

Benefits and Well-Being Perceived by Pedestrian in Vegetated Urban Space in Periods of Heat Stress

Samira Louafi Ep Bellara and Saliha Abdou

Abstract—This research aims to study and analyze the effect of the urban vegetation on microclimate and thermal comfort in external spaces. The experimental method used calls upon the techniques of observation and site measurements. A case study of an external space located in the city center of Constantine (Algeria), characterized by Mediterranean climate, hot and dry. The results confirm the role of the quantity of shade by the vegetation on human comfort, a positive correlation between the air temperature, mean radiant temperature (T_{mrt}), and physiologically equivalent temperature (PET) in hot seasons. Vegetated urban space influences the quality of perception, the creation of urban ambience and improves pedestrian's thermal comfort and use of outdoor areas for this type of climate.

Index Terms—Vegetation, comfort perception, outdoor space, hot and dry climate.

I. INTRODUCTION

In urban environments, green spaces have proven to act as ameliorating factors of some climatic features related to heat stress, reducing their effects and providing comfortable outdoor settings for people [1]. The mineralization of outdoor spaces, replacing vegetation and humid zone with concrete and asphalt contributes to appearance of the harmful effects to the environment and human well-being. It develops, in summer, more and more problems related to microclimatic phenomena of urban heat island.

The shade is in general the outside required principal effect in period of overheating for the areas with hot and dry climate. This shade reduces solar flows considerably, by limiting the heating of surfaces which normally should be sunny, also reduces thermal radiative flows.

The benefits of green spaces in urban areas are recognised by many authors. It is well known that the presence of vegetation modifies the microclimate (light, heat, wind, and humidity) and influences the perception of urban spaces by the users [1]-[4]. Trees and vegetation embellish the cities and improve the citizens' quality of life. The trees planted along the streets and in the parks, around the houses or shops or in the green areas throughout the city also improve the quality of the air and water. The urban green areas offer the possibility of recreation, and they make the districts more pleasant [5]. Vegetation can modify urban microclimates by

shading and evapotranspiration, and use of plants to ameliorate urban heating is one strategy that has generated significant interest [6]-[8]. Trees and buildings existing singly or in clusters create strong spatial variability in local heat transfer fluxes that define urban microclimates within the urban canopy layer [9].

In a hot-dry climate, Grimmond; O ke and Cleugh [10] found in that the temperature in a tree-vegetated suburban area in Sacramento was 5 °C to 7 °C cooler than in mineral areas.

It is therefore important to account for, on the other hand, the shading effect of trees on thermal comfort, the influence of reflected and transmitted solar infrared radiation on the energy budget of humans and buildings in their surroundings [11]-[13].

In the present article, the aim is to assess whether people located under tree shade experience comfort or stress in open spaces during hot-dry season. The specificity of this study is to use a quantitative analysis through site measurements together with a qualitative analysis through comfort observation. The detailed objectives of this study are to:

- 1) Investigate the effects of five different spaces on thermal conditions in outdoor spaces.
- 2) Discuss whether trees shade affect people's thermal comfort in hot-dry climate, and evaluate outdoor thermal comfort based on comfort indexes "predict equivalent temperature" (PET) and mean radiant temperature (T_{mrt}).
- 3) Try to highlight the role of presence of trees shade on the use and transit of spaces in hot-dry climate.

II. SITE INVESTIGATION

The investigation was conducted in Constantine City (Algeria), which is located at 36.17_ North and 06.37_ East. The altitude is approximately 687 m above sea level. This city is characterised by a semi-arid climate that is hot and dry in the summer, with an average maximum temperature of 36 °C occurring at 15h00 and an average humidity of 25%. In the winter, the area is cold and humid. In addition, the intensity of solar radiation over this region is high, with clear skies and sunny periods existing during a large portion of the day.

The wind direction comes relatively from the North, with an average speed reaching 2.1 m/s at the meteorological station. All these factors contribute to the climatic harshness of the city. The investigation site is located in the city centre.

