

## Influence of green areas on the microclimate of the contiguous urban perimeter

Influência das áreas verdes no microclima do perímetro urbano contíguo

Influencia de las áreas verdes en el microclima del perímetro urbano contiguo

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### **Abstract**

The daily pressures exerted by urban centers, added to the absence of green areas, end up promoting great damage to the quality of life of the resident population. This study aimed to evaluate the influence of a green park in the central area in Dourados, MS, Brazil, on thermal and sound comfort through environmental indicators. The following measurements were taken: air temperature, relative air humidity, light incidence, and noise variation at sampling points in the Arnulpho Fioravante green park and adjacent areas. The thermal discomfort index (TDI), which considers the variables air temperature and relative air humidity, was also adopted. TDI and noise results indicated that the park has little influence on adjacent areas. On the other hand, the park area with the highest plant density showed significant TDI values, classifying it between “feeling comfortable” and “feeling partially uncomfortable.” Areas of the city and the park without vegetation had many “feeling uncomfortable” ratings. Moreover, the vegetation may have acted as a filter to minimize urban noise. Our results indicate that urban green areas are important components in maintaining the population’s quality of life, provided they have good planning and management of available forest resources.

**Keywords:** Thermal discomfort index; Climate indicators; Urban parks; Noise pollution.

### **Resumo**

As pressões cotidianas exercidas pelos centros urbanos, somados à ausência de áreas verdes, acabam por promover grandes prejuízos à qualidade de vida da população residente. O objetivo do presente trabalho foi avaliar a influência de um parque verde no centro da cidade de Dourados (MS) no conforto térmico e sonoro através de indicadores ambientais. Para tal, foram mensurados: temperatura do ar (°C), umidade relativa do ar (%), incidência luminosa (lux) e variação de ruídos (db) em pontos amostrais no parque verde Arnulpho Fioravante e áreas adjacentes. Também foi adotado o índice de desconforto térmico (IDT), que leva em consideração as variáveis temperatura e umidade relativa do ar. Os resultados IDT e de ruídos indicaram que o parque exerce pouca influência sobre as áreas adjacentes. Por outro lado, a área de maior densidade vegetal (reserva florestal do parque) apresentou valores significativos de IDT, classificando-a entre “sentindo-se confortável” e “sentindo-se parcialmente desconfortável”. Por outro lado, as áreas da cidade e do parque sem vegetação apresentaram muitas classificações “sentindo-se desconfortável”. Também foi observado que a vegetação pode ter atuado como um filtro para minimização dos ruídos urbanos. Nossos resultados indicam que áreas verdes urbanas são importantes componentes na qualidade de vida da população, desde que tenha um bom planejamento e gestão dos recursos florestais disponíveis.

**Palavras-chave:** Índice de desconforto térmico; Indicadores climáticos; Parques urbanos; Poluição sonora.

## Resumen

Las presiones cotidianas que ejercen los centros urbanos, sumadas a la ausencia de áreas verdes, terminan propiciando grandes perjuicios en la calidad de vida de la población residente. El objetivo del presente trabajo fue evaluar la influencia de un parque verde en el centro de la ciudad de Dourados (MS) en el confort térmico y sonoro mediante indicadores ambientales. Para este, se tomaron las siguientes medidas: temperatura del aire (°C), humedad relativa (%), incidencia de luz (LUX) y variación de ruido (dB) en los puntos de muestreo del parque verde Arnulpho Fioravante y áreas adyacentes. También se adoptó el Índice de Malestar Térmico (IMT), que tiene en cuenta las variables temperatura y humedad relativa del aire. Los resultados de IMT y ruido indicaron que el parque tiene poca influencia en las áreas adyacentes. Por otro lado, el área con mayor densidad de vegetación (reserva forestal en el parque) mostró valores significativos de IMT, clasificándola entre "sentirse cómodo" y "sentirse parcialmente incómodo". Por otro lado, las áreas de la ciudad y los parques sin vegetación tuvieron muchas calificaciones de "sentirse incómodo". También se observó que la vegetación pudo haber actuado como filtro para minimizar el ruido urbano. Nuestros resultados indican que las áreas verdes urbanas son componentes importantes en la calidad de vida de la población, siempre que exista una buena planificación y manejo de los recursos forestales disponibles.

