International Journal of Innovative Studies in Sociology and Humanities
ISSN 2456-4931 | Open Access | Volume 7, Issue 12, 2022
DOI: https://doi.org/10.20431/2456-4931.071213

The Influence of Microclimate Parameters on the Outdoor Thermal Comfort in a Coastal City Annaba City, Algeria, as a Case Study

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Received: November 25, 2022 **Accepted**: December 18, 2022 **Published**: December 21, 2022

Abstract

Thermal comfort in the outdoor public space is one of the major issues to which the city must respond in order to improve the quality of life of its inhabitants. In recent decades, several studies have been carried out to study the relationship between urban morphology and microclimate in towns and cities. Thermal comfort in public space is influenced by several factors, among these factors we find; the urban morphology and the vegetation... etc. The objective of this paper is to evaluate the impact of the microclimate parameters on the outdoor thermal comfort and their relationship with the morphology of the plazas and vegetations.

To meet this objective we chose two publics plazas with different morphology. Both plazas are in the city of Annaba, a Mediterranean city in northeastern Algeria. Field measurements during July 27, 2018 were taken, they are of the three climatic parameters: air temperature, wind speed and humidity. Then we carried out a numerical simulations using Envi-met software to calculate the climatic parameters and thethermal comfort index: PMV (predicted mean vote) and PPD (Predicted Percentage of Dissatisfaction) to assess thermal comfort in both plazas.

Key words: Thermal comfort, Urban morphology; microclimatic parameter; numerical simulation; Annaba city.

INTRODUCTION

Thermal comfort in public space is a complicated concept that is difficult to evaluate, because it depends on several parameters and varies on several scales: spatial and temporal (Nikolopoulou and Steemers 2003). Air temperature has traditionally been used as an indicator to assess the thermal environment, particularly to analyze heat-related health risks (Smith, Zaitchik, and Gohlke 2013) , but it cannot fully represent the outdoor thermal environment experienced by humans (Sherwood 2018). because there are other climate parametres impact the thermal comfort sensation, such as the mean radiant temperature, humidity, and wind speed. Hence composite indices of apparent temperature, have been suggested (Barnett, Tong, and Clements 2010; Budd 2008). Compared to air temperature, these indices can provide more pertinent information about the human thermal environment (Cheng, Lung, and Hwang 2019; de Freitas and Grigorieva 2015) these indexes integrate personal factors like occupant's physical activity, age and clothing.

Moreover the outdoor thermal comfort is related to the surrounding enviroment, where there is an interaction of several parameters, including morphological parameters such us: the urban morphology, the hight of buildings and vegetation, climatic parameters such as: temperature, humidity, wind speed, solar radiation ... .etc. Parameters related to the person such as: age, state of health, clothing, level of activity, place of residence ... .etc. these parameters are subjective and difficult to identify, and other parameters, such as entropic heat and the amount of CO2 and dust in the atmosphere ... etc. caused by vehicles and industrial activities in the city (fig01).

To improve people's life quality, planning and mitigation strategies are necessary for critical thermal environments *(Ebi et al. 2004)*, so prediction of the thermal environment is essential *(Urban et al. 2019)*. Adolphe states that the significant variation in urban morphology has a direct effect on the climate: wind speed, air temperature, solar radiation exchange. This variation influences the conditions of outdoor comfort, modifies the thermal balance, intensifies the urban heat island effect and the confinement of atmospheric pollution *(Adolphe 2001)*.

Several researchs has been conducted to study the microclimate and thermal comfort in public spaces. Among them a study on thermal comfort using surveys in two squares in Brazil (Hirashima, Assis, and Nikolopoulou 2016). also other studies about the thermal comfort and heat mitigation stratgies (Gago et al. 2013; Manzano-Agugliaro et al. 2015; Taleghani 2018). Thermal comfort is defined as the conditions for which, self-regulation mechanisms are at a minimum level of activity (Givoni 1978). The level of thermal comfort can be evaluated using several indices (Figure 2)

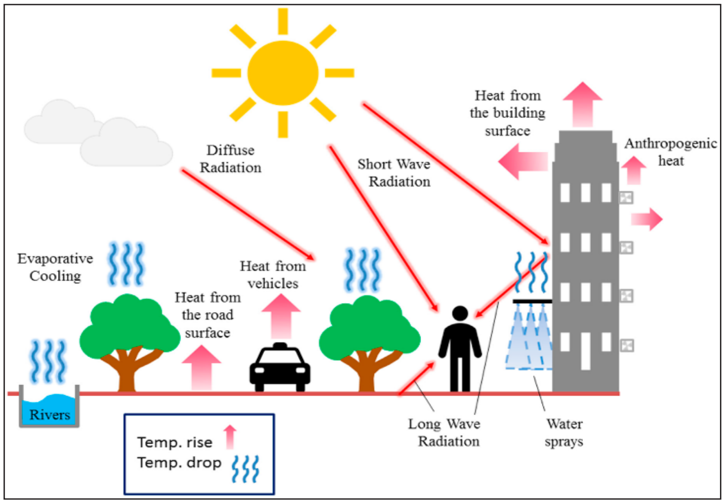


Figure 1. Relationship between the outdoor thermal comfort and surrounding environmental settings. Source : (Wai, Xiao, and Tan 2021)