The city center has a dense traditional urban fabric (up to 80%) deprived from vegetation; and a colonial fabric which was grafted on part of traditional fabric and around this initial

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Samira Louafi Ep Bellara is with the Laboratory ABE, University Mentouri of Constantine Algeria (e-mail: samiralouafi@yahoo.fr).

Saliha Abdou is now with the Department of Architecture and urbanism, University Mentouri of Constantine Algeria (e-mail: outtassaliha2004@yahoo.fr).

core. The presence of the vegetation is not regular there.

The selected site is an open urban space with a row trees with the presence of masse vegetal (square), and an open area without vegetation located next to it (Fig. 1). Five stations were chosen to represent the different vegetal environments encountered in this course. The measurements and observations were performed under these five stations.

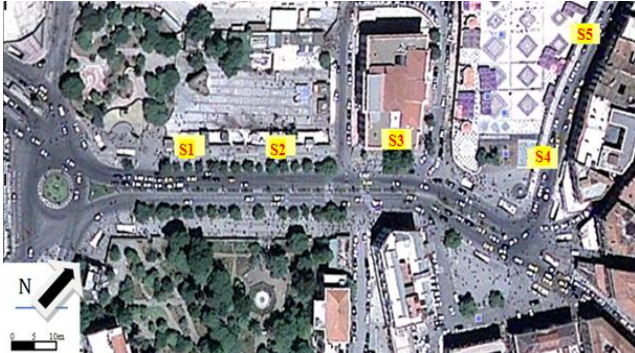


Fig. 1. Measuring station sites

The selected site consists on two spaces; one is a green space with row trees and masse of vegetation (square) and other in a mineral spaces. Five stations of measurements are selected (Fig.2), according to their position near green spaces (S1-S2-S3) and far away in a mineral space (S4 and S5) (see figure in Table II).

III. METHODOLOGY

This article aims to highlight the variation of the climatic parameters that vegetation induces on outdoor thermal comfort during overheating period in hot-dry urban environments, as well as the role of trees shade effects on the use of spaces. The method consists in comparing different spaces around an urban transit space in Constantine city (in Algeria) by site measurements, an observation.

The measurements and the observations were carried out in summer on July 2011, representing the hottest period. These were carried out simultaneously over three weeks. One typical daily cycle has been selected to represent in this article the three weeks period in order to show detailed monitoring results.

Air temperature, relative humidity, wind speed, and solar radiation were collected using digital instruments (Multifunction instrument (LM800), Pho-radiometer HD2302.0 with several probes). The measurements were taken at a height of 1.5m. They were recorded every 2 hours at each station from 6h00 to 20h00 on each day.

IV. RESULTS AND DISCUSSION

A. Perception of Spaces

At each station of measurement the investigators fill a line on the grid with observation. These make a qualitative assessment on the parameters constituting the thermal environment (Q-TH), visual (Q-Vi), acoustics (Q-ac) and olfactive (Q-OL) [14]. It is a question here of making a subjective assessment of a group of 15 individuals on the quality of environments thermal, visual, acoustic and

olfactive through a nominal scale going from 0 to 100, where the 0 mean very uncomfortable feeling while 100 expresses the very pleasant feeling (see Table I).

From the comparison of the various situations (Figures of rose of physical environment of the Table II) we can deduce that external space can be affected by the presence of the vegetation which plays a big part in its environmental quality [15]-[16].

TABLE I: SCALE OF APPRECIATION OF THE FIVE PSYCHOPHYSICAL STATION (Q-TH, Q-Vi, Q-AC ET Q-OL) USED IN THE FRAME WORK OF THIS RESEARCH

Scale	Appreciation
0	Very uncomfortable
25	Uncomfortable
50	Neural
75	Pleasant
100	Very pleasant

TABLE II: PERCEPTION OF DIFFERENT STATIONS, (A) PHOTO OF THE MEASUREMENT STATION (B) PHYSICAL ENVIRONMENT ROSE

Station	Photo at the point measurement (a)	Rose of physical environments (b)
Station1 S1 In Shade Until 13:00		
Station2 S2 In Shade Until 13:00		
Station3 S3 In Shade All the Day		
Station4 S4 Not Shaded		
Station5 S5 Not Shaded		

The points at the stations S1, S2 and S3 are more comfortable than the stations S4 and S3 thanks to the effect of shade. The presence of the vegetation can attenuate intense solar radiations by the effect of the reflection and the absorption. Consequently the shade is important in the use of external spaces.