**Palabras clave:** Índice de malestar térmico, Indicadores climáticos, Parques urbanos, Contaminación acústica.

## 1. Introduction

The daily pressures exerted by urban centers, commonly resulting from losses in air quality, noise, and visual pollution, added to the absence of green areas, end up promoting great damage to the quality of life of the resident population. There is already a consensus among researchers that urban concentrations and their reflections in geographic space produce variations in local climates in relation to the regional macroclimate in which they are inserted (Aram et al., 2019; Buyadi et al., 2014; Colunga et al., 2015; Freitas et al., 2015; Martini et al., 2013; Neumann & Bruna, 2013; Obi, 2014; Oliveira-Filho et al., 2015; Paiva & Zanella, 2013; Alves & Lopes, 2017). Studies focused on climate variations in the urban perimeter have been commonly called urban microclimate (Paiva & Zanella, 2013).

This subject, inserted in the discussions on global warming, is already part of the agenda of the great environmental movements. In addition to directly compromising human health, climate change has pointed to consequent gradual losses in environmental quality. The influence of the human population on the climate on a global scale is still the subject of much discussion among numerous scientists and, therefore, what seems to be unanimous is the fact that humans can change the climate on a local scale (Nobrega & Lemos, 2011). However, urban microclimate still needs to reach other spheres that go beyond scientific research.

Elements such as geographic location, topography, vegetation, and soil surface characterize the local climate factors, which interfere with and originate the various microclimates found in urban centers (Shams et al., 2009; Ignatius et al., 2015). In recent decades, investigations related to urban microclimate have been disseminated with higher intensity, becoming allies of urban planning, as they contribute to the development of effective actions that aim to improve thermal comfort, resulting in a better quality of life for everyday people (Alves, 2016).

The local microclimate change is associated with the effects of energy transformation in the urban area as a function of its structure, causing a reduction in the evaporative and convective cooling rates due to soil sealing, the reduction of the surface covered by vegetation, and the reduction of wind speed due to an increase in surface roughness (Castro, 1999; Assis, 2005; Nunes, 2016). Gomes e Soares (2004) propose other factors of microclimate changes, such as traffic, excessive population concentration, disorderly constructions, and various types of pollution in all its dimensions.

Thus, urban centers have been undergoing intense socio-spatial transformations (Surya, 2020), standing out, among them, the environmental degradation process due to the pollution of their water resources, the increase in atmospheric pollution, and the extermination of their green areas (Gomes & Soares, 2004).

Air pollution has been a serious problem in industrialized urban centers since the first half of the 20th century, in addition to other polluting sources, such as the considerable increase in automobiles (Braga et al., 2001), and other environmental challenges of local origin, such as waste management, recycling, and light and noise generation (Martínez-Bravo & Martínez-

del-Río, 2019). The coexistence of living beings, especially humans, with air pollution has brought serious consequences for health. However, what can be done to mitigate these impacts?

The constant neglect of green areas in urban space is an aggravating factor for the population's quality of life. In addition to the impoverishment of the urban landscape, the problems that can occur due to the interdependence of the multiple subsystems that coexist in a city are numerous and of different magnitudes (Loboda & Angelis, 2005). The vegetation arrangement can increase the ability to reduce air temperature and attenuate incident radiation, thus intensifying the sensations of thermal comfort (Labaki et al., 2011). Thermal comfort, however, is understood as a concept that necessarily implies the definition of indices in which the human being feels comfortable as a result of pleasant thermal conditions for the body (Gomes & Amorim, 2003; Frota & Schiffer, 2001; Nobrega & Lemos, 2011).