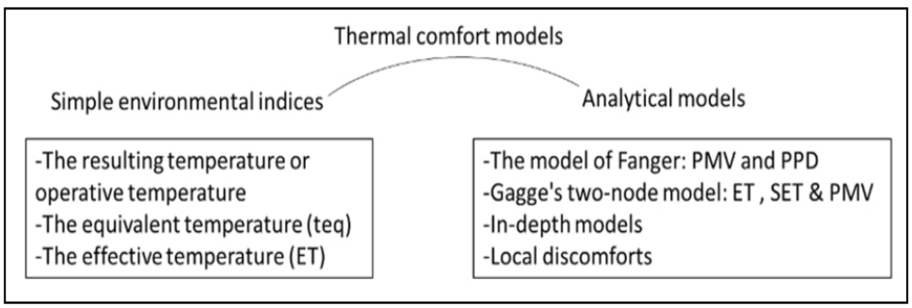


Figure 2. Thermal comfort models.Source: (Bassam, 2007.)

Indeed, our work targets the public plaza. It is a comparative study between two plaza which has two different morphologies in two differents urban fabrics. It is to study the morphological and microclimatic parameters, and evaluate the level of the thermal comfort by calculating the PMV and PPD index.

PMV and PPD, Indexes

Fanger designed a static thermal comfort model through surveys conducted in a controlled room. This model is based on the theory of the neutral thermal state (Fanger 1972). two indexes are calculated: Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfaction (PPD). PMV aims to predict the mean value of votes of a group of occupants on a seven-point thermal sensation scale The scale's values vary from −3 corresponds to the too cold situation, and the value of +3 corresponds to the too hot situation. Thermal balance is obtained when an occupant's internal heat production is equal to its heat loss figure 3. This thermal balance can be affected by both personal factors (insulation of clothing and metabolic rate) and environmental factors (temperature, relative humidity, and airspeed). Once the PMV is calculated, the PPD index can be determined, by establishing a quantitative prediction of the percentage of thermally dissatisfied occupants (too warm or too cold), and it could be related to PMV (Figure 03.) (Bienvenido-Huertas and Rubio-Bellido 2021)

Presentation of Annaba City

Annaba is a coastal city situated in northeastern Algeria (figure 4). It is characterized by a mediterranean climate, warm and rainy in winter and hot in summer with high humidity due to its geographical location between the mountains and the sea (figure 5).

According to meteorological data, we note that the month of July represents the hottest month of all year, the air temperature can exceed 40°C, also solar radiation is maximum and precipitation is almost zero during this month.

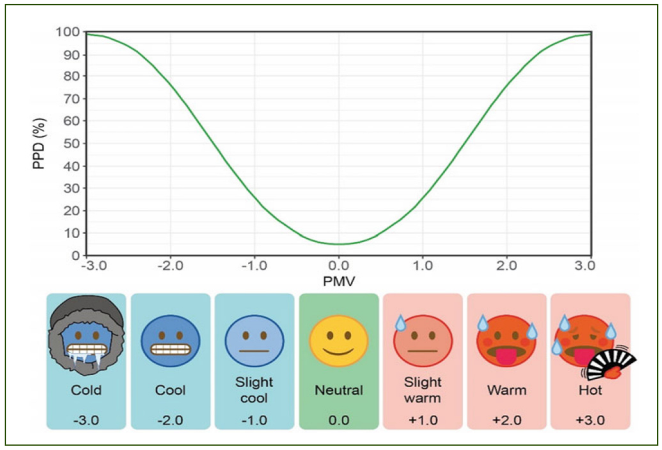


Figure 3. Lineal relationship between PMV and PPD, and the scales considered according to PMV. source: (Bienvenido-Huertas and Rubio-Bellido 2021)

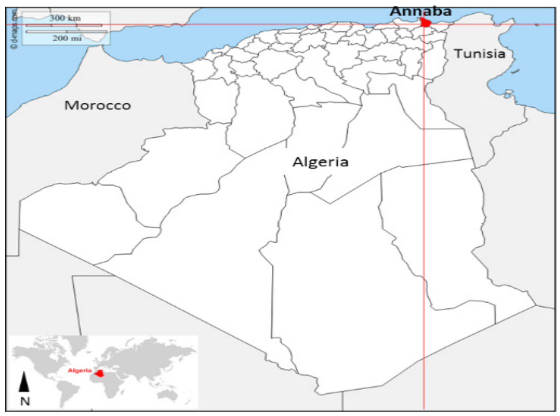


Figure 4. Annaba city situation. (Source: www.d-maps.com, treated by authors)

