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Urban environmental sustainability: analysis of the influence of vegetation in environmental parameters

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Abstract
Objective: The objective of this work was analyzing the influence of vegetation on the microclimate using air and soil surface temperature, relative humidity and the speed of the wind.
Methodology: The research was carried out in a forest on a university campus' forest, where data were either collected inside and in the forest's edge areas, in addition to 20 and 40 meters distance in a nearby parking area. The data were collected during eight days distributed over a period of one month.
Originality/Relevance: Contribution to reflection on current environmental issues, climate change, the spread of environmental education and the way individuals relate to the environment. This is an instrument to stimulate changes in favor of the environment and society.
Main results: Through data analysis it was possible to observe that inside the forest the air temperatures, surface temperatures and relative humidity performed better than in the parking area, such as, on May 21st, while the maximum surface temperature inside the forest reached 17.1°C, that in the parking lot (at 40m from the forest) was 43.10°C, the same happened with air temperatures, but with smaller thermal amplitudes. The median relative humidity on May 21st inside the forest was 51.5%, while 40 meters away from the edge, in the parking lot, the median was 39.5% that is, lower atmospheric humidity. The occurrence of winds inside the forest was almost nil, in other areas, especially in the parking lot, winds were frequent reaching a maximum speed of 4.2 m/s on the 14th June.
Contributions: The analysis and discussion of this study reaffirmed the influence of vegetation on climatic variables, focusing on the importance of urban forest fragments in the microclimate and the relevance of protecting these areas.

Keywords: Forest fragment. Urban microclimate. Environmental quality. Temperature. Air humidity.

Sustentabilidade ambiental urbana: análise da influência da vegetação em parâmetros ambientais

Resumo
Objetivo do estudo: Analisar a influência da vegetação sobre o microclima utilizando para tanto, temperatura do ar e da superfície do solo, umidade relativa do ar e velocidade do vento.
Metodologia: O estudo foi realizado em um bosque em um campus universitário, onde foram coletados os dados no interior e nas áreas de borda do bosque, além de20 e 40 metros de distância em uma área de estacionamento. Os dados foram coletados durante oito dias distribuídos em um período de um mês.
Originalidade/Relevância: Contribuição nas reflexões sobre questões ambientais atuais, mudanças climáticas, difusão da educação ambiental e sobre a forma como os indivíduos se relacionam com o meio. Sendo este um instrumento de incentivo à mudança em prol do meio ambiente e da sociedade.
Principais resultados: Pelas análises dos dados foi possível observar que dentro do bosque as temperaturas do ar e do solo e umidade relativa do ar apresentaram-se melhores do que na área do

estacionamento, no qual neste último, as temperaturas se apresentaram mais altas, principalmente a da superfície do solo e a umidade atmosférica mais baixa. A incidência de ventos dentro do bosque foi quase nula, já nas outras áreas, especialmente no estacionamento, os ventos foram frequentes.
Contribuições: As análises e a discussão deste estudo reafirmaram a influência da vegetação sobre as variáveis climáticas, com enfoque na importância dos fragmentos florestais urbanos, no microclima e a relevância de se proteger tais áreas.

Palavras-chave: Fragmento florestal. Microclima urbano. Qualidade ambiental. Temperatura. Umidade do ar.

Sostenibilidad ambiental urbana: análisis de la influencia de la vegetación en parámetros ambientales

Resumen
Objetivo del estudio: El propósito de este trabajo fue analizar la influencia de la vegetación en el microclima utilizando la temperatura superficial del aire y del suelo, la humedad relativa del aire y la velocidad del viento.
Metodología: El estudio se llevó a cabo en un bosque en un campus universitario, donde se recolectaron datos en el interior y en las áreas de borde del bosque, además de 20 y 40 metros de distancia en un área de estacionamiento. Los datos se recolectaron durante ocho días distribuidos en un período de un mes.
Originalidad/Relevancia: Contribución a las reflexiones sobre la actualidad ambiental, el cambio climático, la difusión de la educación ambiental y la forma en que las personas se relacionan con el medio ambiente. Siendo este un instrumento para impulsar cambios a favor del medio ambiente y la sociedad.
Principales resultados: A través del análisis de datos se pudo observar que dentro del bosque las temperaturas del aire, temperatura del suelo y humedad relativa (HR), se desempeñaron mejor que en el área de estacionamiento, como por ejemplo, el 21 de Mayo, mientras que la temperatura máxima de la superficie dentro del bosque alcanzó los 17.1°C, la del estacionamiento (a 40m del bosque) fue de 43.10°C, lo mismo sucedió con las temperaturas del aire, pero con amplitudes térmicas menores. La mediana de HR el 21 de Mayo dentro del bosque fue del 51,5%; mientras que a 40 metros del borde, en el estacionamiento, la mediana fue 39,5%, es decir, menor humedad atmosférica. La incidencia de vientos dentro del bosque fue casi nula, en otras áreas, especialmente en el estacionamiento, los vientos fueron frecuentes alcanzando una velocidad máxima de 4.2 m/s el 14 de Junio.
Contribuciones: El análisis y discusión de este estudio reafirmó la influencia de la vegetación en las variables climáticas, enfocándose en la importancia de los fragmentos de bosque urbano, en el microclima y la relevancia de proteger dichas áreas.

Palabras-clave: Fragmento de bosque. Microclima urbano. Calidad ambiental. Temperatura. Humedad del aire.

Introduction

It is known that it was with the beginning of the industrialization processes that the general structural modifications took place; forming new municipalities and access roads, starting the urbanized areas, as they are today and simultaneously occurred acceleration in environmental degradation.

In the city of Campinas, the advent of urbanization occurred in the mid-1930s and it was in this breakthrough process of urbanization establishment of the municipality, which began the massive removal of natural vegetation coming to reflect in the current conditions of forest fragmentation (Briguenti, 2005; Prefeitura Municipal de Campinas [Campinas], 2019).

From the fragmentation of the vegetation cover derive the disturbances responsible for modifying the natural ecological structure and balance of the landscape (Futada, 2007).

Consequently, the disturbance of the natural setting translates not only into the decay of fauna and flora, but also in the complex physical, chemical and biological interactions of which the environment is interconnected, and may even reach a global scale as, for example, when discussing the loss of global biodiversity and about the carbon gas processes (release, capture, fixation, accumulation, recycling and/or emission of carbon to the atmosphere) of which vegetation is directly involved (Gurevitch, Scheiner, & Fox, 2009).