In addition to thermal discomfort, another product resulting from human changes and population growth in urban centers is the produced noise levels, also known as noise pollution. Strieder (2014) considers that the difference between noise and sounds considered pleasant and/or bearable are purely subjective actions of classification of each individual. Thus, the popular classification of noise may simply be an unwanted sound.

National and international legislations have established noise limits for several activities to guarantee the safety and comfort of the community with the objective of trying to reduce the problems generated by excessive noise levels (Nagem, 2004). ABNT (2000a) and ABNT (2000b) have a series of recommendations establishing the noise levels considered adequate for each type of urban area and activity. The purpose of these standards is to guide the appropriate variations to reach the level of hearing comfort considering the characteristics of each urban area.

The vegetation in urban environments directly contributes to better conditions of acoustic comfort, as one of its main functions is noise attenuation (Nucci & Cavalheiro, 1999; Martínez-Bravo & Martínez-del-Río, 2019). In addition to improving conditions of temperature and relative humidity, vegetation also contributes to mitigating the high noise levels produced by automobiles, industries, and the movement of people (Neto, 2002).

Vegetation, among other alternatives, has been identified as a fundamental element for minimizing the effects of climate change caused by urbanization (Labaki et al., 2011). The presence of green areas and street afforestation in urban centers is intended to alleviate the microclimate, improve people's physical and mental health, serve as a leisure area, reduce noise levels, and disperse atmospheric pollution (Haq, 2011). Furthermore, according to Elmqvist et al. (2015), investment in green spaces in the urban landscape area may lead to several monetary and non-monetary benefits to society and community comfort, contributing to the maintenance of biodiversity and the development of more resilient urban areas and environmental sustainability, with the monetization of ecosystem services, for example.

There is a set of technical standards that can help researchers and public agents in controlling these impacts. The technical standards NBR 10151 (ABNT, 2000a) and 10152 (ABNT, 2000b) have a series of recommendations establishing the noise levels considered adequate for each type of urban area and activity. The purpose of these standards is to guide the appropriate variations to reach the level of hearing comfort considering the characteristics of each urban area. The technical standard that directly deals with thermal comfort is 15220 (ABNT, 2003) and presents a simplified method for evaluating the thermal performance of building components. However, this technical standard does not apply to outdoor environments with a focus on urban microclimate. Other texts seek to offer instruments for the evaluation of urban microclimate even without having the status of a technical standard.

Several authors such as Labaki et al. (2011), Alves (2016), Freitas et al. (2015), Franco et al. (2013), Gomes and Amorim (2013), Martini et al. (2013), and Neto et al. (2007) have argued that the vegetation of urban green areas directly interferes with temperature and relative humidity values in urban centers. However, does this effect of green areas on contiguous urban areas actually occur? Thus, this study aimed to evaluate the influence of the Arnulpho Fioravante park in the central area of Dourados,

MS, Brazil, on thermal and sound comfort through climate and sound indicators.

## 2. Methodology

This study is an exploratory field research with quantitative sampling. Climatic parameters were measured monthly from August 2017 to January 2018. The literature review was of the narrative type because it is a comprehensive topic, with arbitrary selection of articles and unspecified search criteria, considering the researcher's personal critical analysis.

