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Effects of Vegetation Shading on Thermal Performance, Towards Sustainability in the Case of an Arid and Dry Area: A Plot In Biskra University Campus as a Case Study

Roumaissa AFREN[1], Djamila DJAGHROURI[2], Djemaa BARROU[3], Moussadek BENABBAS[4]

[1]Department of Architecture, Mouloud Mammeri University, Tizi-ouzou, Algeria
[2,4]LACOMOFA laboratory, University of Biskra, Algeria.
[3]Laboratory Child, City and Environment, University of Batna-1, Algeria.

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Abstract

This research, on external thermal ambiances, tends to highlight and affirm the impact of vegetation on outdoor thermal comfort, in an arid environment, which is very hot and dry. This effect of generating a less harmfully environment, in terms of thermal atmosphere, was emphasized by; in situ measurements and later, by simulations, in a semi-open public space with a set of mature Ficus Retusa trees, which were then cut later. This has given us an important opportunity for an intangible conclusion on the thermal ambiance 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 after these same trees have been cut; case “B”. This helped to deduce the impact of persistent vegetation on thermal comfort in such an environment; we took the measurements before and just after cutting the trees and madecalculation of comfort index from climatic factors, themselves dependent on morphological indices. Theresults we got highlighted the variations in the comfort index (PMV), that is, an indicator of the thermal comfort in both cases. At last, we deducted the great effect of the trees shade on the external thermal wellbeing in a public space located in a very hot and dry zone.

Key words: Vegetation; Outdoor thermal comfort; Sustainability; In situ measures; Simulations; The comfort index PMV; Biskra university campus

INTRODUCTION

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 [1]. 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 urban developments that can be described as sustainable and ecologically designed, and which will best meet the requirements of thermal comfort, 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 [2], while the transpire 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 a hot and dry climate, thus contributing to more sustainability [3]

LITERATURE REVIEW

With steadily growing impacts of global warming, cities are increasingly struggling with new problems such as intensified urban heat island (UHI) effect [4]. 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 [5]. This phenomenon is also exacerbated by the growing size of the city dwelling human population and the increasing rate of energy consumption [6, 7]. Research has shown that cities currently account for 60% to 80% of the world's total energy consumption [8]. 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 [9]. Since it has been estimated that the ratio of the world urban population to total population is set to increase from 54% in 2016 to 60% in 2030, can be expected to become a major challenge in the future urban life. [10]

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.[11] According to a review study published in 2010, green infrastructure (trees, parks, forests, and green roofs) has a higher level of thermal comfort than other urban spaces.[12] This is especially true for larger parks and urban forests, 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 directly correlates with its vegetation cover and tree shade area [13]. In a recent review paper by (Taleghani. M), 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. [14]

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, [15, 16] the stack night ventilation, [17] the use of water bodies [18,19,20] and the use of materials with a high albedo rating for pavement and other ground surfaces. [21,22,23,24] When using vegetation cover, it is 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.

A study by (Bernatzky, A.) 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. [25] This study 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 plots. [26] For their part, (Chatzidimitriou and al.), 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. [27] Compared to the study by (JörgSpangenberg,), 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. [28] A research team from (the ABC laboratory in Marseille) 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. [29] Utilizing a three-dimensional CFD model in Ljubljana in Slovenia by (Vidrih and Medved), 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. [30] According to a study conducted by (Park and al,) in Seoul, small green spaces with an area of 300 m2 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. [31]This study found that the CEI of a park correlates with its size, and accurately predicted that a 1500 m2 green space would reduce the temperature by up to 3.6 °C. This study also showed that polygonal lands with combined vegetation cover could reduce the temperature by up to 4 °C.

Outdoor Thermal Comfort Evaluation

The average radiation, temperature (Tmrt) is considered 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, confirmed that the average radiation temperature is a more precise indicator than air temperature for evaluating thermal comfort. [32] (Thorsson, and al,) 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. [33]

Universal Thermal Climate Index (PMV)

Today, one of the best-known thermal indices used to be the Fanger's comfort equation specific to interior spaces, which allows the calculation of the predictable average vote (PMV) [34]. Fanger, in his work, arrived at the average assessment of the thermal environment for a large sample of individuals based on the seven comfort scales defined Ashrae. Figure01