Global perception of the different stations shaded by trees are neutral than ones in full insulation which are uncomfortable (Fig. 2). This effect results from the important exchanges produced in the tree and where solar radiation is absorbed by the majority of the leaves [13], [17], [18]; that gives place to the evapotranspiration: a phenomenon determining for the lowering of the air temperature [19]-[22].

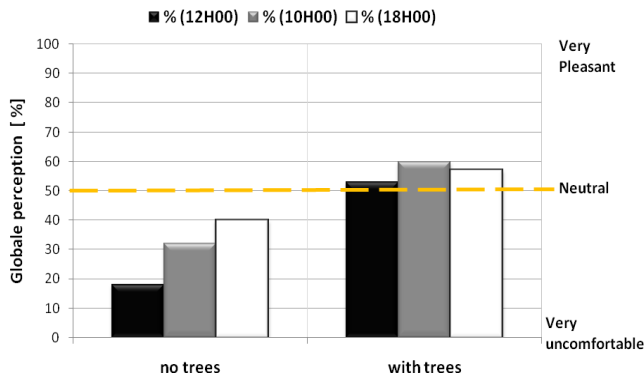


Fig. 2. Comparison between the various urban situations in terms of total physical perception, in the course.

B. Impact of the Vegetation on the Air Temperature

Fig. 3 shows the air temperature evolution during a typical summer day at the five stations of measurement. It shows that open space without trees is warmer from 10h00 to 18h00 than the vegetal areas under trees coverage, which is consistent with previous studies of the literature on this subject [1], [4], [11], [21].

The air temperatures in all stations are higher than 34 °C during the day, but the temperatures recorded in S1, S2 and S3 remain lower than that in the stations S4 and S5 with a variation of -2.5 at mid day 12:00 and -3 °C at after mid day 14:00 this result agrees with the results [10], [23]

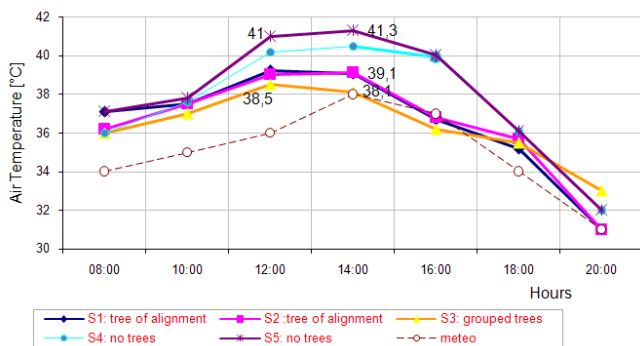


Fig. 3. Variation of air temperature in various stations period July 2011

C. Impact of the Vegetation on Air Relative Humidity

The relative humidity depends on the temperature and the quantity on water contained in the air. The values of air humidity at the beginning of the day are very high; on the other hand those of after midday are most significant [24].

According to graph of Fig. 4, a negative correlation between the air humidity and the air temperature. It is noted that vegetable stations has higher air humidity S1, S2 and S3 that the other stations S4 and S5. The relative humidity highest of the day is recorded at 20:00 in the station S1 in the trees alignment and proximity to the square and S2 in line trees with a variation of 4.4%, compared to the station S4, S5 (with no trees).

At the time of the maximum of energy of 12:00 to 14:00, we observe variation between 2.7% and 4% in stations S3, S4 and S5. After one cumulates solar energy, one record an increase in the water content, this rise is explained by the effect of the latent heat of the vaporization of the vegetation [25], [26].