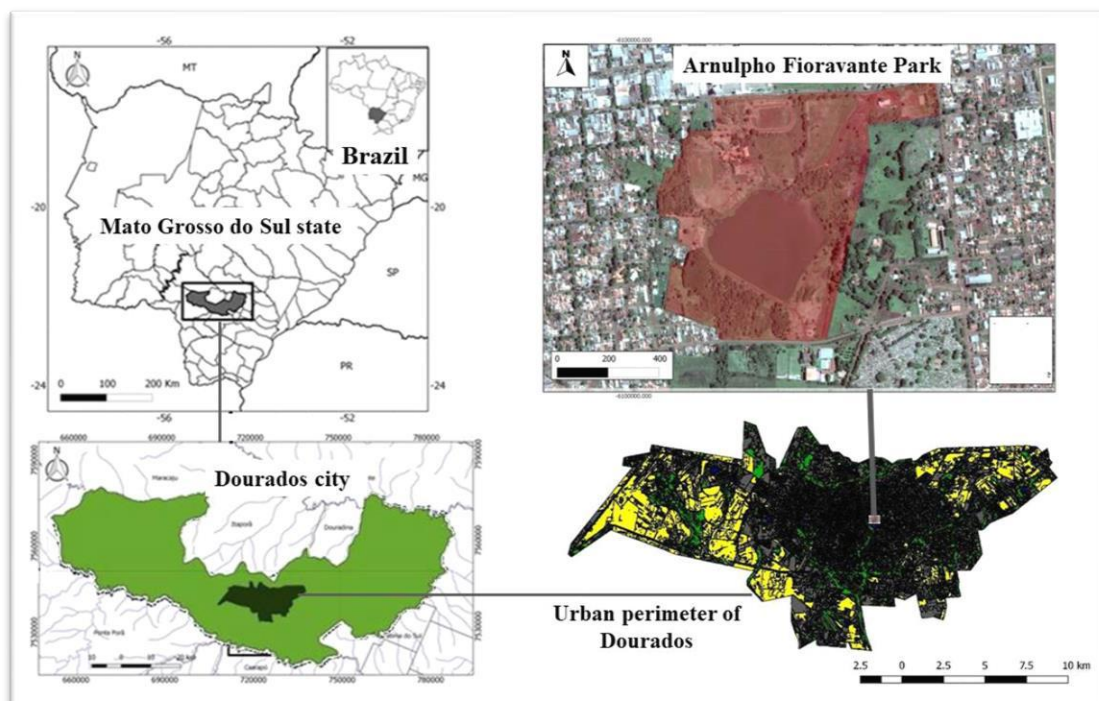
### 2.1 Study area

The research was carried out in the Arnulpho Fioravante Municipal Park (Figure 1) and contiguous areas (Presidente Kenedy Avenue, Marcelino Pires Avenue, Weimar Gonçalves Torres Avenue, and Major Capilé Street). The park is located in the central east region of the municipality of Dourados, in the Vila Maxwell neighborhood, state of Mato Grosso do Sul, Midwest Region of Brazil.

This municipality was founded on December 20, 1935, and had an estimated population of 225,495 inhabitants in 2020. The occupation of the municipality occurred with the opening of highways, which accelerated its development and Dourados became an important agricultural and service center, with the second-largest economy in the State.

The Arnulpho Fioravante municipal park has gained visibility in the city of Dourados, as it is located in the vicinity of the local mall, commercial points, hotels, and bus station. The park has an area of 58 ha, is located in the central region of the city of Dourados, and has an artificial lake, where the springs of the Paragem stream are located. The park area also has the Environmental Institute of Dourados (IMAM), the headquarters of the Municipal Guard (GM), and the headquarters of Environmental Military Police.

