Lucila C. Labaki

Thermal effects of Woody Green Areas in Urban Landscapes in Campinas City, Brazil

Cristiane Dacanal[1], Lucila Chebel Labaki[2]

[1]*Universidade Estadual de Campinas - Programa de Pós-Graduação em Arquitetura, Engenharia e Cidade, Rua Saturnino de Brito, 224. Cidade Universitária Zeferino Vaz, Campinas/SP,Brazil,llabaki@gmail.com*

[2] *Instituto Universidade Federal do Vale do São Francisco - Colegiado de Pós-graduação em Engenharia Agrícola, Avenida Antônio Carlos Magalhães, 510. Santo Antônio, Juazeiro, BA, Brazil, cristiane.dacanal@univasf.edu.br*

1. Introduction

Urban green areas have an important role in environmental control, especially against global warming. The thermal effect of urban green areas has an importance in warm climates for it improves the comfort conditions and minimizes the need for mechanical cooling of buildings. The thermal effect of green areas in cities is a subject studied worldwide. In fact, some studies have shown that thermal effect provided by urban green areas varies in magnitude, extension, as well it depending on weather conditions, urban pattern and vegetation class.

One of the first studies about the effect of urban green areas in the climate was carried out by Chandler (1962) in London. The author observed higher relative humidity in the greenbelt when it was compared to the central area. Despite this, air temperature in the greenbelt was higher than the urban area in the morning and early afternoon, but not at night.

Also, Jusuf et al. (2007) in Singapore, had used the technique of mobile transects to obtain the urban thermal differences at night. Average air temperature showed 0.51 ^{o}C higher in the built environment than in the green areas. Based on thermal images, the author observed a decrease in surface temperature in the following order of urban patterns: industrial, commercial, airport, residential and park.

Jauregui (1990/91) observed that the extension of cooling effect by a green area of 5,000,000 m^2 in Mexico city was approximately 2,000 m, coinciding with the width of the park. The monthly average minimum temperature between the park and the reference station achieved greater difference in the dry season at 4^{o} C. However, the maximum temperature in the park was equal to or higher than the urban area.

In Brazil, several researches on green areas have been developed. Cox (2008) related the land use to the air temperature in the dry season. As well as Jusuf et. al (2007), Cox observed that commercial corridors and urban centers presented elevated air temperature and low humidity. By the other hand, the neighborhoods next woody areas presented lower air temperature and higher relative humidity. Similarly, Gomes and Lamberts (2009) found a correlation between the percentage of urban vegetation and meteorological data. They measured a thermal difference between a native vegetated area and the downtown about 4 ° C at 14h, and the thermal effect of vegetation is greater in the dry season. Leal et al (2014) obtained a positive relationship between the decrease of air temperature and humidity due to the proximity of urban forest fragments, in study realized in neighborhoods in Curitiba city (Brazil). Already, Cruz (2009) found that the thermal effects of green areas is local, like a cool island immersed in heat island.

Brazil has vast territory, diversity of climates and vegetation. It is necessary to expand research on urban climate and vegetation, as well establish urban and environmental parameters that may be incorporated into the urban laws. Thus, this study aimed to quantify thermal effects of forest fragments in different urban patterns in Campinas - Brazil and establish a minimum percentage of woody green areas in this city for a sensitive thermal effect.

3. Methodology

Campinas city, located in the coastal interior of the state of São Paulo - Brazil, is influenced by Tropical Wet and Dry Climate, and population is about 1 million. This city has some urban forests fragments, dispersed in urban tissue, with characteristics of Brazilian Tropical Semi-deciduous Forest (Figure 1).

Urban patterns, near these green areas, were identified, according Urban Climate Zones (UCZ) classification proposed by Davenport et al (2000), as show Figure 2, and it results in four different zones (Z1 to Z4).

Fig. 1 View of Campinas, SP – Brazil and an example of urban forest fragment studied.