Although the action of habitat fragmentation is harmful, according to Futada (2007) and Feiber (2004), the remaining patches of urban forest cover, even if degraded, denote many environmental services and favor the region where they are located.

The shadows of the trees generate urban thermal comfort and temperature reduction, the forest fragments bring urban beautification in the midst of buildings and the massive sealing, the trees absorb contaminants through photosynthesis, there is also reduction of urban noise pollution through the acoustic barrier formed by the vegetation in the fragments among other environmental benefits (Feiber, 2004; Paiva & Gonçalves, 2002).

Due to the importance of these fragments, the study of these areas for preservation purposes has been increasingly recognized as necessary (Siqueira, 2008).

One way to study and analyze the influence of vegetation on the urban environment is through the use of environmental parameters (Costa, Silva, & Peres, 2007).

Ramos (1997) defines environmental parameters as "a quantity that can be measured accurately or evaluated qualitatively, and that is considered relevant to the evaluation of environmental systems". The author also says that environmental parameters present themselves as variables of the environment, capable of expressing information about the quality or local situation and that in general they serve for environmental assessment.

In this context, the present work aims to discuss the contributions of urban forest fragments to the microclimate.

The methodology is based on exploratory and descriptive research, data survey through field collection of environmental parameters and qualitative and quantitative analysis of the data using scientific literature.

The analysis of the parameters reinforces the benefits that these urban forest remnants represent to society. It also interferes in the way individuals relate to the environment, their awareness, besides being an incentive for companies interested in recovery projects and conservation of green areas and forest fragments.

Since this work is aimed at becoming another instrument to encourage changes in favor of the environment, it presents significant scientific value and, if added to other studies already carried out, will gain more and more space, favoring the continuity of such analyses. The academic sphere is also understood as a means of disseminating such knowledge and a way to help transform social issues.

The central objective of this study is to analyze the influence of vegetation on air temperature, surface temperature; relative humidity and wind speed in urban areas, through studies carried out in a forest located on a university campus in the city of Campinas/SP.

Literature review

The problem of deforestation copiously intensified from the industrial revolution that occurred in the mid-1930s post-war period, adding also to the issue of urbanization arising from the industrial rise (Leal, Farias, & Araujo, 2008).

According to Moraes, Conceição, Cunha, and Moruzzi (2012), particularly in the interior of the state of São Paulo, the fragmentation of the natural vegetation of the Atlantic Forest biome increased severely with the rise of the industrial revolution and also by population growth, caused by labor speculation and people's search for jobs and a better life in the cities.

The fragmentation of the landscape is a result of human interference in natural environments and gives rise to the so-called "urban forest fragments" (Fengler, 2014).

For Melo, Carvalho, Castro, and Machado (2011), Urban Forest Fragments (FFUs) are the remnants of native vegetation that survived deforestation, the urbanization process, and the establishment of man in cities, and are then surrounded by the urban structure.

For Primack and Rodrigues (2001) the FFUs arise from the development and advance of man over natural habitats, reducing and dividing them; resulting then in a fragmented landscape with a larger area of edges and the core closer to this edge, thus differentiating them from the natural forests of origin.

Urban forest fragments are survivors of the process and establishment of urbanization, which in turn, interferes negatively with these ecosystems.

Some of the impacts to these already fragmented ecosystems are: edge effects, microclimate alteration, biodiversity reduction, imbalances of the complex natural interactions, invasion of exotic species, tree death and opening of clearings (Primack & Rodrigues, 2001; Santin, 1999; Melo, 2009; Dacanal, 2011).

Some factors related to the decrease in biodiversity are, for example, the degradation of areas of circulation and dispersal of fauna and flora, important for their survival; the occupation of exotic species that can suppress native species; the interference of edge effects; chemical, physical and biological modifications can also lead to the decline of biodiversity (Ramos, Simonetti, Flores & Jiliberto, 2008; Primack & Rodrigues, 2001; Santin, 1999).

Commonly observed edge effects in fragments are related to high solar irradiance, warm winds, low air humidity, increased air and soil temperatures, increased evaporation and water demand combined with insufficient soil moisture due to higher temperatures (Futada, 2007; Primack & Rodrigues, 2001; Santos & Carlesso, 1998).

The combination of these effects results, for example, in the death of vegetation at the edges and an increase in the number of standing dead trees, and an increased risk of fires at the edges due to the drier microclimate (Primack & Rodrigues, 2001; Melo et al., 2011).

The degree of environmental disturbance and habitat degradation also depends on several factors that make up and interfere with the quality of the microclimate of the edge of a fragment, some of the factors that can be cited are: the use and land occupation of the surrounding area of the fragment, the presence of climbing native species on the edges that play a protective role, the presence of invasive species on the edges, the size of the fragment, the shape that interferes with the ratio edge/area and the proximity and connectivity with other nearby fragments (Melo et al, 2011; Primack & Rodrigues, 2001; Gurevitch et al., 2009; Viana & Pinheiro, 1998).

According to Primack and Rodrigues (2001), despite all the impacts that forest fragments suffer and the fact that they are degraded, they retain the particularities of natural environments that exert positive influences on the environment where they are located in the social, environmental, bioclimatic, urban and even economic context.

The presence of green areas in the economic and social factors, are important for the quality of life in cities and in view of the constant impacts that these areas suffer from the urban scenario, it is even more evident the need to preserve them to ensure better quality of life in urban centers, not only for the population but also for the species linked to these ecosystems (Lucon & Longo, 2019; Garcia, Longo, Penereiro, Mendes, & Mantovani, 2018).

The importance of urban forest fragments in the social sphere is related to several issues; one of them being the health and well-being of the population. Within the urban scenario, the fragments are able to create and provide shade that intervenes in the temperatures bringing a pleasant perception of fresh and pure air to the population (Gartland, 2011).

Thus, these natural habitats serve as refuges for their users, who live a routine amidst impermeable areas, densely occupied by buildings and roads with high vehicle traffic, places that are usually hot, noisy, and polluted (Dacanal, Labaki, & Silva, 2010).

In this context, urban forest fragments can bring several psychological benefits by being environments favorable to the feeling of peace, psychological and mental restoration, tranquility and relaxation to its users (Dacanal et al., 2010; Feiber, 2004; Paiva & Gonçalves, 2002).

People also frequent these places in search of the experience of contact with nature while enjoying moments of leisure, physical activities, and socialization, in a sensorial pleasant microclimate that these environments possess (Dacanal et al., 2010; Feiber, 2004).

