BIOCLIMATE PROVIDE BY SHADE TREES AS FACTOR IN URBAN AND ARCHITECTURAL PLANNING IN TROPICAL CLIMATES – THE CASE OF CAMPINAS, BRAZIL

Loyde V. ABREU Arch, Ms. Eng.1

Lucila L. LABAKI, Dr. Eng1

Andreas MATZARAKIS, Dr. Met2

[1] Department of Architecture and Construction, School of Civil engineering, Architecture and Urban Design, University of Campinas – SP, Brazil, loydeabreu@gmail.com

[2] Meteorological Institute, Albert-Ludwigs-University Freiburg – BW, Germany, andreas.matzarakis@meteo.uni-freiburg.de

Summary

Urban expansion and modification without climate responsive guidelines can provide progressively falling short of sustaining outdoor and, also, indoor life of cities in the Tropics. To re-establish and sustain life inside and outside, it is important to define the thermal bioclimatic of outdoor and, consequently, to make urban spaces comfortable as far as the ambient climate permits. The urban climate studies show that shade trees can improve thermal comfort on Tropical cities. The canopy type is an important characteristic of arboreal vegetation that it must be considered on microclimate due to different capacities of attenuation of solar radiation provided by each arboreal species. This paper presents thermal bioclimate analyses using physiologically equivalent temperature conditions and the benefit of shade trees as guidelines factors for urban and architectural planning in tropical climate of Campinas, Brazil. The meteorological data: air temperature, relative humidity, wind speed and solar radiation from the period 2003 to 2010 over were used for the calculation of physiologically equivalent temperature with the aid of RayMan Pro model. The simulations of shade variations were done for verify the influence on urban climate changes in thermal comfort due shade trees. The solar radiation by different arboreal species was measured in the shadow of individual trees and simultaneously in the sun from period 2006 to 2010 by using tube solarimeters. Ten species were chosen: Tabebuia chrysotricha (deciduous), Jacaranda mimosaefolia D. Don. , Caesalpinia peltophoroides L., Lafoensia glyptocarpa L., Tipuana tipu F., Spathodea campanulata P.Beauv., Pinus palustris L. and Pinus coulteri L. (semi-deciduous), Syzygium cumini L. (perennial) and Mangifera indica L. (perennial).The results shows not only the solar radiation can influence air temperature, but also thermal comfort as well. Furthermore, the simulation of variation of shade conditions demonstrates the shade trees can improve thermal comfort in PET above 18oC. Percentages of solar radiation reduction by trees as Caesalpinia peltophoroides L. (deciduous), Syzygium cumini L. (perennial) and Mangifera indica L. (perennial) that have the best results, shows that canopy provide shadow and consequently, improve microclimate. The comfortable ambient climate leads to comfortable indoor environment particularly in buildings and consequently, the energy efficiency. The appropriate conditions for outdoor thermal comfort are an important step towards achieving sustainability on urban spaces. An awareness of these issues would be valuable to architects, planners and urban designers, not by the way of limiting possible solutions, rather by enriching the design possibilities.

Keywords: thermal bioclimate; shade trees; urban spaces; tropical climate, Brazil (Campinas)

1. Introduction

One of the main causes of the air temperature increase and of the energy consumption, as well as the change of the people's behaviors, is the lack of appropriate landscape treatments around a building. Different methodology confirms that the vegetation can influence in urban microclimate and improving thermal comfort and increasing the potential of health impairment of urban populations (Santamouris, 2001; Akbari, 2002; Dimoudi, et al., 2003; Akbari, et al., 1997). In fact, the arboreal species behave in different ways in outdoor spaces, in especially because of the differences in shadows tree, but there are few studies that quantify these benefits (Bueno-Bartholomei, et al., 2003; Katoshevski, et al., 2007). The tree canopy is a major component that is able to contribute to microclimatic environments because it can attenuate solar radiation and control the wind speed (Steven, et al., 1986) . In tropical climates, the possibility to change wind condition and shade modify the microclimate and improve thermal comfort (Lin, et al., 2010).