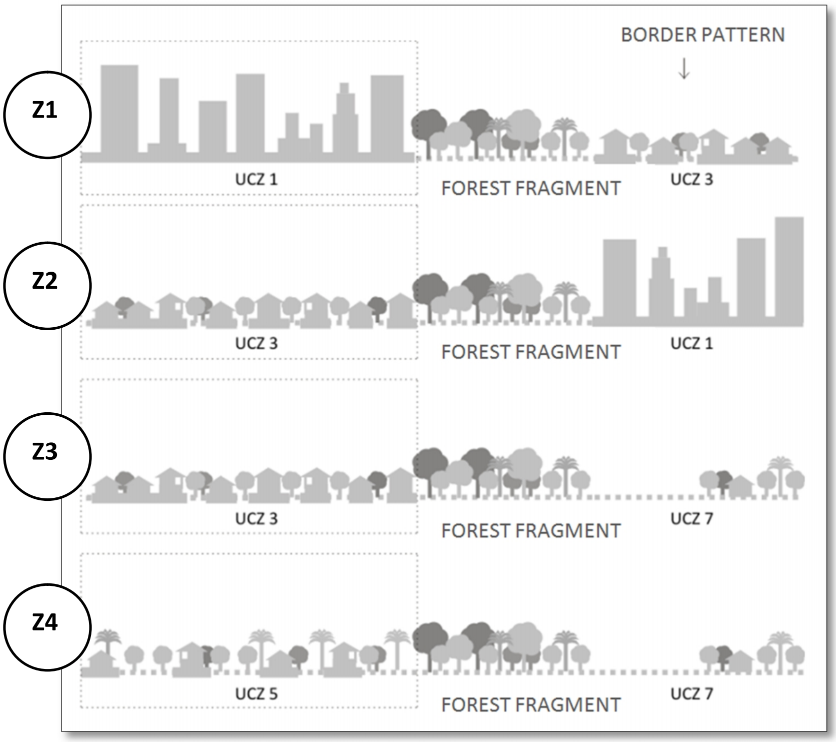


Fig. 2 Patterns of urban zones monitored.

Meteorological campaign were done in 2010, through mobile transects and fixed stations disposed in each zone, as show Figure 3. Temperature and humidity data were automatically registered in fixed stations located into the UCZs, at 1,5 m and 10 m high, and sensors had remained protected of the direct solar radiation. Mobile transects were done by car to register temperature and humidity at 9 h, 13 h and 21 h, local time, and the travel time was about 50 minutes. A GPS was carried in the car, to register time and position of the routes' points.

As air temperature amounted though the route by the delay of data acquisition, is necessary to adjust them. So, it has been parameterized to data of fixed points, observing the exact time of the acquisition registered by the GPS.

The average of air temperature of each zone was calculated and these values were considered the reference (T_{UCZ}). Then, the hourly average temperature of urban points apart 0-800 meters (T_{POINTS}) from the forests was calculated, and these means were compared to the reference ($\Delta T_{POINTS\text{-}UCZ}$).

Analyzing this thermal differences it was calculated the minimal forest cover percentage (Urban Forest - %) relative to the total urban area (Urban Area - square meters) for each UCZ that is sufficient to modify the urban microclimate.