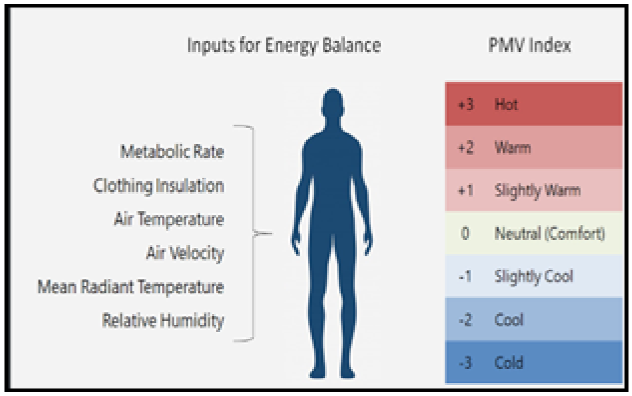


Figure 1. Classification of PMV values according to the seven "ASHRAE" comfort scales. Source: H. Mayer, 1993

However, H. Mayer in his work carried out during the updating of his simulation program adopted nine comfort scales specific to outdoor spaces, where the theoretical zone of outdoor comfort is between -4 and +4, which will be the basis for the assessment of thermal comfort. [35]

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), which let the outdoor public spaces to be deserted, assailed all day by a hot and burning sun, the people rush 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). This is the case of the city of Biskra, Algeria.The concern of our article 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 in end of school years. Figure 02.

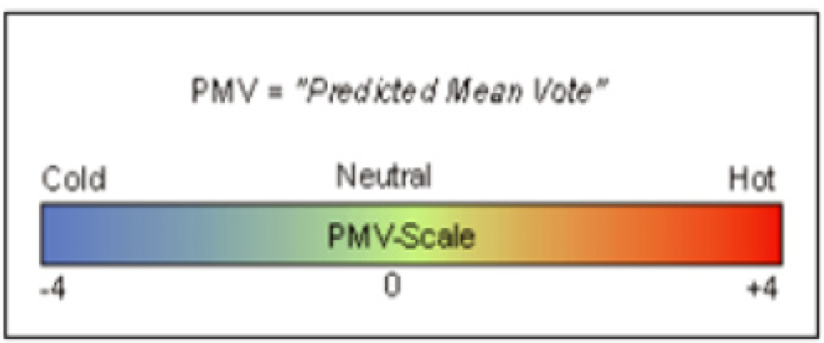


Figure 2. Classification of PMV values according to nine comfort scales. Source: Michael BRUSE, 2015

The objectives of this research are to confirm, through fieldwork and simulations, the effect of urban vegetation and shade on the environment and thermal comfort, in a semi open public space in a southern Algerian city with a hot and arid climate (the city of Biskra). The main objective is to confirm the impact of the shade of trees (Ficus retusa) on both; the atmosphere, and the thermal comfortof the two situations in this space; 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 assess the thermal environment from an objective point of view based on real measurements in situ and simulation.

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. Figure03.