Other social benefits attributed to natural fragments in the urban environment are:

- Relating to the permeability and decompacting of the soil by the presence of the roots of the vegetation of the urban forest fragments, which retain part of the water that would run off superficially, especially rainwater which in urban areas can come to cause flooding due to the high compaction and impermeability of the surface (Paiva & Gonçalves, 2002).
- Related to the minimizing function of urban air pollution that vegetation exerts through the process of photosynthesis and that influences the improvement of air quality (Feiber, 2004).
- In the contribution of noise pollution reduction inside the fragments through the acoustic barrier formed by the vegetation of forest fragments in large urban centers (Paiva & Gonçalves, 2002; Primack & Rodrigues, 2001).
- On the contribution of noise pollution reduction inside the fragments through the acoustic barrier formed by the vegetation of forest fragments in large urban centers (Paiva & Gonçalves, 2002; Primack & Rodrigues, 2001).
- In relation to its power to stimulate a differentiated look on green areas, thus acting in the promotion of education and environmental awareness of its frequenters, this being an important social and environmental gain (Cielo & Santin, 2002; Melo et al., 2011).
- In the association of these areas with initiatives for environmental studies, they can be used for research aimed at protecting biodiversity and represent a benefit not only socially but also for the environment (Melo, 2009; Primack & Rodrigues, 2001).

In the environmental context, urban fragments play an important role in environmental conservation (Feiber, 2004).

According to Troppmair (2008), the ecological structure of green areas represents shelter for native flora and fauna and can also serve as ecological corridors of gene flow of species, minimizing the effects of fragmentation and assisting in the perpetuation and survival of local biodiversity.

In urban forest fragments it is possible to find several fruit tree species that serve as shelter for fauna and ensure their food, preserving their existence and ecological interactions (Feiber, 2004; Santin, 1999; Paiva & Gonçalves, 2002).

Green areas are also fundamental in the conservation and renewal of natural resources, such as their influence on the water cycle through evapotranspiration, infiltration and surface runoff of rainwater; influence of vegetation on air and soil temperature, shading of the banks of water resources preserving them in the function of riparian forest, soil protection against erosion, control of siltation of waterways, the absorption and capture of water in the soil that ensures the replacement of groundwater and soil moisture for and by the vegetation, the presence of fragments also ensures soil fertility through the *serrapilheira* that decomposes on the soil surface (Paiva & Gonçalves, 2002; Feiber, 2004; Primack & Rodrigues, 2001).

For the bioclimatic context the urban forest fragments exert great influence on the thermal comfort in micro-scale and in the softening of the temperatures of the built environment (Troppmair, 2008; Dacanal et al., 2010).

According to Gartland (2011), Feiber (2004), Dacanal (2011), forest fragments bring climatic benefits in the urban context that mitigate the heat island phenomenon:

- Through the shade of the trees that reduce the direct incidence of solar radiation on surfaces and inhabitants;
- Reducing the dispersion of high temperatures into the atmosphere;
- Retaining part of the thermal load (that heats urban areas) through the process of evapotranspiration;
- Favoring relative atmospheric humidity by preventing part of the sun's rays from passing through the tree canopy and by shading;
- Influencing the speed and direction of wind currents;
- Decrease of carbon dioxide (CO_2) concentration in the atmosphere from the photosynthesis process.

And there is also the thermal comfort in microclimatic scale within the urban forest remnants, in which there are milder temperatures, higher air humidity and impression of air breezes inside (Dacanal et al., 2010; Feiber, 2004).

As for the urban aspect, the urban forest fragments complement the architectural structure designed for the cities, presenting functions of smoothing and visual harmony of the urban landscape (Feiber, 2004; Paiva & Gonçalves, 2002), they also present themselves as historical, urban and architectural references (Badiru, Pires, & Rodriguez, 2005).

Regarding the importance of urban forest remnants in the economic context, besides those already mentioned, there are also other indirect values attributed to natural areas, such as the promotion of ecotourism, use of some species as environmental indicators, agents of biological control and use in studies in biomedicine, biochemistry, zoology and others (Primack & Rodrigues, 2001).

Examples of the direct influence on the economy are: the generation of jobs due to the need of adequate labor for the maintenance of these areas and the valuation that green areas attribute in the value of nearby enterprises, as in the case of residential condominiums, buildings and commerce (Paiva & Gonçalves, 2002; Primack & Rodrigues, 2001).

Methodology

The study area is located in the city of Campinas - SP and according to the Brazilian Institute of Geography and Statistics (IBGE) (2002), the city's climate is classified as subtropical, located in the Central Brazil Tropical area.

According to Köppen's classification, the climate of Campinas, for being located in the central region of the state of São Paulo, may be classified as CWA - subtropical climate of dry and cold winter and hot and rainy summer, being that normally the dry and cold period from April to September, with average temperature ranging between 18.1 and 22.3ºC and the hot and rainy period from October to March with average between 23.9 and 25.3ºC - averages of the period from 1990 to 2018 (Center for Teaching and Research in Agriculture [CEPAGRI], 2019; Santin, 1999).

The average annual relative humidity and precipitation of the municipality are 72.1% and 1,380 mm respectively, the wind approximately 2 m/s and average annual temperature of approximately 22.35°C (average temperatures in the period from 1990 to 2018), reaching its maximum temperatures in February and minimum in July (CAMPINAS, 2006; CEPAGRI, 2019).

The study fragment in question is located more specifically in a private area, on Campus I of the Pontifical Catholic University of Campinas in the *Parque Rural Fazenda Santa Cândida* neighborhood (CAMPINAS, 2019).

The grove is located on the UTM coordinates, Zone 23 K, N 7,473,440 m, E 289,896m, has a perimeter of 834.10 m and an area of approximately 34,813.62 m2, which is the equivalent of almost 3.5 ha (Google Earth PRO, 2018, Google Maps, 2019).

The area is located between the parking lots pockets C, E and part of B, it is also close to a smaller fragment that is next to the pocket B and between the avenues Dr. Caio Pinto Guimarães and Cardeal Dom Agnelo Rossi, two roads of great flow of vehicles; the grove is also close to the buildings of the library - unit II and the maintenance engineering department, besides having on one of its sides a large decamped area and on the other side a small power cabin.