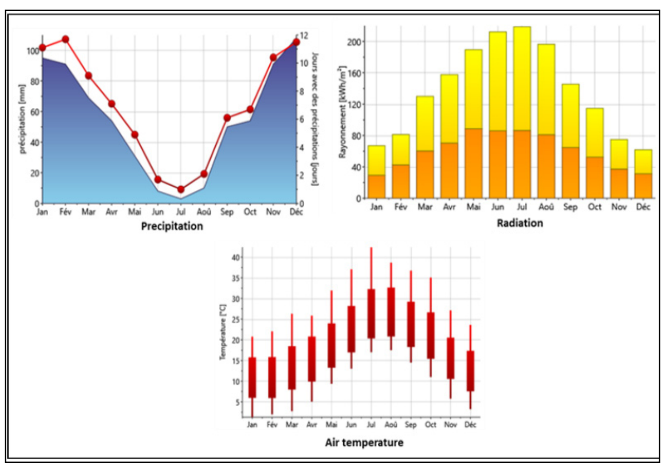


Figure 5. Meteorological data of Annaba region. Source: (www.meteonorm.com)

MATERIAL AND METHOD

This study is founded on an investigative approach based on the method of quantitative assessment of the climatic and morphological parameters necessary to estimate the level of comfort of people in the outdoor urban space. The evaluation method is divided into two parts, the first part concerns in situ measurements of the climatic parameters, namely air temperature, air speed and the relative humidity. the second part deals with the modeling and numerical simulation using Envi-Met software version 5.0.2 (Bruse and Fleer 1998). According to research on thermal comfort, the mean radiant temperature, air temperature, air velocity and relative humidity are the major climatic factors affecting the level of thermal comfort (Sharifi and Boland 2020). Therefore, numerical measurements are viable tools to calculate these parameters (Djamila et al. 2022).

Case Study

We chose two plazas located in two different urban fabric with various morphology. The first one is *Allexis lambert* plaza located in an haussmanien urban fabric with hight urban density, and the second is *el Bouni* plaza located in a contemporary fabric with low urban density (figure 6). The choice of these two plaza was made according to the following criteria: the first criteria is urban density, where the site (1) is very dense, while the site (2) is less dense, the second criteria is Morphological parameters specific to plaza, namely the ratio height-to-width (H/L) and the sky view factor (SVF), and the third and last criteria is vegetation density: Table 01.

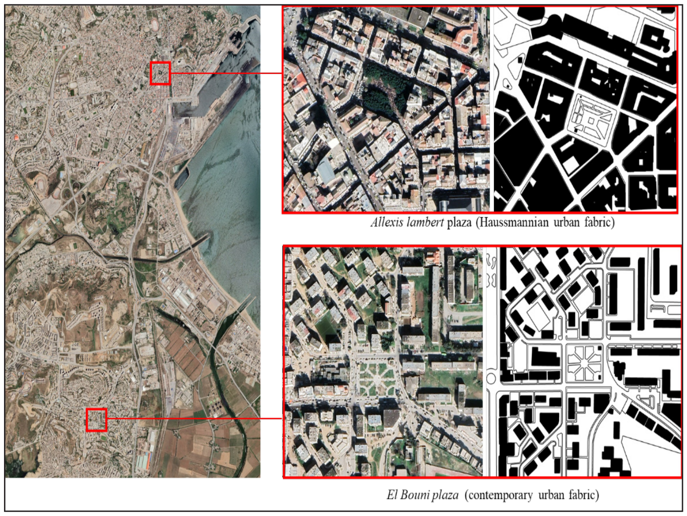


Figure 6. Location of the case study. Source: (Google earth treated by authors)

Table 1. Morphological parameters of the two plazas. (Source: Authors)

Morphological parameters	Ratio H/W	SVF	Vegetal density	Build density
Alexis Lambert plazas	0.17	0.4	0.31 %	64 %
El Bouni plazas	0.15	0.9	0.09 %	0,21 %

Field Measurements

Field measurements of the climatic parameters namely: Air temperature, humidity, wind speed, were taken during July 27, 2018, every two hours from 8:00 am to 6:00 pm using Testo 480 devise (figure 7) positioned at 1.10 m above the ground. Two measurement points for each of the two plazas were fixed. As we can see in (figure 7), one of the two points is located in the center of the plaza, and the second point is located in its boundary.