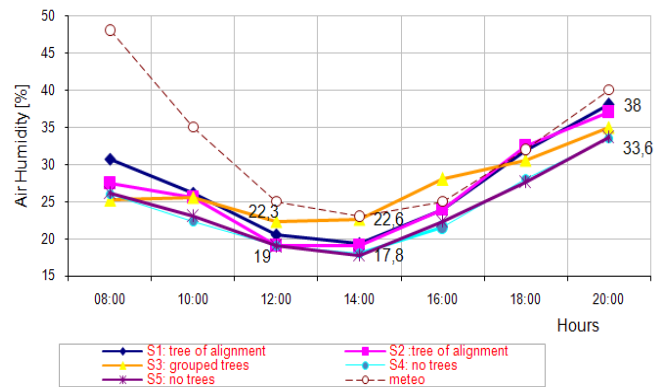


Fig. 4. Variation of air relative humidity in the various stations period July 2011.

D. Thermal Comfort Analysis

The comfort parameters and indices adopted for this study were: air temperature (Ta), mean radiant temperature (Tmrt), and physiologically equivalent temperature (PET).

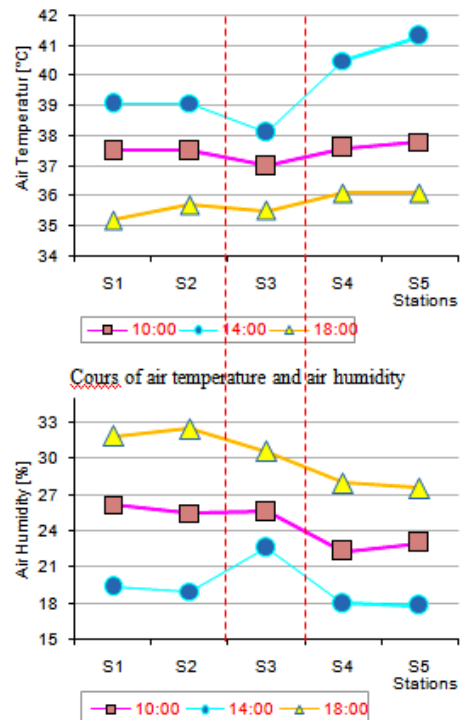


Fig. 5. Course of the air temperatures and the air relative humidity.

A positive correlation exists between the air temperature, mean radiant temperature (Tmrt), and physiologically

equivalent temperature (PET). In hot seasons, the Tmrt and PET see (Table III) shows how reflect solar radiation affects the space. High shaded station present a low value of PET and perception of lightly hot space (Fig. 6).

In after midday (14h00), the air temperature of two spaces without vegetation (S4 and S5) knows an important rise reaching 40.5 °C and 41.3 °C respectively and lower value of air relative humidity 18% and 17.6% with a wind speed less than 1.0m/s, which make the two stations uncomfortable (Fig. 5).

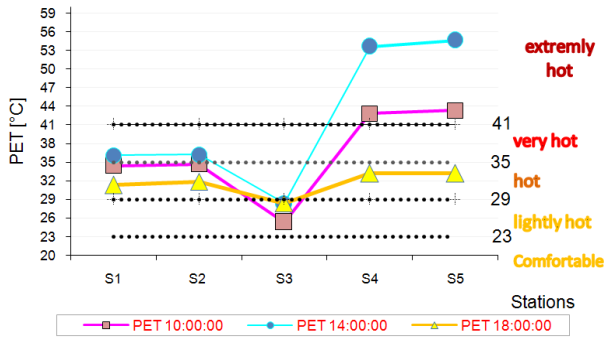


Fig. 6. PET variation in various cours at 10:00, 14:00 and 18:00

The mean radiant temperature at the level of the whole of spaces opened knows a great correlation with the temperature of the air and also with the index of comfort PET. This is explained by the direct impact of the irradiations coming from various surfaces on the air temperature. Space with the presence of the trees and near a public garden is fresher and more comfortable. This correlation is presented in the following table:

TABLE III: RELATION BETWEEN THE AIR TEMPERATURE, THE MEAN RADIANT TEMPERATURE AND THE PET

	14 :00		
	ta	Tmrt	PET
S1=Tree of alignment	39	31,6	36,1
S2= Trees of alignment	39,1	31,7	36,2
S3=Group of trees	38,1	29,1	28,4
S4=No trees	40,5	62,7	53,6
S5=No trees	41,3	63,6	54,6

The mean radiant temperature is an important parameter affecting the human well-being. It expresses the radiative effect of the whole of the environment. Tmrt varies according to the importance of the solar radiations received and reflected by surfaces. Its maximum value reached 63.6 °C for t stations S4 and S5 (without trees).