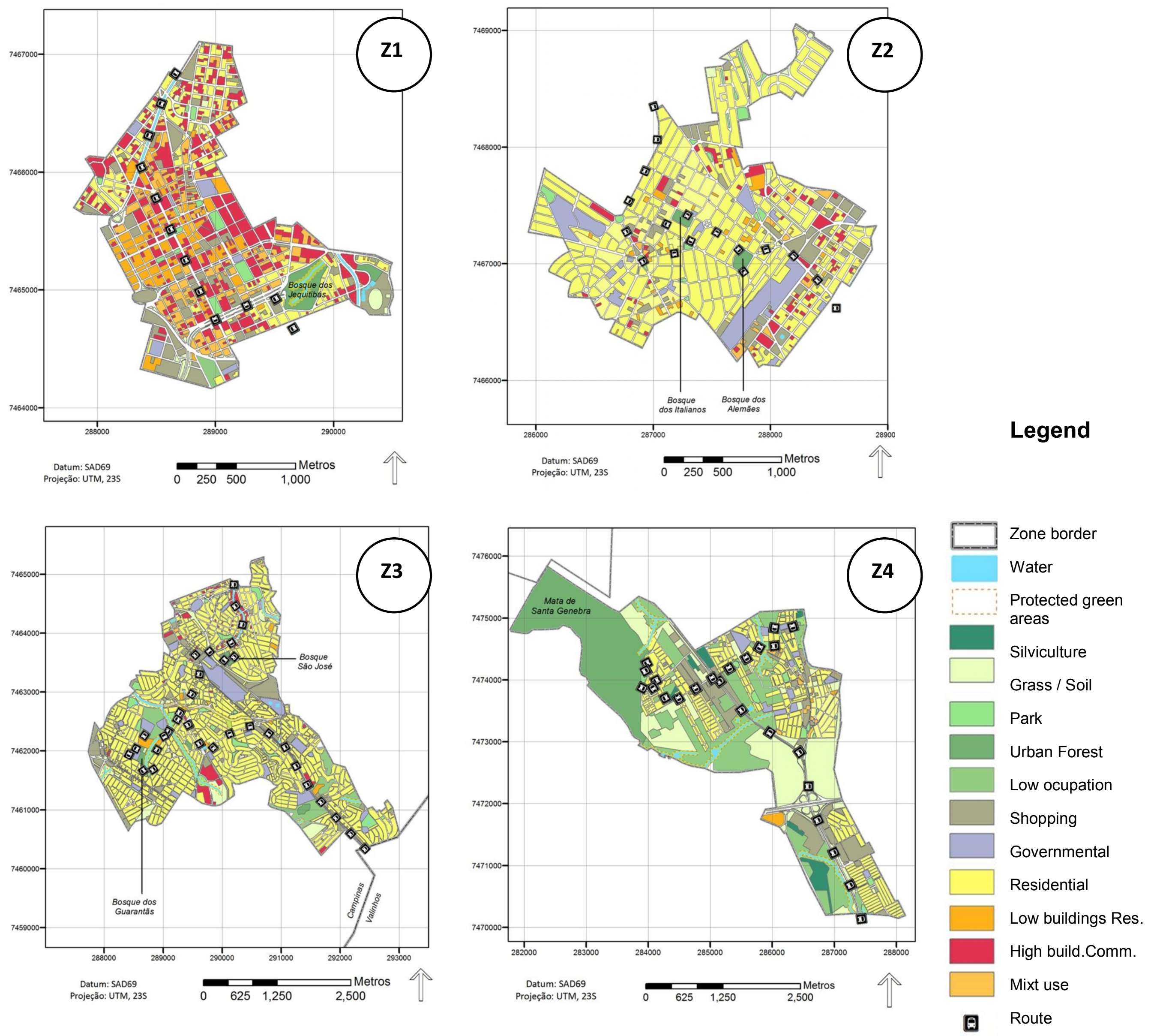


Fig. 3 Routes on the urban zones monitored.

3. Results

Variations in air temperature were found due to the proximity of forest fragments, however, both the magnitude as extension of the cooling effect varied with the urban pattern and time of data acquisition.

In **Z1** where a forest fragment with an area of 105,000 m^2 (*Bosque dos Jequitibás*) it was followed a gradual heating throughout the day in the points near the woody area. The wide avenue with commercial buildings favored the heating surfaces, intensifying heat islands at 21 h , which reached 2.9 ^{o}C in the main avenue and 3.6 ^{o}C in the in the streets bordering of Jequitibás Wood (Figure 4).

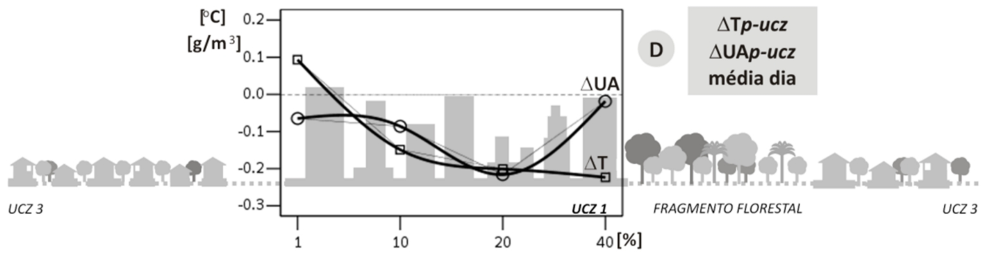


Fig. 4 Cooling effect in Z1 with percentage of forest fragment

In **Z2** were two forest fragments (*Bosque dos Italianos*- 15,000 m^2 and *Bosque dos Alemães* - 20,000 m^2) at a distance of 500 m distance between each other. Thermal stability was found in the streets bordering the forests, showing, nevertheless, heat islands at 21 h with an intensity of ~ 2.2 ° C. The squares between the two forest fragments presented cooling and thermal stability at the three moments during the day with the diminution of air temperature by ~2,5 ^{o}C comparing to the Z2 temperature reference. This zone has a slope and it was verified thermal differences (max. 1.6° C, at 9 h) between the elevated point and the valley, that presented cooler. A reduction of urban air temperature , at 15 h , was caused both by the approaching forest fragments and distancing if the frontier to the commercial zone (border), reaching a thermic difference of 1,8 ^{o}C at 800 m (Figure 5).