After evaluating thermal comfort by index PET (Physiologically Equivalent Temperature) in outdoor spaces in Freiburg, German, authors verified that the trees can modify the microclimatic (Gulyás, et al., 2006). In Brazil, recent researches concluded that thermal comfort in outside is closed related with urban forestry (Spangenberg, et al., 2007). Vary Brazilian research used PET, but this index need to be adopted by local climate (Monteiro, et al., 2010). However, climate and microclimate of outdoor spaces in different latitudes suggest distinct thermal comfort index, because these are not associated just with characteristics of ambient but the population (Moreno, et al., 2008).

The purpose of this article is the evaluation of the radius of influence of some arboreal species in the microclimate, through the measurements of environmental parameters and comparison of thermal comfort and solar radiation attenuated provided by them.

2. Benefits associated with trees in subtropical climate

Additionally to their aesthetic value, urban trees can modify the climate of a city and improve urban thermal comfort in hot climates, as subtropical climate in Brazil. The urban trees, individually can also act as shading and wind-shielding elements modifying the ambient conditions around individual buildings. As well collectively, forestry can moderate the intensity of urban heat island by altering the heat balance of the entire city (Akbari, 2002; Akbari, et al., 2008). Studies show that shade and wind speed promotion can improve the thermal comfort on tropical climates (Lin, et al., 2010). Therefore, planting trees is a good solution for improve thermal comfort in tropical cities.

The canopy characteristics of trees can influence direct in thermal comfort results, fig.1, therefore, the behavior of individuals arboreal in microclimate can modify according with type, high, age, season, and disposition in urban outdoor space (Peixoto, 1995; Falcon, 2007; Brown, et al., 1995.). The trees leaves can be absorbed and reflect and transmitted the solar radiation by the evapotranspiration and influence indirect in thermal comfort (Santamouris, 2001; Scudo, 2002; Abreu, et al., 2011).

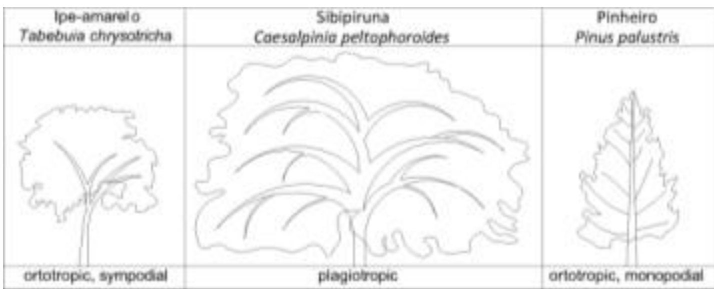


Figure 1 - Trunks characteristics

Trees casts its own distinctive shadow, both in shape and density, and these behavior depend on the shadow and filtering the radiation influenced by the form and density of the canopy (Robinette, 1972). The amount of radiation intercepted depends on the density of the twigs and branches and leaf cover, where these elements influence the overall character of tree shape and density. Not only the form and density of canopy can influence in shade tree qualities, but, individuality of trunks, fig. 1, and leaf needs to be considerate, fig. 2, (Abreu, et al., 2011).