Thermal comfort on the level of the two calculated stations is evaluated according to the index of comfort “physiologically equivalent temperature” PET. This index is between 28.4 °C and 36.2 °C in the stations were there are shade of the trees and freshness from public garden and between 53.6 °C and 54.6 in the mineral stations. The value of PET in the station with groups of trees and quantity of important shade is lightly hot during all the day however, it is more comfortable compared to the station which is on the alignment of the trees and which are shaded only during the morning until 13:00 and which is hot. Nevertheless, thermal

environment in the stations S4 and S5 without trees are extremely hot and makes uncomfortable felt in these spaces.

Dense vegetation optimises the microclimatic environment for pedestrians’ thermal comfort in urban spaces, under hot and dry climate.

V. CONCLUSION

The vegetation can affect the microclimate in many ways, in particular reducing the air temperature compared to stations without trees, while getting shades.

The vegetation makes esthetic improvements to an environment differently dominated by asphalt and the concrete.

In this external environment, that is the center of the town of Constantine, the vegetation (trees) has positive effects on the air temperatures and the shade like on the microclimatic conditions. We can note a variation in the air temperature of 2.5 °C to 3 °C in open spaces according to the quantity of the shadow , the duration of sunning, and an increase in the air relative humidity about 2.7% to 4.4% what supports the bioclimatic effect of the shade by the vegetation.

According to the results of the observation and taken measurements, we can retain the following projecting points:

- 1) The presence of the vegetation modifies the solar radiations in external space, the air temperature and the air relative humidity;
- 2) Vegetalized space develops lower air temperatures and higher air humidity, thus a more pleasant comfort.
- 3) There is a correlation between the air temperature, mean radiant temperature (Tmrt), and physiologically equivalent temperature (PET) in hot seasons, which influences the quality of perception
- 4) There is a significant correlation between vegetation, shade and the use of external space;
- 5) The relation between shade and vegetation depends on the choice of the gathering space or transit space.

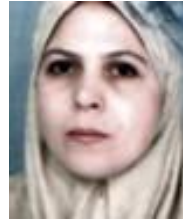
Trees very often constitute an important component of the opened external space, which strongly contributes to the environmental quality. For that the valuation of the essential courses is recommended by the deciduous tree implantation for the more refined environment.

In addition, the trees increase the well-being perception of external space and thermal comfort felt on period of heat stress in Mediterranean climate, hot and dry.

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Samira Louafi Ep Bellara was born in June 1985 – Constantine. Diploma for the occupation of architect of state: 1990, University of Constantine, Algeria. Diploma of Magistere in Bioclimatic Architecture: 2005, university of Constantine, Algeria. Inscription in Doctorat Es-Science: since 2007 (in discussion, will be presented in November 2012) Topic: "Impact of vegetation on the quality of thermal et visual ambience in urban public space» case of hot and dry climate Rank: Titular Master assistant category a, teaching researcher; She works in University Mentouri of Constantine, Member of ABE laboratory "Architecture Bioclimatic and Environment".



Saliha Abdou is an architect, senior lecturer at school of architecture at Constantine university Algeria since 1987, permanent member of the laboratory of bioclimatic architecture and environment of the same university. Mphil degree (CARDO) at university of Newcastle upon town England (1987), state doctor in bioclimatic architecture in Algeria (2004). Her topics of interest are thermal performance of buildings, thermal comfort, energy building consumption, vegetation impact on building performance, urban heat island. She supervised nine masters (magister in architecture bioclimatique) and seven doctorates are still ongoing.