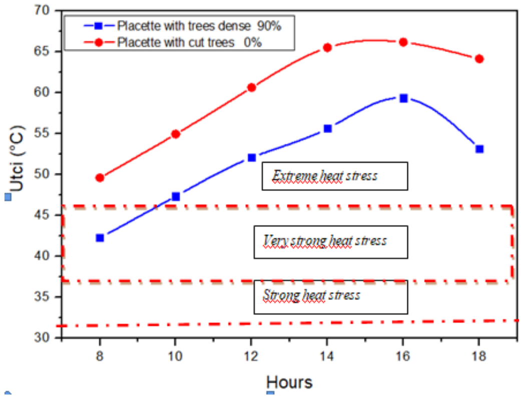

Figure 13. UTCI values in the plot at 1.5 m in both cases, (Source Author 2019)

7.8.Comparison between Tmrt and UTCI

First recalling this:

1- In relation to the air temperature; the curves are homogeneous in their form with differences ranging from 5.2 ° c at 8:00 a.m. to 3.4 ° c at 6:00 p.m. in favor of case "A", (plot with trees)

2- In relation to relative humidity. The curves are also homogeneous but in contrast with those of air temperatures, with variable deviations, ranging from 5.6% at 2 p.m. to 1.4% around 4 p.m.

Compared to the Tmrt, we confirm the differences between the two scenarios but in a rather specific report since this difference is reduced at the start of the day (2 ° C to 3 ° C) to progress substantially with the advancement of the day to reach values up to 18 °C difference around 2:00 p.m. and then gradually descend.

Compared to the UTCI, the deviations are quite pronounced even in the morning with values in the limit sensation interval for case A, at the beginning of the day until 10:00 am. Apart from this situation, it is the total heat stress but with a significant difference in favor of case A.

Undoubtedly, the plot in case "A" is the most comfortable because it is the most shaded and therefore the cooler. *Figure 14.*

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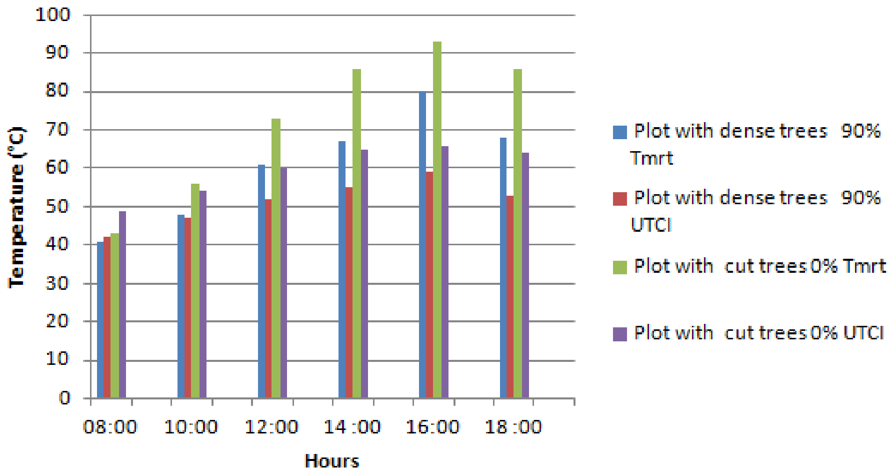

Figure 14. Comparison between Tmrt and UTCI in the plot at 1.5 m from the ground in both cases, (Source. Author 2019)

8. Conclusion

The vegetation (spatially the trees), whose presence is very beneficial to improving the conditions of thermal comfort in outdoor spaces. In this experimental work, this is confirmed in an intangible way since it involves a comparison between two situations of the same space which contained a set of trees that made it a very attractive space during the hard-hot days and which aroused our interest to study it in depth.

Given that we cut the trees just after, so we said we can confirm the refreshing contribution of the trees and quantify it, using simulations with Envi-met program and field measurements of climatic factors resulting from this new situation, during the days of the end of July.

The climatic situation is practically identical, and by comparison we can deduce that in this precise case, it is indeed the effect of the shadow of the vegetation (especially ficus trees) which is at the origin of its frequentation, in fact, these persistent trees have dense foliage, rounded, thickened and varnished leaves, which gives them an important leaf area index (LAI) and a high density of leaf area (LAD) of the canopy.

These, again, prove to be essential parameters having a significant influence on the micro climate, the denser the plant cover (LAI and LAD) are, the lower the temperatures of air and shaded surfaces we get and better is the thermal comfort, especially in the case of arid and semi-arid climate

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