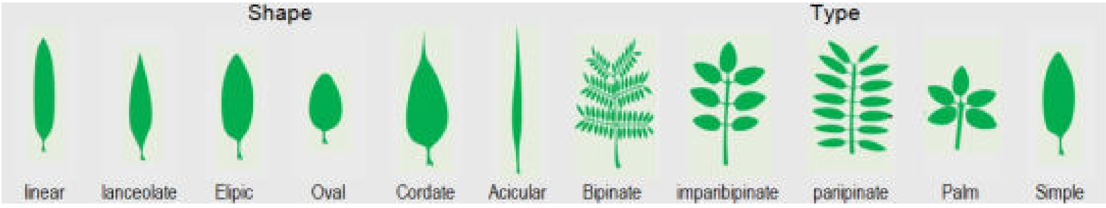


Figure 2 - Leaf characteristics

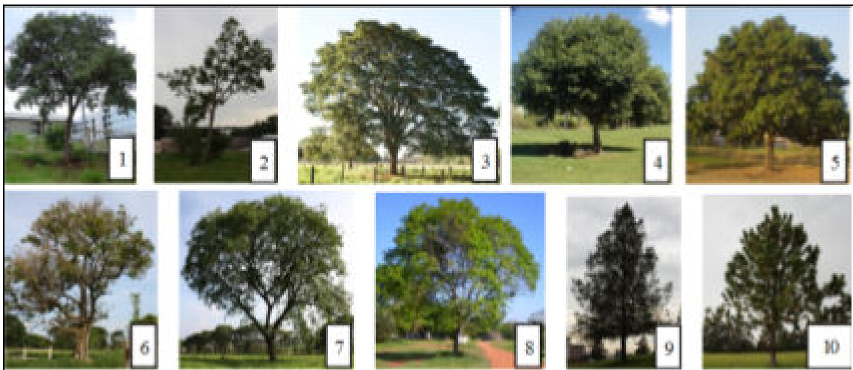
For example, trees species in Brazil can attenuated solar radiation between 76.3 – 92.8 % in summer (Abreu, et al., 2010; Bueno-Bartholomei, 2003) and trees species in Malaysia have difference density value when the average heat infiltration under canopy is comparing (Shahidana, et al., 2010). These results confirm that structure of crown, dimension, shape and color of vegetation leaves influence reduction level of solar radiation.

Individual trees can also reduce the air temperature in different distances and consequently improve thermal comfort (Abreu, et al., 2010). By computer simulation of the air temperature distribution of around 10m height single tree, it was observed that the maximum range of air temperature is approximately 25 m from the tree (Hiraoka, 2002). The air temperature distribution as well humidity still depends on wind velocity and direction.

It known that vegetation has a great potential to control air movement but, this effect cannot be determined with certainty. Studies show that the vegetation can influence the pattern of air movement through guidance, filtration, obstruction and deflection and it depends on vegetation characteristic, such as geometry, height, permeability and crown of the vegetation are the structural vegetal characteristic that influenced the controlling air movement (Scudo, 2002; Vogt, et al., 2003).

3. Methodology

This research was realized in Campinas, Brazil, that is located at 22 ° 48'57 "S, 47 ° 03'33" W and at altitude of 640 m. The city's climate is classified as tropical of altitude, Cwa by Köppen (Kottek, et al., 2006), with mean annual air temperature of 22.3º C, annual rainfall of 1411 mm, with the predominance of rain in the months from November to March and dry periods of 30 to 60 days during July and August. In this research, the microclimatic and instantaneous scales are adopted. This choice of scales allows analyzing in loco the degree of influence through mitigation of air temperature and solar radiation incident on individuals of trees.



1. *Tabebuia chrysotricha*
2. *Jacarandá mimosaefolia*
3. *Syzygium cumini*
4. *Mangifera indica*
5. *Caesalpinia peltophoroides*
6. *Spathodea campanulata*
7. *Tipuana tipu*
8. *Lafoensia glyptocarpa*
9. *Pinus palustris*
10. *Pinus coulteri*

Figure 3 - Tree analyzed

The criteria for the choice of species were those most used in tree planting programs by the city government in Campinas, Brazil. The trees should fulfill such conditions as: to be adult in age, to have representative physical characteristics of the species, and to be located in areas with the adequate conditions for measurements: no shading by other trees or buildings; topography of the ground around the species; accessible area for the measurement equipment; no interference of other people; uniformity of conditions around the trees.

Ten arboreal individuals were selected: *Tabebuia chrysotricha* (deciduous), *Jacaranda mimosaefolia*, *Caesalpinia peltophoroides*, *Lafoensia glyptocarpa*, *Tipuana tipu* , *Spathodea campanulata* P.Beauv., *Pinus palustris* and *Pinus coulteri* (semi-deciduous), *Syzygium cumini* (perennial) and *Mangifera indica*, fig. 3.

The data was collected by meteorological urban station of Campinas Agronomic Institute (IAC). The meteorological data: air temperature, relative humidity, wind speed and solar radiation of an over seven year period (25.6.2003 to 14.12.2010) were used. The equipment used for experiments were two sets of tube solarimeters, type TSL (Delta-T Devices). Sensors from the tube solarimeters were connected to a logger, model DL2, also from Delta –T. One set of equipment was installed at the middle of the tree shadow, while the second one was installed at sun. Data are collected beneath crowns of studied trees and in the open simultaneously. Measurements started at about 6:00 a.m. and finished at about 6:00 p.m. and were recorded each ten minutes. This equipment measures average irradiance (W/m2) in situations where the distribution of radiant energy is not uniform, such as beneath tree crowns and greenhouses. The spectral response corresponds to visible and near infrared radiation (350 nm to 2500 nm).