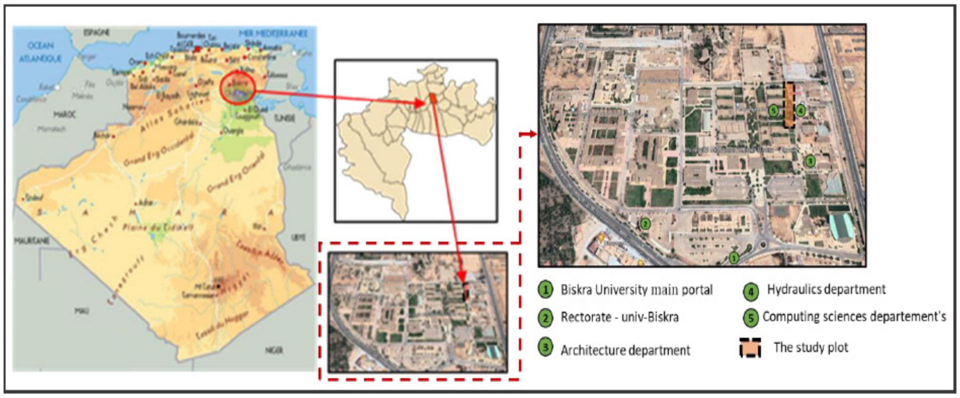
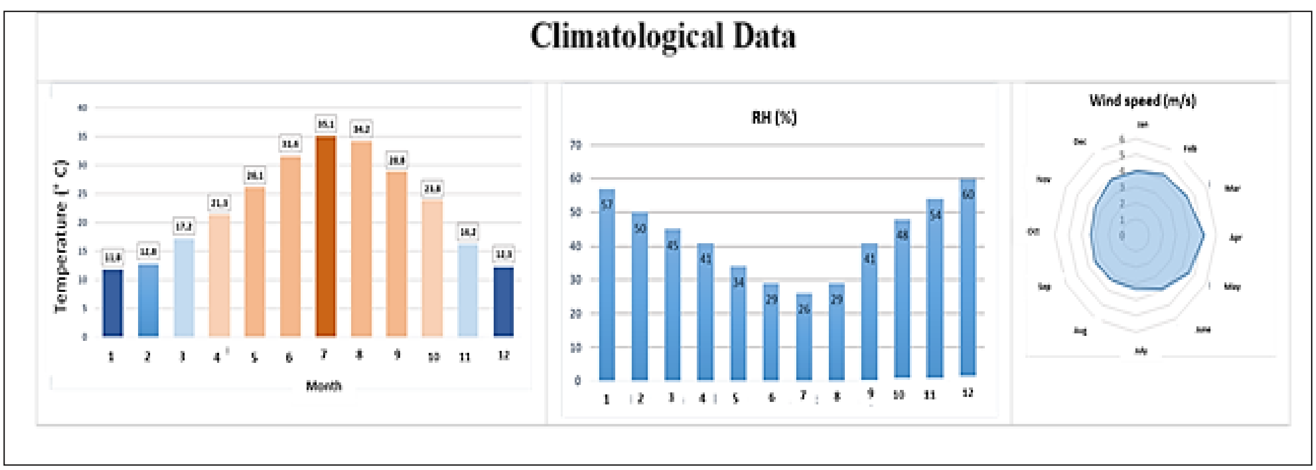


Figure 3. Biskra situation and the study plot in it(Source: https://www.mondecarte.com/carte/biskra-carte)

The context of this study is devoted to the city of Biskra (34.8 ° N, 5.7 ° E). It belongs to an arid region with hot and dry climate. The city is located in the southeast of Algeria. It belongs to a region classified arid with cold winters and hot summers. The maximum temperature reaches 50 °C during the month of July and the minimum temperature decreases to 7°C in winter during the month of January.

The average annual temperature is 21.7 °C while the average annual humidity is 46%. Very low precipitation is recorded with a maximum of 20mm / year, and an annual average of about 8.8mm / year. The prevailing winds are northwest in winter, southeast in summer at a speed of 6 to 10 m/s. Table 01.

Table 1. Biskra city climatic data: (relative humidity, above and temperatures, below). Source: Weather station data Biskra, 2013-2019.



In this study, we will therefore limit ourselves to presenting the results obtained during the hot period Biskra receives around 3300 hours of sunshine a year in all parts of this city. It is characterized by a clear and sunny sky almost throughout the year, a global radiation, which varies between 240 kWh / m2 and 90 kWh / m2, with an average precipitation almost zero in the summer period and which reaches 3mm (Meteonorm7).

Presentation of the Investigated 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 SidiOkba, and above all, having the characteristics of the 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, The fish eye views show the state of the two case studies.

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

The geometry of our case study is almost square, dimension 25m * 30m, it is a clear space with H / L = 0.25. The dominant orientation is North - South. The airflow 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").

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 negligible. In this context, 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").

The morphological characteristics of the plot in the two cases are summarized in the table 02 below, knowing that:

Table 2. The morphological characteristics of the plot in both cases.

Morphological indicators of the plot	The Plot with dense ficus trees Case "A"	The Plot with cut ficus trees Case "B"
H /L	0.24	0.24
SVF	0.046	0.43
Albedo « a »	Wall=0.45	Wall =0.45
	Ground=0.2	Ground =0.26
Orientation	North /South	North /South
Vegetation	Gcr =90%	Gcr=0%
Characteristics	The presence of the sun, mask of the surrounding buildings and very dense vegetation, the earth bare. Case "A"	The presence of the sun mask of the surrounding buildings without trees, the lawn soil, Case "B"

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

A) **-** the H / L Ratio prospect: According to Michael, Bruse The mathematical calculation of the H / L ratio depends on the horizontal and vertical dimensions of the space. [36]

B) – The 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. [36]

C) **-** Opening factor to the sky (SVF): The Sky view factor (SVF) allows researchers to assess the heat exchange by radiation between the studied space and the sky.