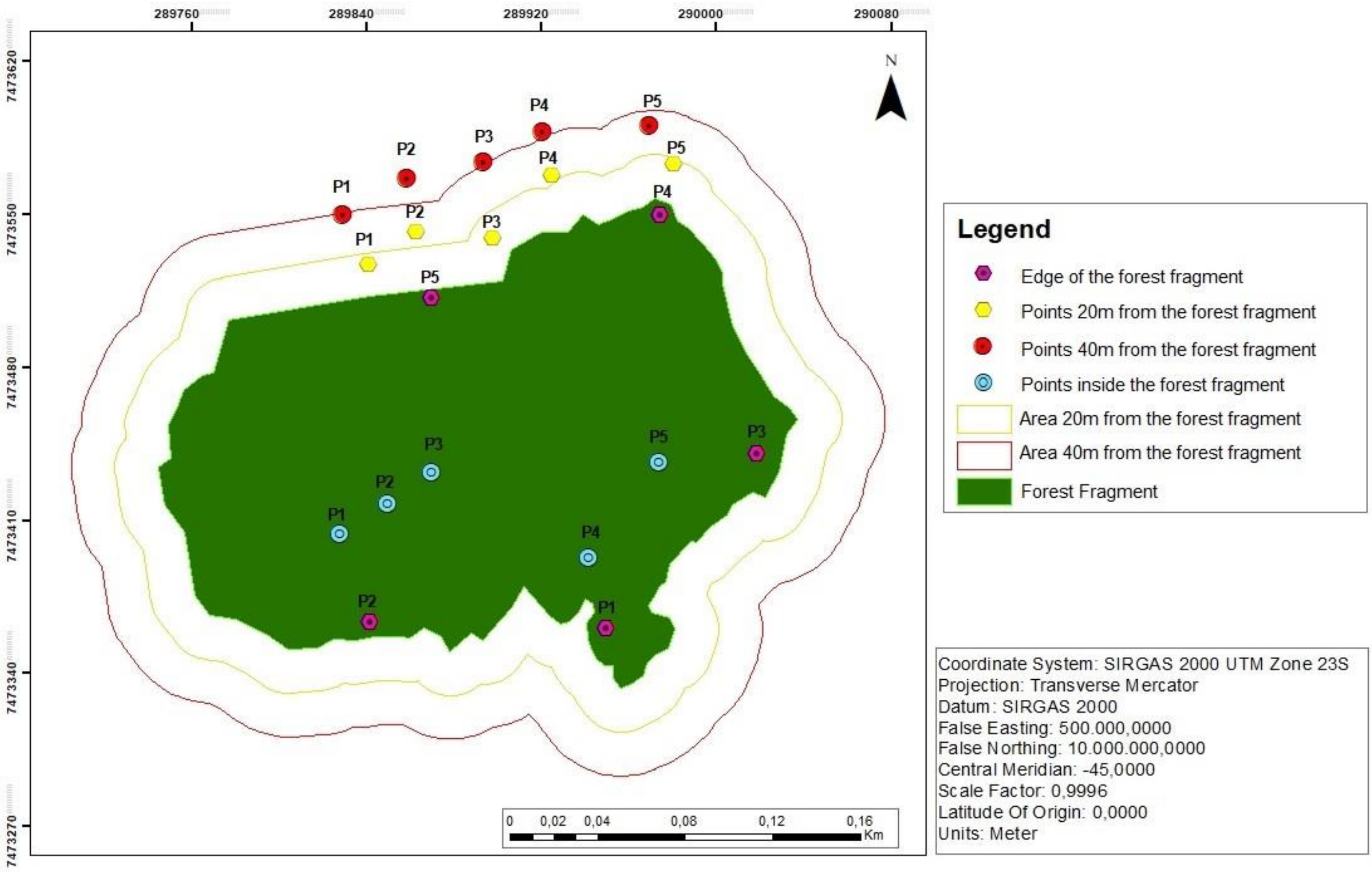
About the internal characteristics of the forest, it has a central paved trail and other smaller unpaved ones, an artificial pond, a small impermeable area used as a deposit of old flowerpots and a water reservoir that forms a clearing.

After analyzing and studying the area, twenty points were marked for collecting the parameters (air temperature, surface temperature, relative humidity and wind speed), five of these points are inside the forest starting from the access to the trails inside the forest, other five points on the edges of the forest, five points 20 meters away from the forest towards the parking lot and other five points 40 meters away from the forest also inside the parking lot - pocket C.

Figure 1 depicts the distribution of points where the parameters were collected.

Figure 1

Sample location at the forest area



Source: Adapted from ArcGIS software (2019) and Google Earth PRO (2018).

The collections of environmental parameters were performed at two periods; in the morning, starting at 9:30 am and in the afternoon after 3:30 pm on May 14th,18th, 21st and 25th, 2018 and on June 04th, 07th, 11th and 14th, 2018, that is, two days a week, distributed over a period of approximately one month at the end of the fall season, a methodology similar to that used by Lucon and Longo (2019) and Monteiro and Pezzuto (2017).

At each point, the following environmental parameters were collected with their respective measuring devices:

- Soil/surface temperature using a GS320 digital and manual direct surface temperature measurement infrared thermometer;

- Relative humidity using a digital thermo-hygrometer with an external air temperature and humidity sensor;
- Air temperature and wind speed using a portable digital minyanemometer GM816;

The wind speed was collected at a height of approximately 2 meters from the ground, with the anemometer in hand and arm extended upwards and the parameters air humidity and temperature were measured with the device at chest height.

On the first day of collection we also used a Garmin - etrex GPS to record the coordinates of each point and a tape measure to measure the distances of 20 and 40 meters in the parking lot pocket C.

After the collection of the parameters, the data of each parameter was individually planned, and later used in the preparation of tables and figures with the synthesis of information, whose objective was to enable the analysis and discussion of the behavior of each parameter. The figures were prepared from the average of the two times of day and between the points of each of the four collection sites (inside the forest, at the edge of the forest, in the parking lot 20m and 40m from the edge of the forest).

Results and discussion

Table 1,

Table ***2***, and Table present, respectively, the Surface Temperature (ST), Air Temperature (AT), and Relative Air Humidity (RH) data broken out by collection date and environment (inside the forest, at the edge of the forest, and 20 m and 40 m away from the forest edge). Also, statistic values, i.e., the daily maximum and minimum, amplitude, and mean, are summarized into the tables.

In Table 1, it is possible to observe that the maximum and minimum surface temperatures inside the forest are generally lower than those registered in the parking lot, as the maximum surface temperature in the forest of 17.10°C on the 21st of May, much lower than the maximum surface temperatures of 43.70 and 43.10°C in the parking lot. It is also possible to verify that the thermal amplitudes inside the forest were considerably smaller than the variation in the parking area.