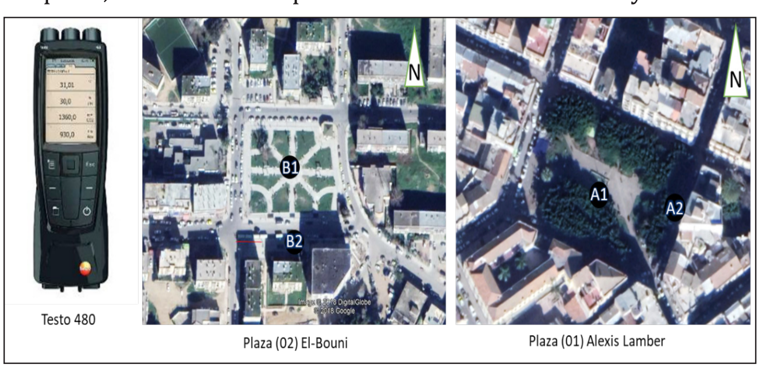


Figure 7. Measurement points. Source: (Authors)

Numerical Simulations

The numerical simulation was carried out using the Envi-met software, the simulation day is the same day of measurement (July 27, 2018). We first created a database which constitutes the 3D model by integrating all the information concerning the height of the building, the occupation of the ground, the vegetation and the geographical coordinates of the studied area. Then we integrated the meteorological data of the day chosen for the simulation. We also did a simulation without vegetation to see its impact on the level of thermal comfort.

The objective of the simulation is to calculate the microclimatic parameters (air temperature, mean radiant temperature, air velocity, and relative humidity) as well as the PMV to analyze the impact of these parameters on the level of thermal comfort Figure 8 illustrates the numerical simulation process adopted in this research.

The modeling tool in ENVI-met (Spaces. INX) allows us to create and visualize the areas in two dimensions 2D as in three dimensions3D. Table 2 represent the two sites models used in this simulation, with and without vegetation.

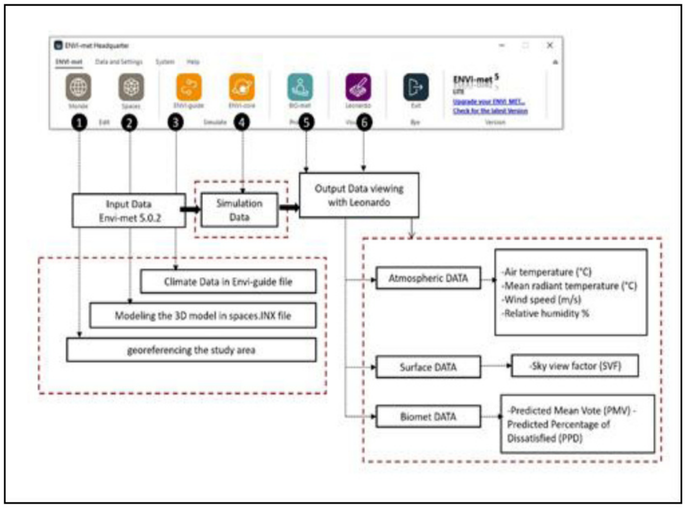
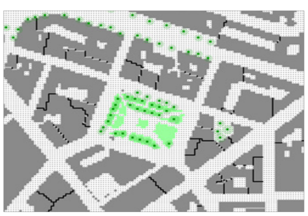
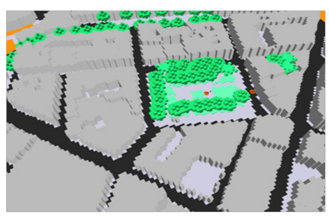
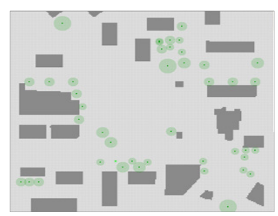
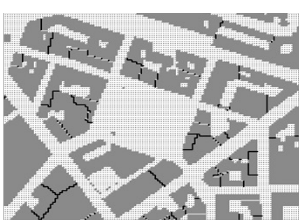
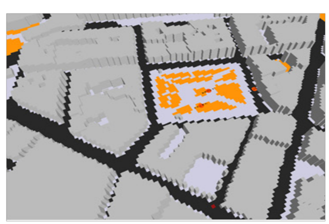


Figure 8. Diagram showing the simulation process source: (Djamila et al. 2022) treated by authors

Table 2. Modeling of the two plaza "2D model area and 3D model area" created using (Spaces.INX) (Source: Authors)

scenario	Alexis Lambert plaza		El-Bouni plaza	
With vegetation	 2D model	 3D model	 2D model	 3D model
Without vegetation	 2D model	 3D model	 2D model	 3D model

RESULTS AND DISCUSSION

Field Measurement Results

We note that the recorded air temperatures in Alexis Lambert plaza are lower than those recorded in *El Bouni*, especially at 4 pm, we recorde a gap of 4 ° C (figure 9(a)). this could be explained by the large difference in SVF and vegetation density(Table 2). Also we note a difference in the relative humidity because of the presence of vegetation in the place alexis lambert and proximity to the sea (Figure 9 (b)). However the wind speed is more important in *El Bouni* plaza (Figure 9 (c)). this is due to the opening of space and the absence of opstacles.