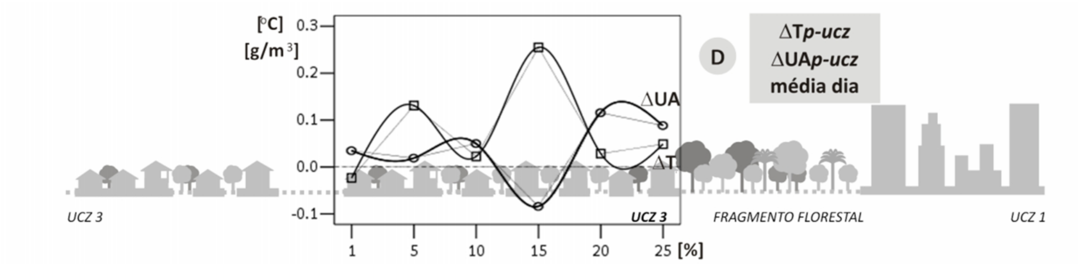


Fig. 5 Cooling effect in Z2 with percentage of forest fragment

In **Z3** where two forest fragments at a distance of 2000 meters between each other (Bosque São José - 33,600 m^2 and Bosque Guarantãs - 33,000 m^2). There was found a subtle diminution of the air temperature because of the approaching urban forest fragment and the distance from the commercial zone (border), reaching 0.3 ^{o}C at 21 h. The temperature of the forest nearest to the commercial zone was 0.7 ^{o}C higher than the other green area. Also, air temperature in the squares under the influence of rural zone (border) was low, diminishing the intensity of the nocturnal heat island of 0.8°C when compared to the residential squares located between the two forest fragments (Figure 6).

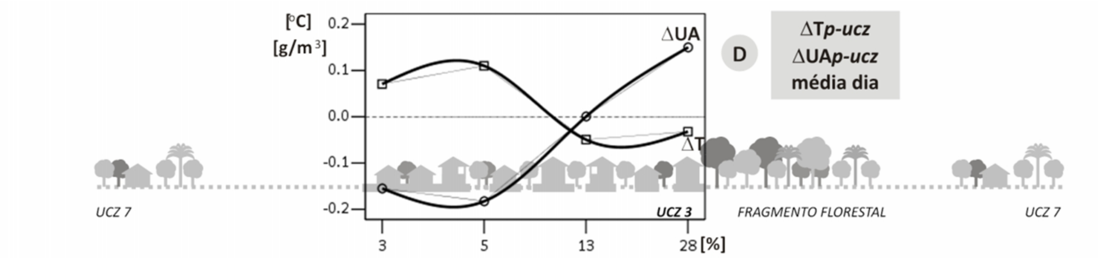


Fig. 6 Cooling effect in Z3 with percentage of forest fragment

In the **Z4**, which the forest fragment has an area of 2,517,700 m^2 (*Mata de Santa Genebra*), a urban point distant 800 meters from the forest presented 0,4 ^oC low than the Z1 temperature reference, at 21h. But, comparing the Z1 temperature reference to another urban pointed located 4.500 m from the forest, it was 1.4 ^oC lower. It was observed a hot island at night (1.7 ^oC) on the border of this forest, that is higher in points near the grass area. On the other hand, points nearest the water (a small river) presented 0,8 ^oC lower than the points nearest the grass (Figure 7).

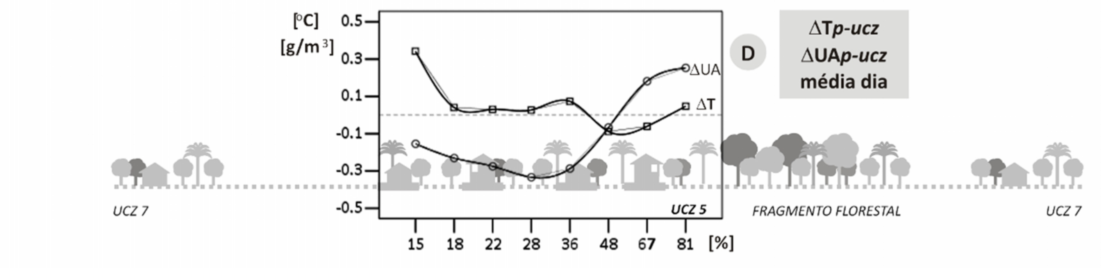


Fig. 7 Cooling effect in Z4 with percentage of forest fragment

An increase of absolute air humidity was found in the approach of the forests fragments in all UCZs at the three moments during the day. Also, it was found a non-occurrence of nocturnal heat islands at 21 h, with air temperatures inferior to the rural environment, both in urban squares jointly to the *UCZ 7* (rural zone) as in monitored points nearest waterflow.

Whereas the effect of the fragments of the built environment is identified by reducing air temperature and by increasing absolute humidity, it was possible to identify the following minimum percentages of urban forest to modify local climate, as show Table 1:

Table 1 – Minimum percentage of urban forest in Campinas city to obtain cooling effect.