The average was another feature that well expressed the phenomenon of the influence of green areas on the surface temperature, by the medians it was possible to observe that the temperatures in the parking area were clearly higher.

Regarding the behavior of surface temperature, the study carried out by Lucon, Longo, Georges, and Bordim (2018) can be taken as a comparison, in which surface temperature values collected in four environments in distinct days, times and points were analyzed, from which the results showed that the highest amplitudes and the highest temperatures were in exposed and waterproofed soil while in the other two areas with vegetation cover the thermal amplitude was smaller and the maximum temperatures considerably lower as well. The work also cited oscillations in some values due to influencing factors, such as: points covered by the shadow of the treetops, days and times with higher temperatures and colder days or with the presence of rain.

Table 1

Maximum and minimum surface temperature, thermal amplitude and median of each day's sampling points and collection environment

	SURFACE TEMPERATURE (ST)								
Forest Inside	*Analysis parameters*	*14/May*	*18/May*	*21/May*	*25/May*	*04/Jun*	*07/Jun*	*11/Jun*	*14/Jun*
	ST max. (ºC)	25,50	27,10	17,10	24,50	21,00	20,10	27,10	28,40
	ST min. (ºC)	22,20	19,80	12,00	18,20	15,90	17,40	19,20	17,00
	Thermal Amplitude (ºC)	3,30	7,30	5,10	6,30	5,10	2,70	7,90	11,40
	Average (ºC)	24,10	23,15	14,80	21,05	18,75	18,40	22,85	18,90
Forest Edge									
	ST max. (ºC)	37,10	33,80	33,60	34,70	29,10	24,10	31,40	27,50
	ST min. (ºC)	19,10	21,00	10,00	18,90	16,90	19,00	23,30	17,30
	Thermal Amplitude (ºC)	18,00	12,80	23,60	15,80	12,20	5,10	8,10	10,20
	Average (ºC)	25,10	24,05	17,15	25,60	23,75	20,35	25,30	21,20
20m Edge									
	ST max.(ºC)	39,90	42,50	43,70	42,00	37,20	28,10	37,90	39,80
	ST min. (ºC)	28,10	21,50	35,10	27,10	23,40	20,80	28,80	25,90
	Thermal Amplitude (ºC)	11,80	21,00	8,60	14,90	13,80	7,30	9,10	13,90
	Average (ºC)	34,25	29,50	39,90	38,55	31,85	22,55	31,95	32,30
40m Edge									
	ST max.(ºC)	49,90	42,80	43,10	42,20	37,40	33,90	45,80	40,90
	ST min. (ºC)	31,10	24,00	30,40	33,00	21,80	21,10	32,80	26,60
	Thermal Amplitude(ºC)	18,80	18,80	12,70	9,20	15,60	12,80	13,00	14,30
	Average (ºC)	38,00	33,05	37,30	38,50	33,15	23,30	37,65	35,25

Source: Prepared by the authors (2018).

It should be noted that the maximum and minimum temperatures registered inside the forest were generally lower than in the edge or beyond. This fact can be clearly observed on June 4th, in which the minimum air temperature inside the forest and in the parking lot was respectively, 17.7°C and 30.1°C.

Distinguishable from the surface temperature, some significant thermal amplitude between groups (environments) were not identified in this study because of the lower air temperature variation.

The higher thermal amplitudes collected inside the forest are probably due to differences between the collection points within the forest, with some being closer to clearings, one closer to a pond and another in a denser forest area, thus interfering with the difference of air temperature between the points.

Table 2

Maximum and minimum air temperature, thermal amplitude and median of each day's sampling points and collection environment

	AIR TEMPERATURE (AT)								
Inside Forest	*Analysis parameters*	*14/May*	*18/May*	*21/May*	*25/May*	*04/Jun*	*07/Jun*	*11/Jun*	*14/Jun*
	AT max. (ºC)	27,10	27,80	23,20	25,80	23,80	26,60	29,00	24,50
	AT min. (ºC)	25,40	21,40	16,30	20,80	17,70	21,10	22,40	20,70
	Thermal Amplitude (ºC)	1,70	6,40	6,90	5,00	6,10	5,50	6,60	3,80
	Average (ºC)	26,65	24,45	21,70	23,00	20,50	23,25	25,60	21,70
Forest Edge									
	AT max. (ºC)	30,30	31,00	26,40	29,30	26,30	25,90	30,50	25,50
	AT min. (ºC)	26,30	21,30	16,20	20,60	17,50	21,10	23,10	20,00
	Thermal Amplitude (ºC)	4,00	9,70	10,20	8,70	8,80	4,80	7,40	5,50
	Average (ºC)	26,85	25,30	21,25	25,35	22,85	22,40	27,40	21,85
20m Edge									
	AT max. (ºC)	31,10	31,50	26,10	31,10	28,40	26,60	32,00	26,60
	AT min. (ºC)	27,90	22,00	19,80	24,20	19,50	20,90	25,20	21,90
	Thermal Amplitude (ºC)	3,20	9,50	6,30	6,90	8,90	5,70	6,80	4,70
	Average (ºC)	28,95	26,10	23,10	27,45	24,50	23,10	28,05	24,35
40m Edge									
	AT max. (ºC)	30,50	32,30	27,00	31,30	30,10	28,00	45,80	26,00
	AT min. (ºC)	27,20	22,30	21,40	22,80	19,30	21,10	32,80	21,70
	Thermal Amplitude (ºC)	3,30	10,00	5,60	8,50	10,80	6,90	13,00	4,30
	Average (ºC)	28,70	26,60	23,85	27,60	24,85	22,95	37,65	24,65

Source: Prepared by the authors (2018).

Table 3 shows the data on relative air humidity (RH), divided by day and collection environment (inside the forest, on the immediate edge of the forest, 20m away from the forest and 40m away), listing the maximum and minimum AT, the thermal amplitude and the median of the relative humidity of the air of the day.

The maximum and minimum RHs within the forest were, in general, higher than in the other environments, as well as the average values within the forest were higher, with the exception of June 07, which presented constancy in the RH due to intense rain. The amplitude in the parking area varied less than in areas with the presence of vegetation, as seen in Table 3.

On June 14, for example, while the maximum and minimum atmospheric humidity inside the forest were 74% and 60% respectively; 40 meters away from the edge, in the parking area at maximum and minimum were 66% and 55%, that is, lower.