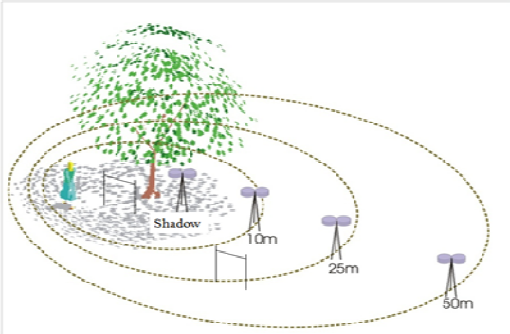


Figure 4 - The measurement points from the tree trunk

For the collection of the data of the environmental parameters (air temperature, relative humidity) sensors were fixed to a tripod at different distances (in the shadow, at 10m, 25m and 50m), fig 4. In each set there was one temperature and humidity recorder, model Testo 175-1, connected to a temperature sensor, placed in the interior of the globe. And, wind speed data was collected in one fix site with Testo anemometer, model 0635-1549, connected to a multifunction recorder, model 445. All recording sets were protected from solar radiation through especially prepared shelters for this research outdoors and data were collected each 10 minutes, in 12 hours throughout the day. The data were collected between 2007 and 2010.

The hourly meteorological data of air temperature, air humidity, wind speed and global radiation of study period were used to calculate the Physiologically Equivalent Temperature (PET). Therefore, simulations were done by RayMan model (Matzarakis, et al., 2007; Matzarakis, et al., 2010) which can transfer the global radiation from an area with free horizontal urban structures and make the estimation of mean radiant temperature due to atmospheric influences firstly by clouds and other meteorological compounds as vapour pressure or particles. For simulation of tree shading influences, the following setups were used: fish-eye hemispheric photographs of arboreal species studied in this research.

The minutely meteorological data collected in loco during 12 hours throughout the day of air temperature, air humidity, wind speed and global radiation in different distances (2,5m –shadow-, 10m, 25m and 50m) of study period was the input data to calculate PET.

4. Results

In order to quantify the background at the urban climate of Campinas, the frequency distribution in each month for PET-Classes, fig 5, were presented. It was observed that the temperatures above 29°C occurs during the study period are around 20% during the year.

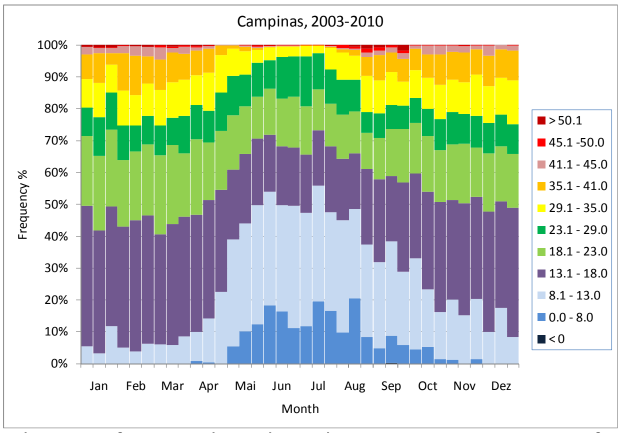


Figure 5 - The frequency distribution of PET at the urban climate station Campinas for the period June 25th, 2003 to December 31st, 2010.