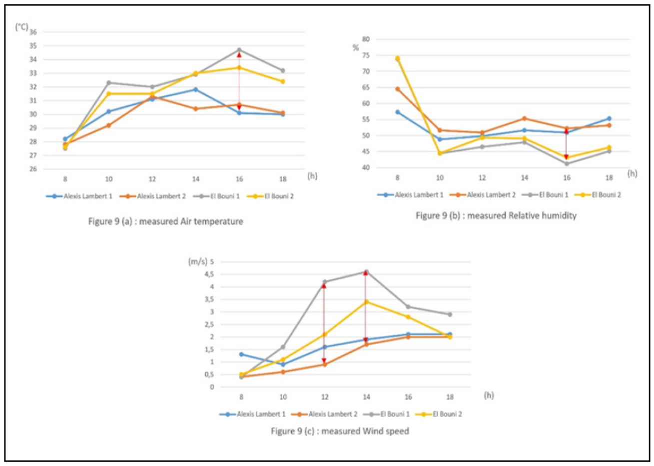


Figure 9. The measured climatic parameters. Source: (Authors)

Simulation Results

We resorted to simulation to explain the difference in the values recorded in the two plaza. the simulation was done according to two scenarios. First we simulated the microclimate without vegetation. Then we integrated vegetation as we took 2 p.m. as a reference time to make the comparison between the two scenarios. Tables 3 and 4 represent the results of the first scenario (whitout vegetation) and the second scenario (with vegetation) respectively. In the first scénario, (without vegetation) a difference of 0.5 ° C is recorded between the two plazas and a difference of 1 °C in the second scénario. Also we notice a big difference in the mean radiant temperature between the two plazas on the one hand, and between the two scenarios on the other hand. This difference could be explained by the presence of the shade provided by vegetation and building. Also the plaza of Alexis Lambert has a higher building density than the plaza of El Bouni and a higher sky view factor, this difference in morphological parametres can explain the difference in the mean radiant temperature between the two plazas.

In order to better understand the difference between the two plazas, we have drawn graphs for each microclimatic parameter (figure 10). The graphs confirm the difference between the two plazas especially in the mean radiant temperature during the day and there is also a difference in wind speed and relative humidity, with a slight difference in air temperature.

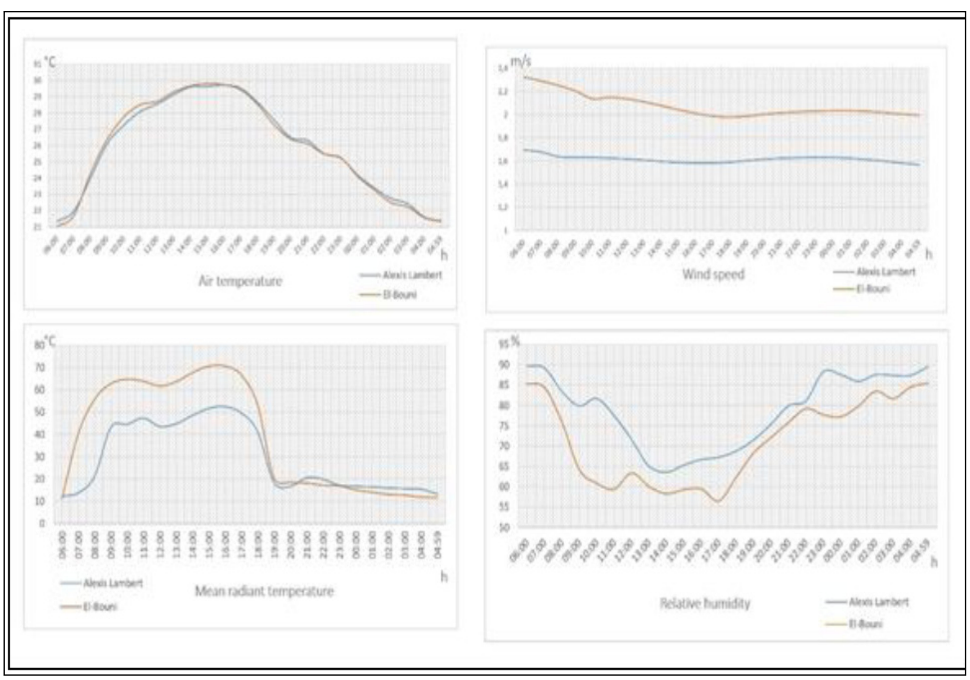


Figure 10. Comparative graph between the microclimatic parameters in the two plazas. Source: (Authors)