In studies carried out by Dacanal (2011) on microclimatic parameters in urban and rural areas with or without vegetation nearby, it was found that the values of air temperatures in areas very close to the vegetation cover were lower, as were the values of relative humidity. The air temperatures were higher due to evapotranspiration, while in exposed soils and mainly in densely built areas, away from vegetation, air temperatures were higher, mainly the temperatures close to the ground and the relative humidity of the air were lower.

Still on the parameters of air humidity and temperature, Oliveira *et al.* (2015) also obtained results in the same behavioral line as those obtained in the present work, in which it was found that there was a gradual increase in air temperature in areas with low vegetation, while in the area with more vegetation the increase was small and the mean maximum temperature of the day (27.80 °C) of the area with greater tree cover was lower than that of other areas with predominance of urban cover, results which are equivalent to those found in the course of this work.

Table 3

Maximum and minimum relative humidity, amplitude and median of sampling points for each day and collection environment

	RELATIVE HUMIDITY (RH)								
Inside Forest	*Analysis parameters*	*14/May*	*18/May*	*21/May*	*25/May*	*04/Jun*	*07/Jun*	*11/Jun*	*14/Jun*
	UR max. (%)	65,0	81,0	65,0	68,0	69,0	94,0	77,0	74,0
	UR min. (%)	51,0	53,0	44,0	45,0	49,0	74,0	51,0	60,0
	Amplitude (%)	14,0	28,0	21,0	23,0	20,0	20,0	26,0	14,0
	Average (%)	58,5	64,5	51,5	56,0	59,5	88,5	62,5	73,5
Edge Forest									
	UR max. (%)	61,0	79,0	55,0	66,0	68,0	97,0	74,0	75,0
	UR min. (%)	41,0	45,0	38,0	37,0	40,0	80,0	45,0	56,0
	Amplitude (%)	20,0	34,0	17,0	29,0	28,0	17,0	29,0	19,0
	Average (%)	56,0	63,0	45,5	51,0	55,5	92,0	61,0	67,0
20m Edge									
	UR max. (%)	51,0	75,0	46,0	56,0	63,0	95,0	66,0	65,0
	UR min. (%)	42,0	43,0	34,0	35,0	40,0	70,0	42,0	54,0
	Amplitude (%)	9,0	32,0	12,0	21,0	23,0	25,0	24,0	11,0
	Average (%)	46,5	60,5	40,5	46,5	51,0	87,5	56,5	60,5
40 Edge									
	UR max. (%)	51,0	73,0	45,0	56,0	62,0	94,0	68,0	66,0
	UR min. (%)	42,0	41,0	34,0	34,0	38,0	68,0	41,0	55,0
	Amplitude (%)	9,0	32,0	11,0	22,0	24,0	26,0	27,0	11,0
	Average (%)	46,5	57,5	39,5	45,5	50,0	88,0	56,5	60,5

Source: Prepared by the authors (2018).

In Table 4, the data referring to wind speed are distributed, divided by day and collection environment (inside the forest, on the immediate edge of the forest, 20m away from the forest and 40m away), listing the maximum and minimum wind speed of the air, the thermal amplitude and the average of the day.

The maximum and minimum wind speeds inside the forest were mostly null, the little presence of wind occurred in points of clearing, with the wind actually being more present in open areas, mainly in the parking lot, 20 and 40 meters away from the forest edge and reaching a maximum speed of 4.2 m/s on June 14, as can be seen in Table 4.

In this sense, Dacanal (2011) discusses the influence that vegetation exerts on the reduction of wind speed, stating that within the fragments the wind speed tends to zero, because it is retained in the different size ranges of plants and also identifies the presence of water as a source of cooling.

Table 4

Maximum and minimum wind speed, amplitude and median of sampling points for each day and collection environment

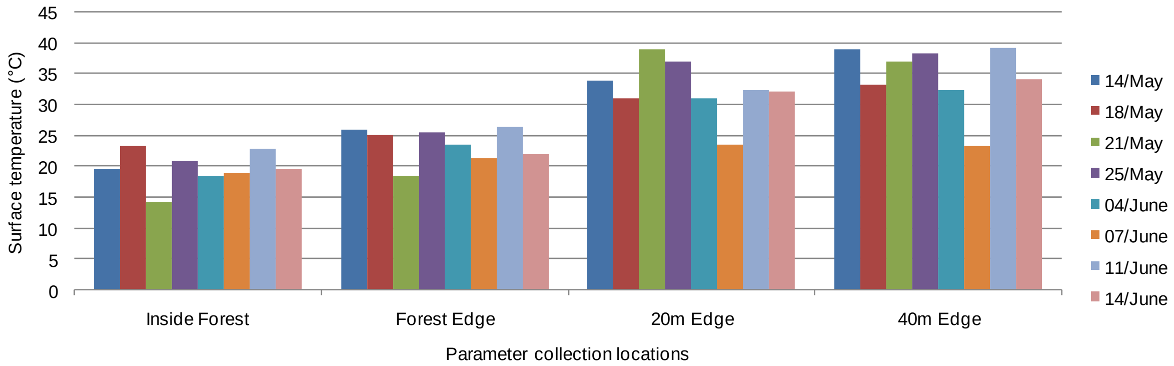
	WIND SPEED (W)								
Inside Forest	*Analysis parameters*	*14/May*	*18/May*	*21/May*	*25/May*	*04/Jun*	*07/Jun*	*11/Jun*	*14/Jun*
	W max. (m/s)	0,0	1,1	0,0	0,7	0,0	0,0	0,0	0,9
	W min. (m/s)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Amplitude (m/s)	0,0	1,1	0,0	0,7	0,0	0,0	0,0	0,9
	Average(m/s)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Forest Edge									
	W max. (m/s)	1,8	1,6	1,6	1,8	3,9	0,0	1,8	4,1
	W min. (m/s)	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0
	Amplitude (m/s)	1,8	1,6	1,6	1,8	3,2	0,0	1,8	4,1
	Average (m/s)	0,0	0,0	0,0	0,4	1,5	0,0	0,4	2,1
20m Edge									
	W max. (m/s)	1,9	2,4	1,8	1,7	2,4	1,9	2,2	4,2
	W min. (m/s)	0,0	0,0	0,0	0,0	0,9	0,0	0,0	1,3
	Amplitude (m/s)	1,9	2,4	1,8	1,7	1,5	1,9	2,2	2,9
	Average(m/s)	0,0	1,1	0,0	0,9	1,6	0,0	1,2	2,2
40m Edge									
	W max. (m/s)	2,2	2,0	2,2	2,0	3,0	0,0	1,9	3,8
	W min. (m/s)	0,0	0,0	0,0	0,6	1,0	0,0	0,0	1,1
	Amplitude (m/s)	2,2	2,0	2,2	1,4	2,0	0,0	1,9	2,7
	Average(m/s)	0,0	0,5	1,2	1,5	1,7	0,0	0,9	2,4

Source: Prepared by the authors (2018).