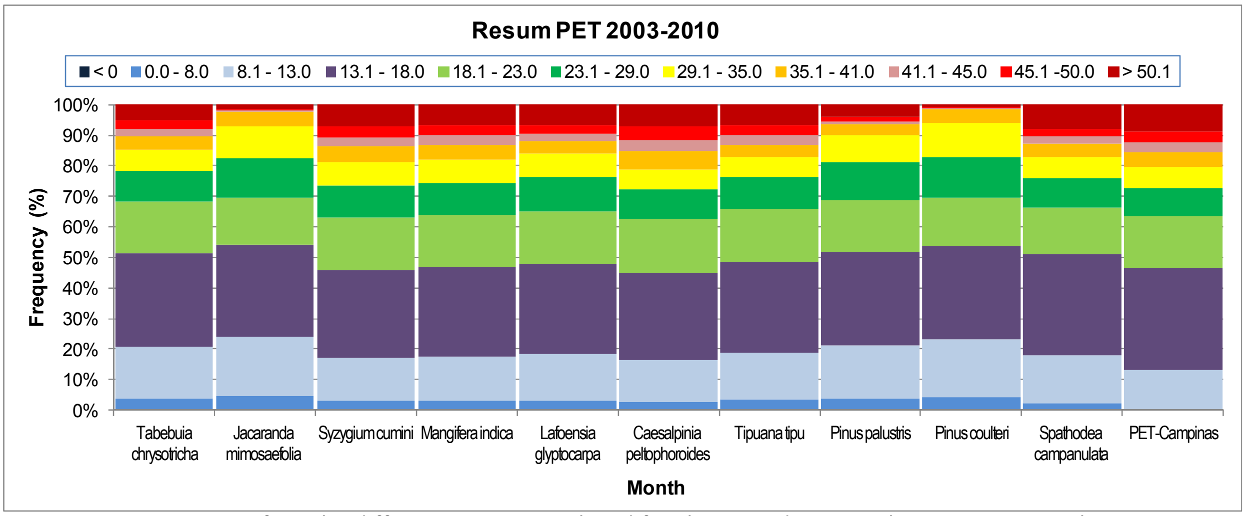


Figure 6 - Frequencies of PET by different species analyzed for the period June 25th, 2003 to December 31st, 2010.

For classification of trees shade benefits based in urban climate of Campinas, the mean frequency distribution during study period for PET-Classes, were shows, Fig 6. It was observed that arboreal shade can modify the microclimate by different ways.

The figures 7 and 8 present the results of PET by Tabebuia chrysotricha (deciduous), Jacaranda mimosaefolia, Caesalpinia peltophoroides, Lafoensia glyptocarpa, Tipuana tipu , Spathodea campanulata P.Beauv., Pinus palustris and Pinus coulteri (semi-deciduous), Syzygium cumini and Mangifera indica (perennial). The results confirm that tree's shadow had more sensation of thermal comfort than sun sites studied. Jambolão (Syzygium cumini), Mangueira (Mangifera indica), Sibipiruna (Caesalpinia peltophoroides) were the best and similar results at shadow in the winter. Jambolão (Syzygium cumini), Mangueira (Mangifera indica) were the most excellent results in summer. Sibipiruna (Caesalpinia peltophoroides) provided the greatest influence in the radius 10m, 25m and 50m in winter. In summer, the comportment all species analyzed were similar.

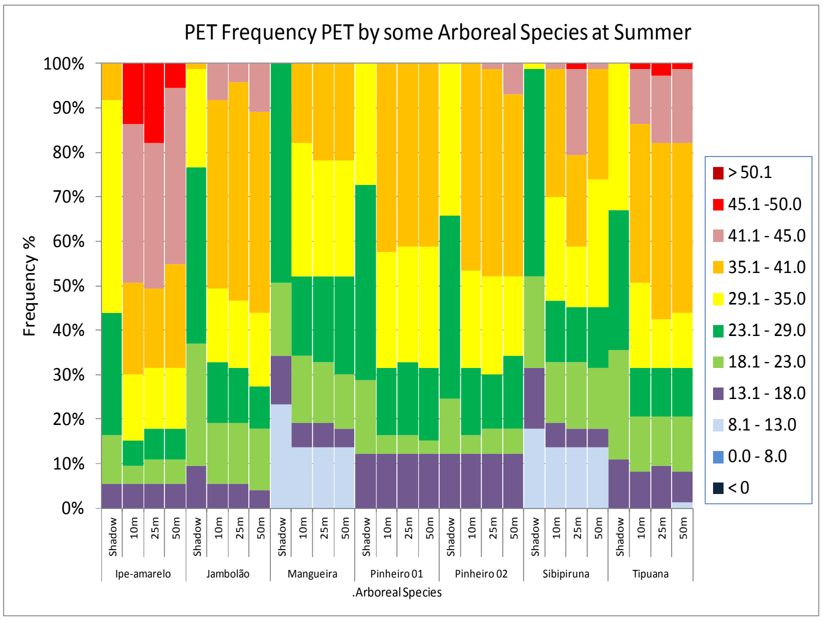


Figure 7 - Results of PET by different species in summer and winter from study period