The latter can be obtained by calculating (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.). An SVF of 0 expresses that the view of the sky is completely obstructed.

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

D) **-** Green coverage ratio (Gcr) [37]

It is the ratio of the sum of the areas of all trees, shrubs, plants, and weeds from the general area GCR, it is evaluated according to the following formula: Where: GS: is the general area, Gi: is the area of the green field and its number n:

$GCR = \sum_{i=1}^{n} G_i/GS$ …………………………..(1)

MATERIALS AND METHODS

In order to assess outdoor thermal comfort, the work is based on an inductive experimental approach, itself based on the in-situ measurement companions. 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 2020 (with the presence of trees) at the beginning of the month, and with cut trees, towards the end of the same month where the different measurements are taken at two hour intervals; from 8 a.m. to 6 p.m. for both cases, that is, 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 temperature globe. This is assumed in the Figure 6 below.

Figure 6. Measurement instruments.

In order to assess thermal comfort by the PMV thermal index, we adopt the results of our simulation in both cases, but, this first requires the calculation of the mean radiant temperature (Tmrt), which is done by method B, described by (Peng, S., Piao, S., Ciais, P., Friedlingstein, P., Ottle, C., Bréon, F. M.,... &Myneni, R. B.), it is based on the previously measured climatic variables and the global temperature, according to the following formula. [33]

Tmrt = [(Tg + 237) 4 2.5 × 108 × Va0, 6 × (Tg-Ta)]] 1/4 – 273 …….. (2)

With Tg: Globe temperature in ° C

Va: wind speed at 10 m above the ground (in m/s)

Ta: air temperature (in ° C)

PRESENTATION AND DISCUSSION OF THE INVESTIGATION RESULTS

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 situation 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 in sunny areas than for shaded ones. Figure 7.

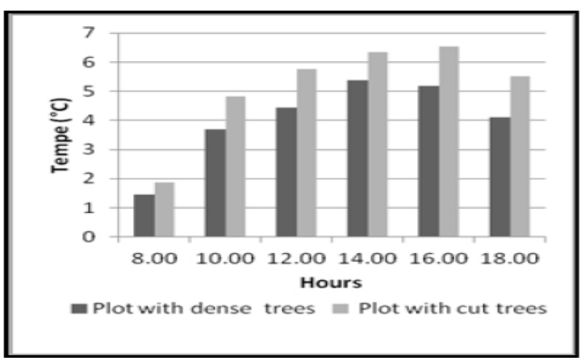


Figure 7. The air temperatures in the plot, at 1.5m from the ground, in both cases

Effects of Trees on Humidity

The humidity graphics 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. Figure8.

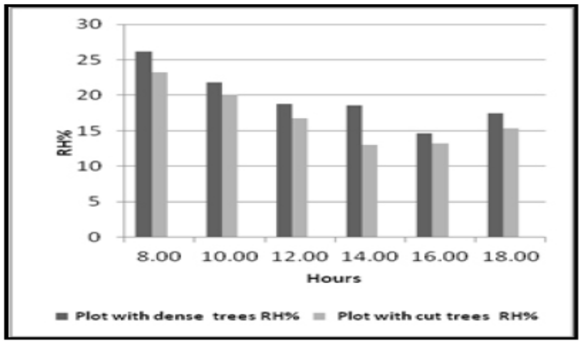


Figure 8. Relative humidity in the plot at 1,5m from the ground in both cases

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 9.

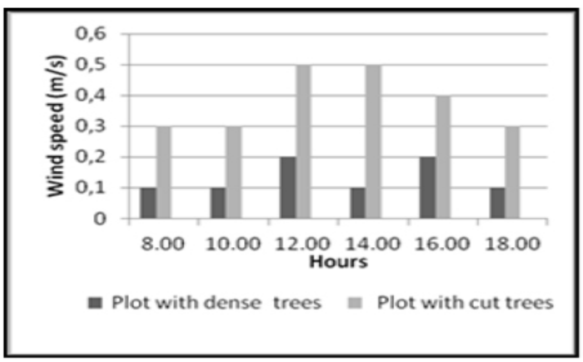


Figure 9. The wind speed in the plot at 1.5m from the ground, in both cases

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 intensity of solar radiation, with increasing differences between the two cases (the values in case "B" are greater compared to the 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 10.