Table 3. Simulation resulats of microclimatic parameters for the first scénario (without vegetation). (Source: Authors)

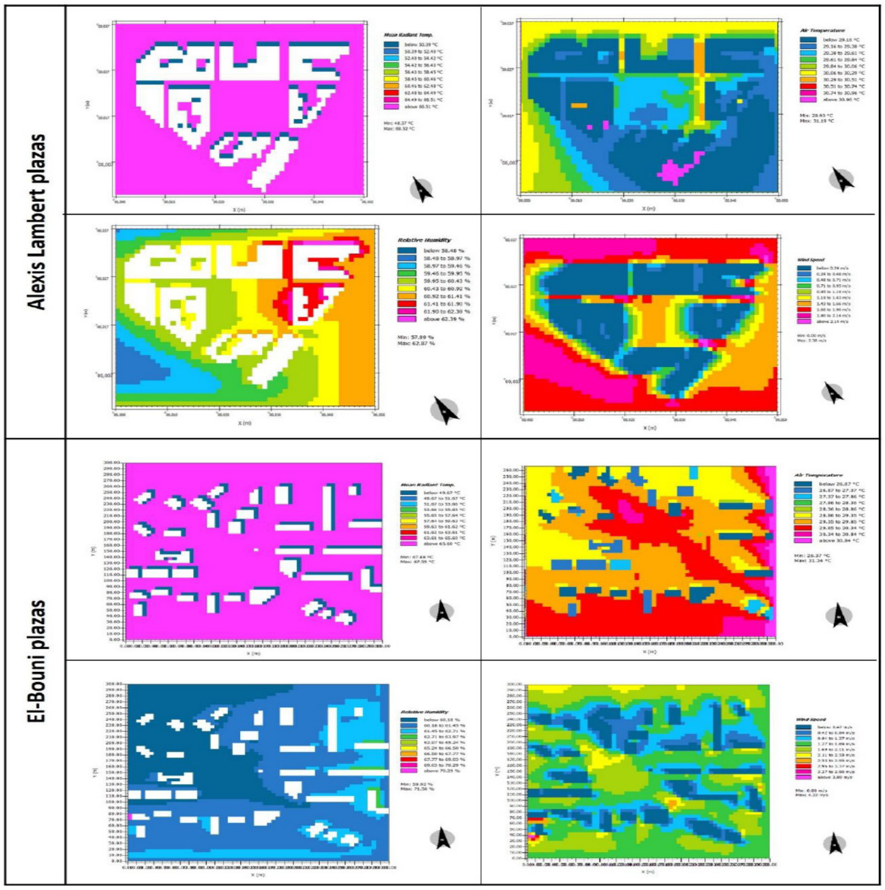
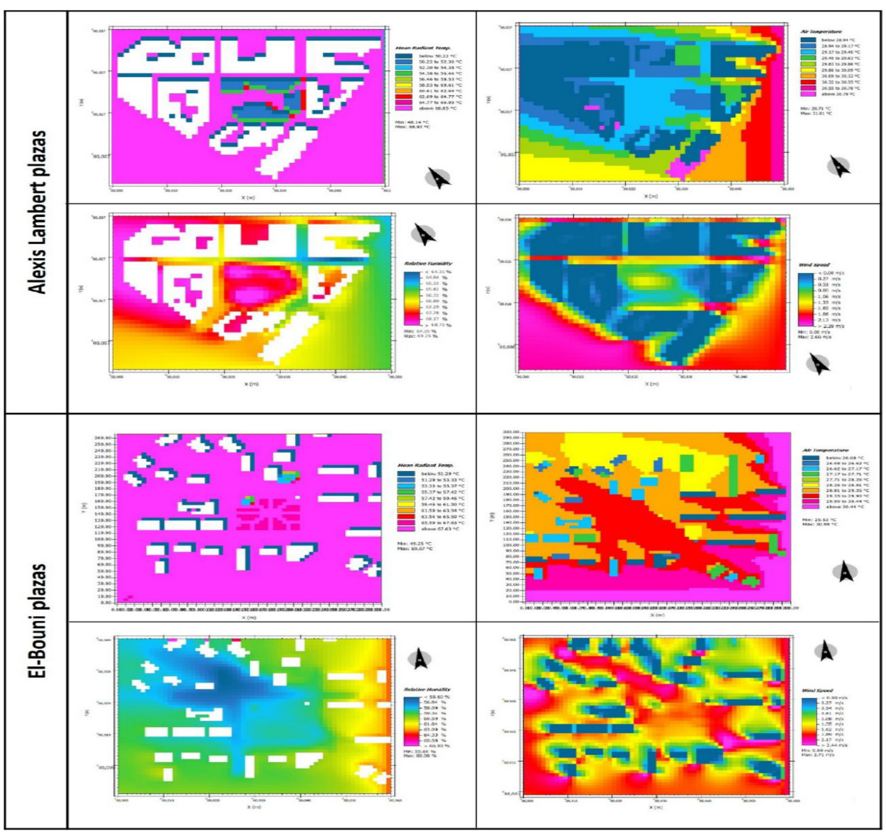