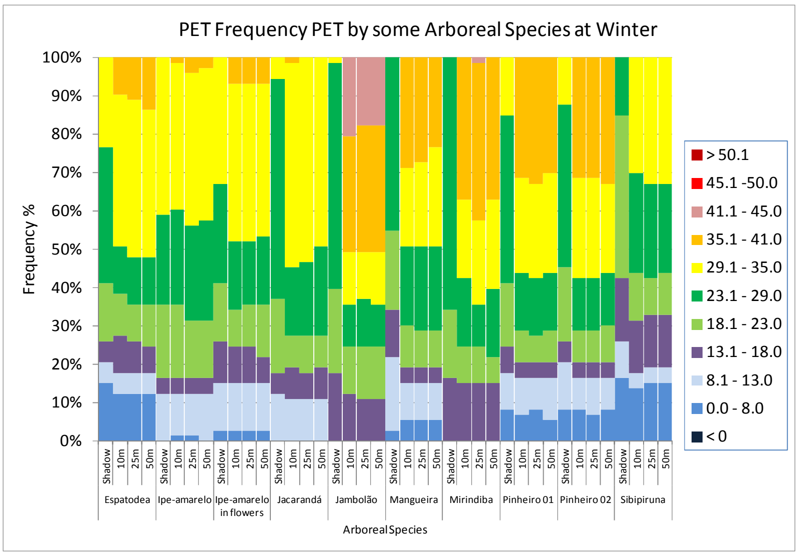


Figure 8 - Results of PET by different species in summer and winter from study period

5. Discussion And Conclusion

The solar radiation influenced directly in thermal comfort sensation in open spaces and the arboreal species behave in different ways in the microclimate, thus each one offer distinct influence radius. In all species analyzed, the tree's shadow affords more thermal benefits than sun places during the year. The shadow of perennials species Jambolão (Syzygium cumini) and Mangueira (Mangifera indica) had similar comportment in summer and winter, consequently, there were more thermal comfort sensation in shadow during the year. The perennials species had variant results of solar radiation attenuated in summer and winter, accordingly, there were slight thermal comfort influence among radius in winter and there were a great influence in shadow in summer. All arboreal individuals studied did not influence significantly in thermal comfort in radius 25m and 50m, as well. Therefore, this study proves that it is able to provide thermal conditions in sun places, 10m from the trunk tree, such as deciduous specie Sibipiruna (Caesalpinia peltophoroides).This results suggest that the thermal comfort improvement quality of arboreal species is related not just the solar radiation attenuation percentage, but with the characteristics of each tree species – canopy, texture, positioning of its elements, physio-ecological and morphological factors.

This paper verified the benefits of influence radius in microclimate provides by different arboreal species and how the crown characteristics as solar radiation attenuation percentage can benefit the outdoor spaces. Cities with topical of altitude climate as Campinas, Brazil, should used the trees, like strategy of thermal comfort control. The solar radiation intercepted by crown provides natural protection of outdoor spaces, mitigation of temperatures and reduction of energy spent on cooling indoor spaces. In outdoor spaces, the urban forestry is able to controlling and improving thermal comfort, mitigated air temperature and controlling relative humidity, consequently, it provides pleasure sensations. And indoor spaces, the shadows can reduce the solar radiation influence in facades, accordingly, it can improve the thermal comfort, save energy spend in cooling and keep the environment healthy. These characteristics of vegetation should be taken into account by professionals of the urban built environment to improve the thermal comfort outdoors, reducing the effect of heat island so ensuring better quality of life for people.

Evaluation of different arborous species commonly found in the urbanization of cities is important information for urban planning aiming to re-qualify the urban microclimate. In addition, tree-planting is a practical and inexpensive solution, and is considered an energy-efficient alternative.

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