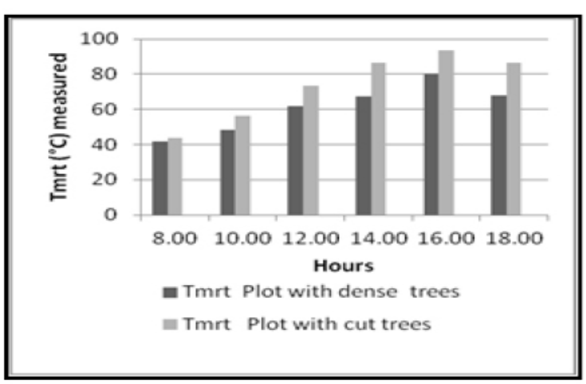


Figure 10. Average radiant air temperatures in the plot at 1.5 m from the ground, in both cases.

DISCUSSION OF THE SIMULATED RESULTS

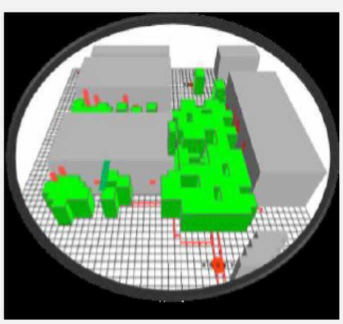
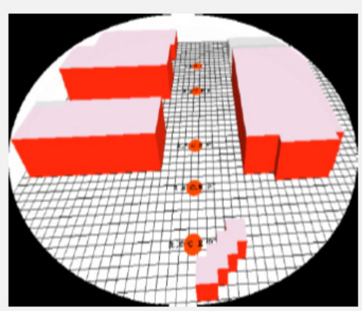
The investigation is based on a three-dimensional model ENVI-met, which simulates the ambiance conditions in an urban environment. This is assumed in the Table 3 below. It is a 3D simulation model developed for numerical modeling of urban ambiances and the majority of atmospheric processes that affect the environment.[38].

Table 3. The morphological characteristics of the plot in both cases. Source: Author 2019

Situation of the two sites	biskra Algeria Longitude 5.73 E Latitude: 34.73 N
Type of climate	Climate:arid and dry climate in summer
simulation day	Typical hot summer day, 26.07.2020
Simulation time	From 07.00 a.m. to 7.00 p.m.: (12 hours)
Climatic parameters: **Average wind speed (m/s)** **Wind direction** **Average relative humidity (%)** **Average temperature (°C)**	 1.50m/s 180.00 north 28-28% 31-45 C
Buildings: **height of the Buildings** **Wall Albedo** **Roof Albedo**	 08m 0.6 0.18
Vegetation and floor ;	40% with (05% deciduous trees and 35% evergreen trees). (15% grass, 25% gray concrete pavement and 60% natural soil).

The impact of vegetation can be quantified at different levels, indeed, the consequences of this presence in the plot reflects the ambiance scale in terms of: quantity of air temperature, leaf temperature, humidity of the air and wind speed. Table 4.

Table 4. Modeling of the scenarios A and B "3D model area created using ENVI-met, showing the exterior spaces and the buildings.

Scenario A	Scenario B
	

Correlation between Simulated and Measured TMRT in Both Cases

In this study, vegetation significantly affects the outdoor thermal comfort condition as observed in previous studies. Since the study aims to predict the effects of vegetation on ambiances and thermal environment conditions, a numerical simulation is a suited method for this task. A critical issue to assessment of human comfort in outdoor environments is the mean radiant temperature (Tmrt), which sums up all short wave and long-wave radiation fluxes absorbed by a human body. On this regards, solar access is a key variable in evaluating thermal sensation outdoors during daylight hours, therefore, the methodology examines the relationship between vegetation and solar access as a means to understand the thermal behavior of the plot in terms of Tmrt. Besides, from the relationship between Tmrt and vegetation, this study makes a parameterization of thermal environment conditions at pedestrian level. In this study, outdoor thermal environment conditions at ground level of the plot configurations are performed via using an urban environmental simulation model, ENVI-met [40]. The average long-term meteorological data for University campus of Biskra area used in the simulation model was obtained from the Laboratory LACOMOFA weather station) at The Architecture department, which represents the hourly mean air temperature and relative humidity from 2016 to 2020 on July.