Table 4. Simulation results of microclimatic parameters for the second scénario (with vegetation). (Source: Authors)

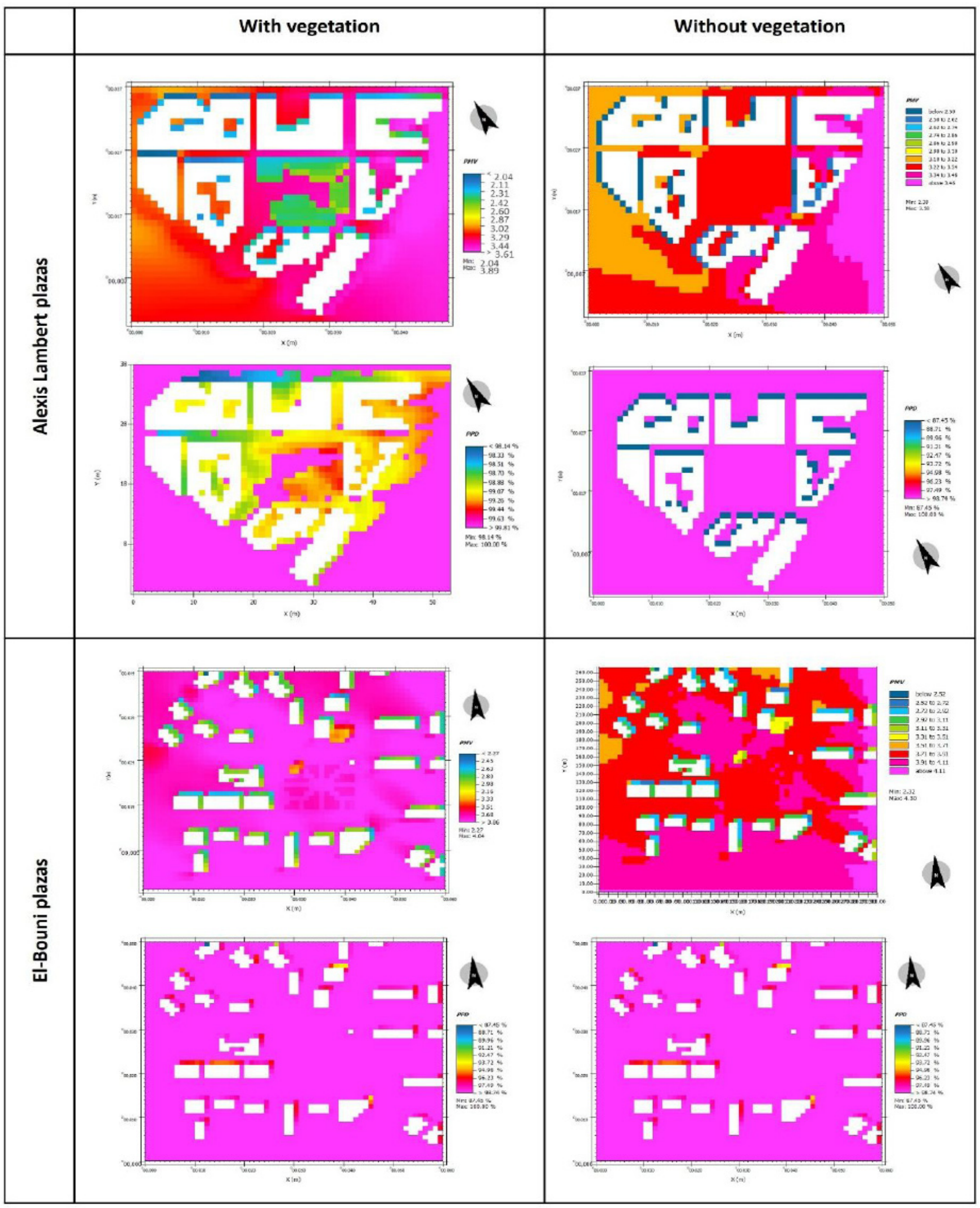


The PMV and PPD, Thermal Comfort Indexes

The Predicted Mean Vote (PMV) aims to predict the mean value of votes of occupants on a seven-point thermal sensation scale The scale's values vary from −3 corresponds to the too cold situation, and the value of +3 corresponds to the too hot situation. and Predicted Percentage of Dissatisfied (PPD) aims to predict the percentage of occupants dissatisfaction towards the thermal environment.