UCZ	Percentage of Forest to start thermal effect	Minimum percentage of forest to observe thermal effect in terms of temperature and air moisture
Z1	20%	> 40%
Z2	15%	20%
Z3	4%	13%
Z4	18% thermal stability 30% increase air moisture	50%

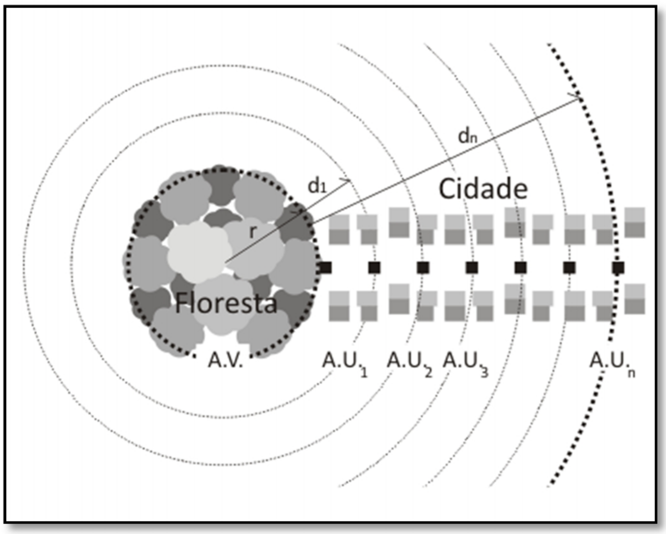
4. Conclusion

Urban forests in the city of Campinas configure islands of coolness during the day and heat islands at night.

It was found that the percentage of the forest area (A.V.) on the total urbanized area should be superior to 20% to be able to assess the start of the cooling effect and the increase in air humidity for any standard of urban occupation (Figure X). For the air temperature to be below average and for the absolute air humidity to be over the expected average for an urban zone, the percentage has to be greater, being able to reach between 40-50% in verticalized urban areas or with a predominance of agricultural lands, exposed soils and grasses.

There are indications that the extension of the effect on the built environment is equal to the diameter "*d*" of of circumference with an area equivalent to that of the forest, confirming the results of Upmanis et al. (1998) and Jauregui (1990/1991). The extension can increase in urban areas under the influence of more than one forest fragment, reaching 1,5 times this diameter, as it may well diminish when the format of the fragment were irregular.

In face of this, it is recommended to plant at least 20% of the urban forest areas on an urban total, as a regular format, homogeneously distributed over the urban fabric, at a distance equal to two times the minimum length of the smallest fragment. It has to be pointed out that this percentage is valid for conditions in Campinas, as well as for the specific category of the studied green area.



** Urban forest = A.V. / A.U (%), need to be≥ 20%; and the diameter of green area "d" is the distance effect.*

Fig. 3 Minimum percentage of forest fragments in cities to obtain a cooling effect.

Acknowledgment

The authors want to thanks the Brazilian funding agency CNPq that support this project.

References

Chandler, T. J. 1962: London's Urban Climate. The Geographical Journal, v. 128, n.3, p. 279-298.

Cox, E. P. 2008: Interação entre clima e superfície urbanizada: o caso da cidade de Várzea Grande, MT. Dissertação (Mestrado em Física e Meio Ambiente) - Universidade Federal de Mato Grosso. Cuiabá, Brasil.

Cruz, G.C.F. 2008: Clima urbano em Ponta Grossa –PR: uma abordagem da dinâmica climática em cidade média subtropical brasileira. Tese (Doutorado em Geografia) - Universidade de São Paulo, Faculdade de Filosofia, Letras e Ciências Humanas. São Paulo, Brasil.

Gomes, P.S.; Lamberts, R. 2009: O estudo do clima urbano e a legislação urbanística: considerações a partir do caso Montes Claros, MG. Ambiente Construído, Porto Alegre, v. 9, n. 1, p. 73-91.

Jauregui, E. 1990/91: Influence of a large urban park on temperature and convective precipitation in a tropical city. Energy and Buildings, v. 15, n.3-4, p.457- 463.

Jusuf, S.K.; Wong N.H.; Hagen, E. ; Anggoro, R.; Hong, Y 2007: The influence of land use on the urban heat island in Singapore. Habitat International, v. 31, p. 232–242.

Leal L., Biondi, D.,Batista A.C. 2014: Influence of urban forests in the thermo-hygrometric variation in intra-urban area of the city of Curitiba – Paraná State. Ciência Florestal, v. 24, n. 4, p. 807-820.