The simulated climatic condition then transfers to Envi-met Model to calculate the Tmrt, which further use to evaluate hourly thermal comfort across the plot in the two case configurations. On-site measurements were performed from 8h00. to 18h00 p.m. on July 26, 2020, for the "B" case and "A" case, that is, in the hottest month of summer, for Biskra city. The Tmrtmust be validated by comparing field measurements and model simulation results to fit the local climate and base case configuration [41, 42].

The correlation between measured Tmrt and simulated Tmrt have similar trends and strongly correlated with R2 = 0.99 in case "A". Figure 11, and R2 = 0.92 in case "B". Figure 12, in both cases ($p < 0.001$). This indicated that the ENVI-met model capably simulated the microclimatic conditions in both cases in a hot summer season.

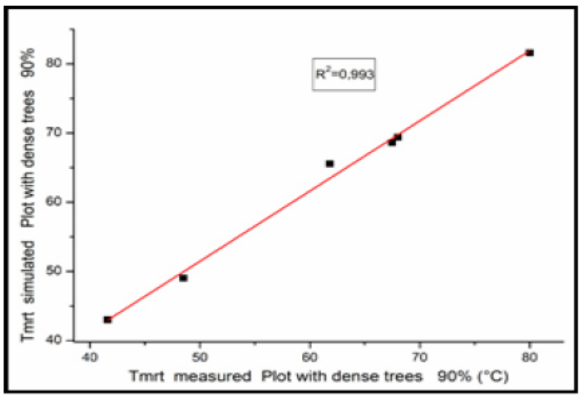


Figure 11. The coefficient R2=0.993. Correlation between (Tmrt measured) and (Tmrt simulated) in case "A" by Envi-met 443 model

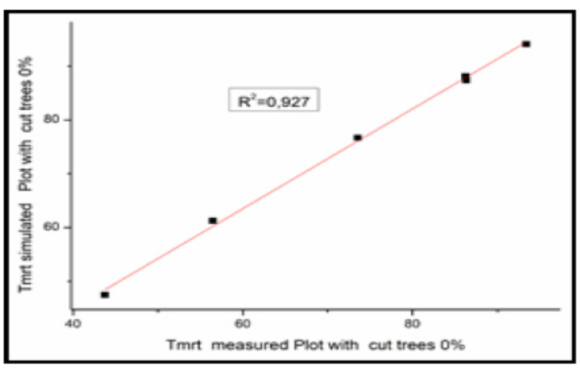


Figure 12. The coefficient R2= 0.927. Correlation between (Tmrt measured) and (Tmrt simulated) in case "B" by Envi-met 443 model.

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 intensity of solar radiation, with increasing differences between the two cases (The values in case "B" are greater compared to the 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 13.

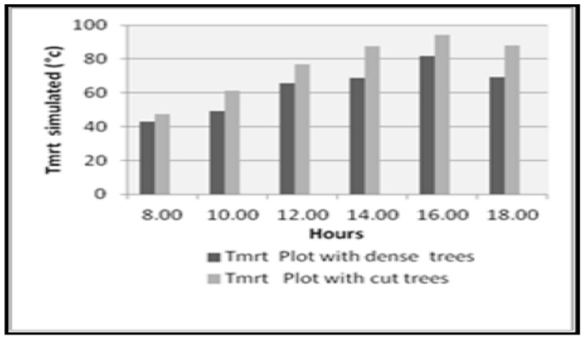


Figure 13. Average radiant air temperatures in the plot at 1.5 m from the ground, in both cases

Impacts of Ficus Trees on the PMV (Predicable Mean Vote)

Typically, PMV range is described within (-4) very cool and (+4) very hot, 0 is the thermal comfort, value (neutral), see Fig (01). Although PMV values are the mathematical function of the local environment, in most utilization, it can also give values below (-4) or above (+4). Implementing of PMV equation to the outdoor circumstances in summer temperature stress conditions can efficiently provide values of PMV high over +4 (+7 and more). While these results are mathematically accurate, it infringes the scale of the actual PMV method.

Figure14, depicts the values of PMV for both cases in the hottest days of July; we observe that the vegetation achieves an improvement in the thermal comfort. PMV values range (1, 46 – 5, 37), for the case "A", whereas, the range in case "B" is (1, 88 – 6, 54), we can notice that the deviations are quite pronounced between the two cases with values in the limit sensation interval in case A, at the beginning of the day until approximately 09:30am, in case "B" and around 10:15 am in case "A".