The simulation resulats of PMV and PPD index for both scénarios (whith and whitout vegetation) are represented in table 5. We can see that there is a big difference between the two scenarios, especially at the level of the Alexis Lambert plazas, where we notice that the vegetation has participated in the decrease of the PMV and PPD values, this is explained by the decrease in mean radiant temperature due to the presence of vegetation. The same difference can also be noticed between the two plazas, because of the difference in the urban morphology. The graphs shown in Figure 10 affirm this gap. We also note that there is a strong relationship between the variation of the thermal comfort indices in figure 11, and the mean radiant temperature in figure 9. Between 10 a.m. and 6 p.m., we note that the values of the PPD and the PMV are maximum, this is due to solar radiations.

Table 5. Simulation resulats of PMV and PPD index for both scénarios. (Source: Authors)



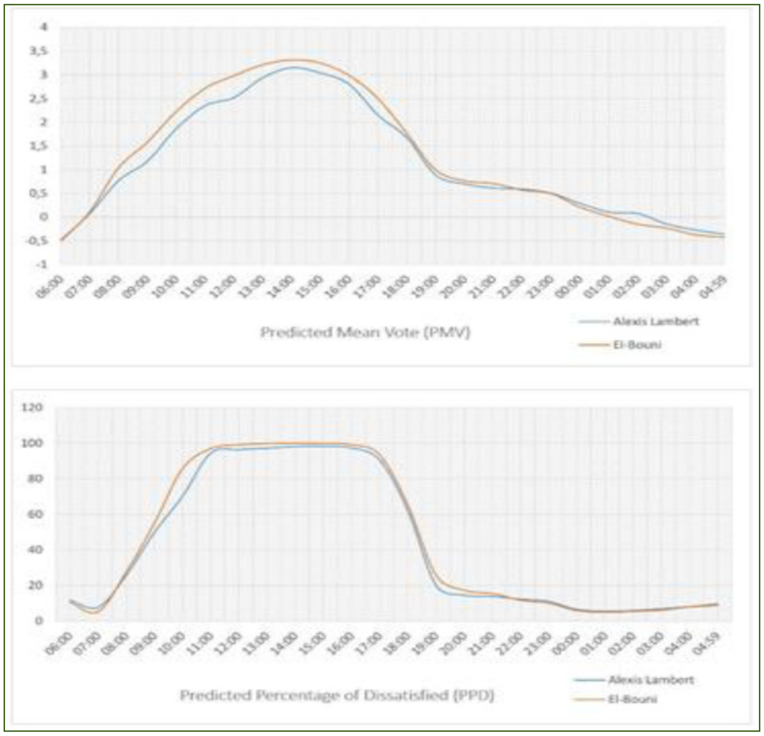


Figure 11. Comparative graph between thermal comfort index (PMV, PPD) in the two plazas. Source: (Authors)

CONCLUSION

The objective of this paper was to evaluate the impact of the microclimate parameters on the outdoor thermal comfort and their relationship with the morphology of the plaza and vegetation. The two plazas are located in two different urban fabric, with various morphology, in the city of Annaba, Algeria, have been chosen for this study.

In situ measurements, as well as numerical simulations of the different scenarios, using the Envimet software, were carried out to study the relationship between the climatic parameters (air temperature, mean radiant temperature, air speed, and relative humidity) and thermal comfort indices (PPD and PMV).

The results of this study can be summarized as follows:

- The thermal comfort is better in the plazas situated in a dense urban fabric (with a minimal sky opening, and a high h/w ratio). This density could be intensified by the integration of vegetation.
- Vegetation plays an important role in improving the thermal comfort of the occupants by creating shade, and therefore reducing the average radiant temperature. This was also confirmed by a study carried out by(Djamila, 2021.)
- The external thermal comfort depends on the microclimatic parameters, and especially on the average radiant temperature.
- Open space promotes air circulation, but is more exposed to the sun, which increases the values of the mean radiant temperature and therefore contributes to thermal discomfort during the summer.

Funding: This research received no external funding

Acknowledgments: We acknowledge the support of Lacomofa laboratory by the materials used for in situ measures (Testo 480 device) and the software program used in this work (Envi-met)

Conflicts of Interest: The authors declare no conflict of interest.

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Citation: **Boussaidi Karima, Djaghrouri Djamila, *et al.*** *The Influence of Microclimate Parameters on the Outdoor Thermal Comfort in a Coastal City, Annaba City, Algeria, as a Case Study. Int J Innov Stud Sociol Humanities. 2022;7(12): 129-139. DOI: https://doi.org/10.20431/2456-4931.071213.*