Figure 2 shows the average between the five collected points on the surface temperature at each location and date. Its appearance reaffirms the fact that temperatures in the parking lot (20 and 40 meters away from the edge) were higher than those in the forest and edges, mainly inside the forest. Among the averages, attention is drawn to the orange columns referring to June 7th, which, in general, appear a little lower than the others; this was due to the weather on this day being rainy and cloudy, mitigating the surface temperature as a whole.

Figure 2

Average surface temperature (°C) of all collection sites



Source: Prepared by the authors (2018).

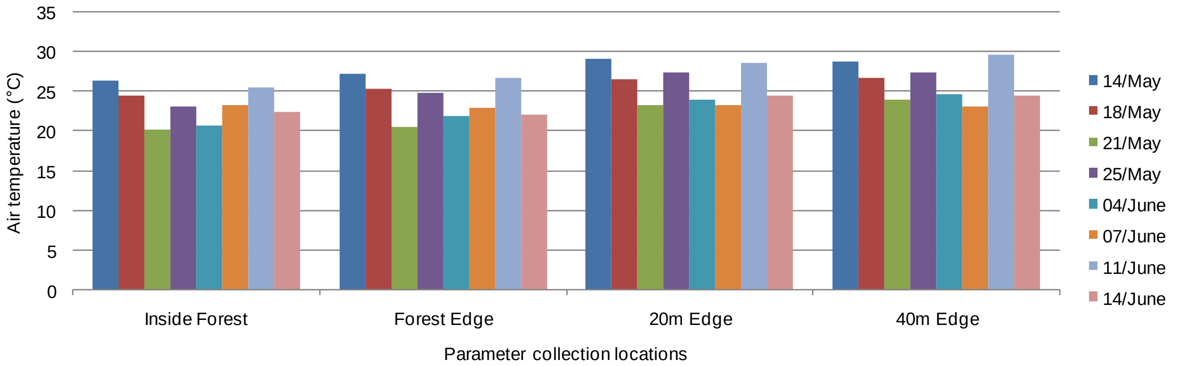
Regarding the differences in the amplitude between surface and air temperatures, it was possible to observe this fact more clearly in Figures 2 and 3.

In Figure 3, it was found that despite the low thermal variation of the air, the averages of air temperatures inside the forest remained below the averages of the other three collection environments, distancing themselves further from the averages of the parking lot. Another observation that can be made was referring to the columns of the averages at the edges of the forest, which were slightly lower than those in the parking lot and slightly higher than those inside the forest. Regarding the columns of the parking averages, there is great similarity between the columns of the respective days of the data at 20 and 40 meters from the edge as they are both in the parking area.

Among the averages in Figure 3, the orange columns on the 7th drew attention again, this time because the air temperature averages were very balanced between all environments. This fact was justified once again by the rainy weather of the day, which softened the air temperature and kept it constant.

Figure 3

Average air temperature (°C) of all collection sites

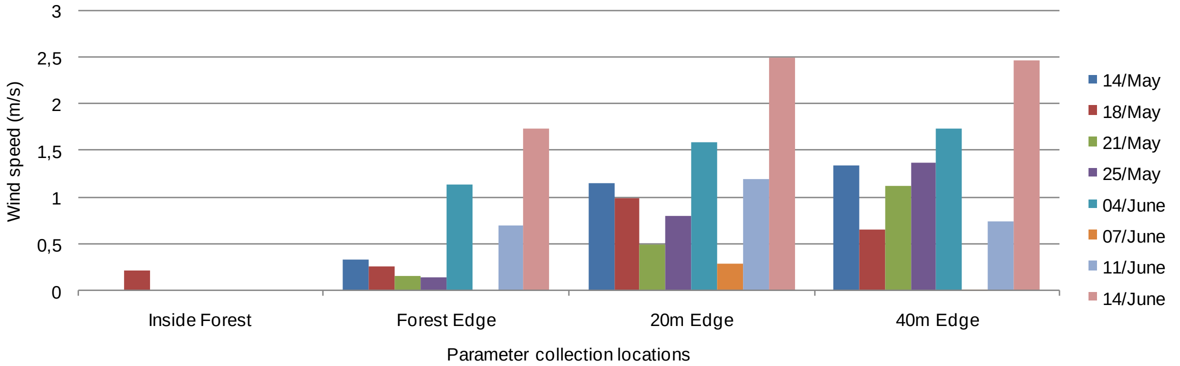


Source: Prepared by the authors (2018).

In an opposing movement to the columns of Figure 3, Figure 4 showed the decrease of its columns in the course of the four collection sites. The higher humidity averages within the forest and lower in the last two groups (20 and 40 meters from the edge respectively) became more evident, another issue that drew attention are the columns of June 7th, which appear once again in disagreement with the others, justified by the presence of rain on that date and which, consequently, influenced the relative humidity of the air, which remained high and regular on that day.

Figure 4

Mean relative humidity (%) of all collection sites

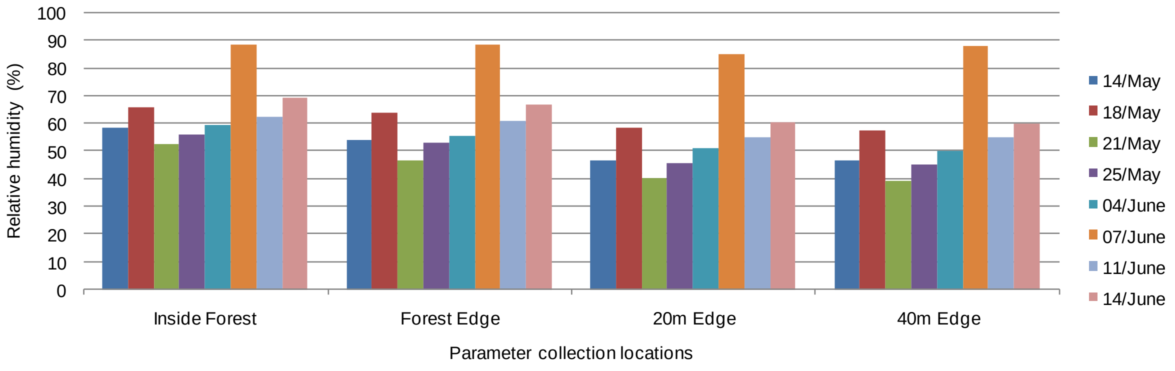


Source: Prepared by the authors (2018).