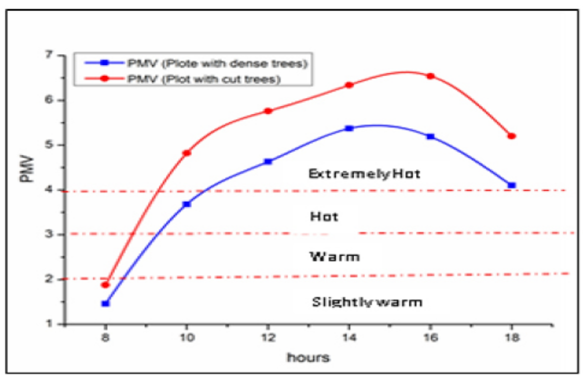


Figure 14. PMV values in the plot at 1.5 m in both cases

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 coolest.

DISCUSSION

The main purpose of this paper is to study the effect of vegetation, especially the evergreen trees, on the ambiance during the hot periods of the year for a plot's users. Three climate key parameters to estimate the human thermal comfort are temperature, humidity and wind velocity. [43] Based on an extensive bibliographic research, the main characteristics of vegetation that can affect the urban environment including evapotranspiration, transmission, albedo and permeability. Evapotranspiration phenomenon causes to the reduction of air temperature. Transmission and albedo related to the impact of vegetation on solar and daylight access that varied during the year, in particular for evergreen trees, permeability is a parameter related to the wind penetration of vegetation [44].

In order to test the state of our case study, in situ measurements and later, numerical simulations using ENVI-met took place in a plot at the university campus. Simulating of two cases, scenarios indicated that when selecting the case "A", plot with evergreen trees, humidity was relatively high in the plot, while simulated temperature and wind velocity were decreased during the studied period. Additionally, the ratio of evergreen trees was greater, the temperature and wind velocity were lower but the humidity was higher. Some previous studies proved that evergreen trees due to the effects of permanent canopy and therefore permanent shadow could reduce the temperature in the summer. [45, 46, 47] In addition, evapotranspiration from vegetation could reduce air temperature and increase humidity. [48, 49]

Evergreen trees due to permanent canopy reduce the hot wind blowing in the summer. Moreover, the evapotranspiration of vegetation in particular from leaves, adds moisture to the environment that could raise humidity. [47]

Vegetation as an important natural element could improve the urban environment and outdoor thermal comfort for the users. As mentioned in the results section, the comfort level in case "A" was the most comfortable. PMV value (about 5) was decreased, especially in the morning. The PMV value was worse than the "extreme heat stress, thermal condition experienced in case "B" (4 < PMV). With dense ficus trees in simulated process, the PMV value was also decreased compared to case "B", during the day. Three important climatic factors that affect the PMV index (temperature, humidity and wind speed)

Ficus retusa as an evergreen tree, due to its rapid growth and drought resistance are planted extensively in semi-arid and arid regions like Biskra. From the ambiance point, some researches indicated that the evergreen trees are the right option for planting in the urban area with a hot summer climate. [50, 49, 46]

The effectiveness of vegetation morphology (presence or absence of leaves in plants, leaves size and angle, plant height, crown density and permeability) in terms of controlling climatic elements is clearly reflected in many studies, which led in the end to more sustainability. [51, 52, 53, 54, 55, 56, 57, 58.]

CONCLUSION

From our findings, it can be seen that vegetation is an influencing factor in the summer time and thermal comfort. The vegetation type and ratio could improve summer thermal comfort in an urban environment. PMV as an important thermal comfort index could be affected by vegetation. Although the results indicated that neither of the simulated cases were in the range without thermal stress (comfortable), However, in the case "A" with evergreen trees when measured and then simulated, the temperature (as a key parameter in climate) was decreased and summer thermal comfort improved, according to PMV values. Results of the present study indicated that the evergreens such as Ficus retusa, mainly due to the creation of permanent shadow, is the right option for setting up outdoor spaces in the arid hot summers' regions.

The findings presented in this study is an applied result of urban landscape designers that should consider the potential of vegetation types and the ratio of them to mitigate of severe heat and improving summer thermal comfort, it is indeed the effect of the shadow of the vegetation (ficus trees, in our case) which is at the origin of the plot frequenting, 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 prove to be essential parameters having a significant influence on the micro climate, the denser the plant cover (LAI and LAD) is, 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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