Figure 5 shows the average wind speed measured on each environment. It can be noted that there is almost no incidence of wind inside the forest. In addition, low wind speed was observed near the edge, while higher values were collected in the parking lot, especially on June 14th.

Figure 5

Average wind speed (m/s) for all collection sites



Source: Prepared by the authors (2018).

The factors that interfere with temperature are diverse, such as the presence or absence of vegetation, litter, precipitation, formation of water puddles, retention of water and/or humidity, shade from trees, direct incidence of solar radiation, waterproofing of the soil or on the contrary, its permeability among others (Dacanal, 2011; Monteiro & Pezzuto, 2017; Rosalem, Cabrera, Leite, Anache, & Wendland, 2016). Both the air and surface temperatures may vary in different degrees and intensities due to the aforementioned factors (OLIVEIRA *et al.*, 2015; ROSALEM, *et al.*, 2016).

The relative humidity of the air is mainly related to the evaporation of water, and the latter in turn is influenced by solar radiation. Other factors can interfere with atmospheric humidity, such as the presence or absence of vegetation, urbanization, water resources (rivers, lakes, etc.) among others (Dacanal, 2011). The presence of vegetation can intensify atmospheric humidity due to the evapotranspiration process of plants, in addition to protecting against direct sunlight and in the case of rivers (for example), they can favor humidity through the process of water evaporation (Jardim, 2011). The relative humidity of the air can influence in several aspects; one of them is the thermal amplitude, in which it is verified that the higher the air humidity, the lower the temperature variation, as well as low humidity allows greater thermal amplitudes of the air (Oliveira et al., 2015). That is, the relative humidity of the air affects the temperature of the air.

In the study in question, it was possible to observe this correlation between relative humidity and air temperature, since in general, atmospheric humidity and air temperature presented synchronized behaviors.

In view of the issues explained, a complementary analysis of the averages of each environment becomes appropriate, from which it is possible to point out that:

From the collection inside the forest, surface temperatures were generally lower than air temperatures, contrary to the other collection sites. The averages of relative humidity inside the forest were higher, mainly in relation to the averages of humidity in the parking lot.

The air and surface temperatures inside the forest were lower than in the other environments for several reasons, among them due to the higher density of litter on the ground, the evapotranspiration of the plants and the collection points being covered by the treetops.

The temperatures were not lower only, due to the presence of gaps and waterproofed stretches that influence the increase in temperature.

The clearings were also responsible for the incidence of winds inside the forest recorded on the 18th of May. Winds inside green areas should not be common since the vegetation forms a kind of green “wall” that protects the environment from winds and hot breaths (Dacanal, 2011; Monteiro & Pezzuto, 2017; Rosalem, et al., 2016).

At the edges of the forest, the average air and surface temperatures were higher than the temperatures inside the forest, this is due to the reduction of trees, but the influence of the shadows of the trees present on the edges made the temperatures not as high as expected, as the trees cause obstruction of direct sunlight on the ground.

In the case of collection on the side of the forest adjacent to the open area, the fact that there is a higher density of trees and grasses on the ground, and the fact that the latter is not waterproofed, had a positive influence on the parameters and, consequently, on the means. The parameters collected on the edge that is adjacent to the parking lot - pocket C, were harmed by the scenario with little shade and soil covered only by dead grass, justified precisely by the very close presence of concrete and asphalt of the parking lot, being this stretch of the edge of the forest the most degraded by edge effects.

Due to the great similarity between the averages at 20 and 40 meters away from the edge and because both are in the parking area, it was possible here to discuss these environments together. The averages of air and surface temperatures in the parking lot were higher than those of the forest and edges, mainly higher than the averages inside the forest, that is, higher temperatures in the parking lot; while the averages of atmospheric humidity were lower than inside the forest and on the edges. The averages of the parameters in the parking lot could have been more affected by the solar incidence if there were not the presence of several trees close to the collection points of the parameters that shaded during the day.

Regarding the occurrence of winds in the parking area, it was found that it was actually higher than in the other two environments.

Comparing the environments, it appears that there was mainly a great difference between the averages of the parameters collected inside the forest and those in the parking lot. In summary, the surface temperatures in the parking lot were high as expected, the thermal amplitudes of the air temperature were higher and the humidity was lower, contrary to what was observed inside the forest.

Through the analysis of the averages of each location, it was also possible to evidence pressures suffered by the fragment that are compromising its structure. But, above all, the discussions made so far have served to reaffirm the influence of vegetation on the microclimate.

Conclusions

By this work it is concluded that the predominant behaviors among the environmental parameters were:

- In the forest, soil temperatures are considerably lower than in other collection sites;
- Air temperatures inside the forest were also lower than in the other collection environments, but the amplitude of the air temperature was lower than the soil temperature;
- Inside the forest, soil temperatures were generally lower than the air temperatures, in contrast to the temperatures in the parking lot, in which the surface temperatures were considerably higher than the air temperatures;
- Air temperatures remaining consistent with the relative humidity of the air, as expected;
- Relative humidity higher inside the forest;
- Almost zero winds inside the forest, slightly increasing its incidence at the edges and high incidence in the parking lot.

It is then concluded that the presence of forest vegetation exerts a strong influence on the microclimate inside the forest, which is in fact more pleasant, confirmed by the values of lower air and soil temperatures inside the forest than temperatures in the area of the forest. parking, by the higher humidity values inside the forest and lower in the parking lot and also by the wind parameter, which is scarce inside the forest, which demonstrates once again the efficiency of the vegetation in protecting this microclimate from the hot air that comes from and is common in urban areas. These results confirm the relevance of forest fragments in the microclimate of urban areas and, therefore, the need to protect these areas.

On the data of the 7th of June, it was concluded that they were different due to the incisive precipitation that occurred on this date.

For future studies, it is suggested that a phytosociological survey be carried out in the forest fragment, verification of the sky view factor, study of the physical and chemical characteristics of the soil and the retrospective analysis of satellite images of the area for a deeper understanding of the characteristics of the forest and its fragmentation history, seeking information that makes possible actions in favor of the conservation of this forest fragment.

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