**Figure 1.** Location of the Arnulpho Fioravante Park in the city of Dourados, MS, Brazil.



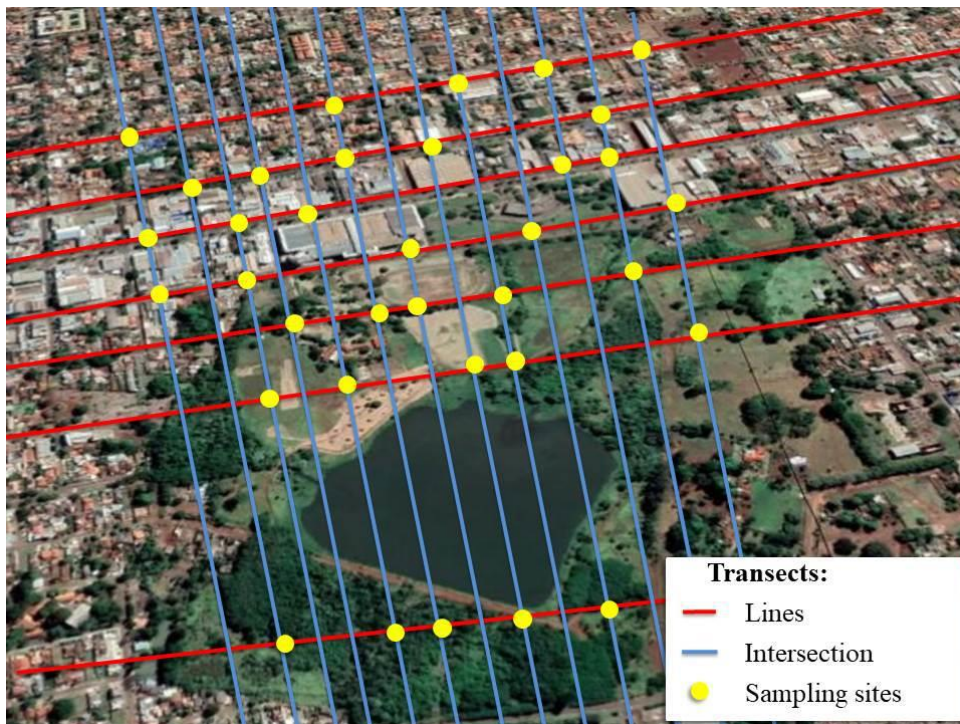
Source: The authors.



## 2.2 Data collection and sampling

Climate and environmental parameters of air temperature ( $^{\circ}\text{C}$ ), relative air humidity (%), light incidence (LUX), and noise variation (dB) were collected monthly for six months from August 2017 to January 2018, with five replicates to each transect line. The sampling design was based on linear transects with projected perpendicular distances. In total, seven lines were selected, being line one (L1) in the area of direct influence of the Arnulpho Fioravante Park, lines two and three (L2 and L3) in the interface area, and lines four to seven (L4, L5, L6, and L7) in avenues with a large flow of pedestrians and vehicles in the city of Dourados (Figure 2). The sampling of temperature, relative air humidity, and light incidence data was always carried out between 12:00 and 13:00 h (time of highest light incidence), while the noise data sampling was carried out between 17:00 and 18:00 h (time of highest vehicle and pedestrian flow). Samplings were carried out in periods of clear sky and without rain to facilitate data collection. In addition, the equipment was not waterproof in case of rain.

**Figure 2.** Design based on linear transect with projected perpendicular distances between sampling sites in Parque Arnulpho Fioravantes and adjacent areas.



Source: The authors

## 2.3 Survey of climate data

The research was based on qualitative and quantitative surveys of environmental data sampled in the field. The variation in air temperature ( $^{\circ}\text{C}$ ), relative air humidity (%), light incidence (LUX), and noise (dB) was analyzed in an area of influence between the Arnulpho Fioravante Park and adjacent areas. This area of influence presents a radius of approximately 1.5 km, from the point with the highest forest density in the park to Major Capilé Street. Climate data were collected using portable devices, that is, a digital thermo-hygrometer, a digital lux meter, and a digital decibel meter. A satellite navigation system (navigation GPS) was used to elaborate maps and sample scales, and the data were organized in the geographic information system (GIS) Qgis v. 1.8.

After data collection, the temperature and relative humidity values were used to measure the thermal discomfort index

(TDI) through the equation developed by Thom (1959) and cited by Santos (2011):

$$\text{TDI} = T - (0.55 - 0.0055 \text{ RH}) \times (T - 14.5)$$

where T is the air temperature (°C) and RH is the relative air humidity (%).

## 2.4 Data analysis

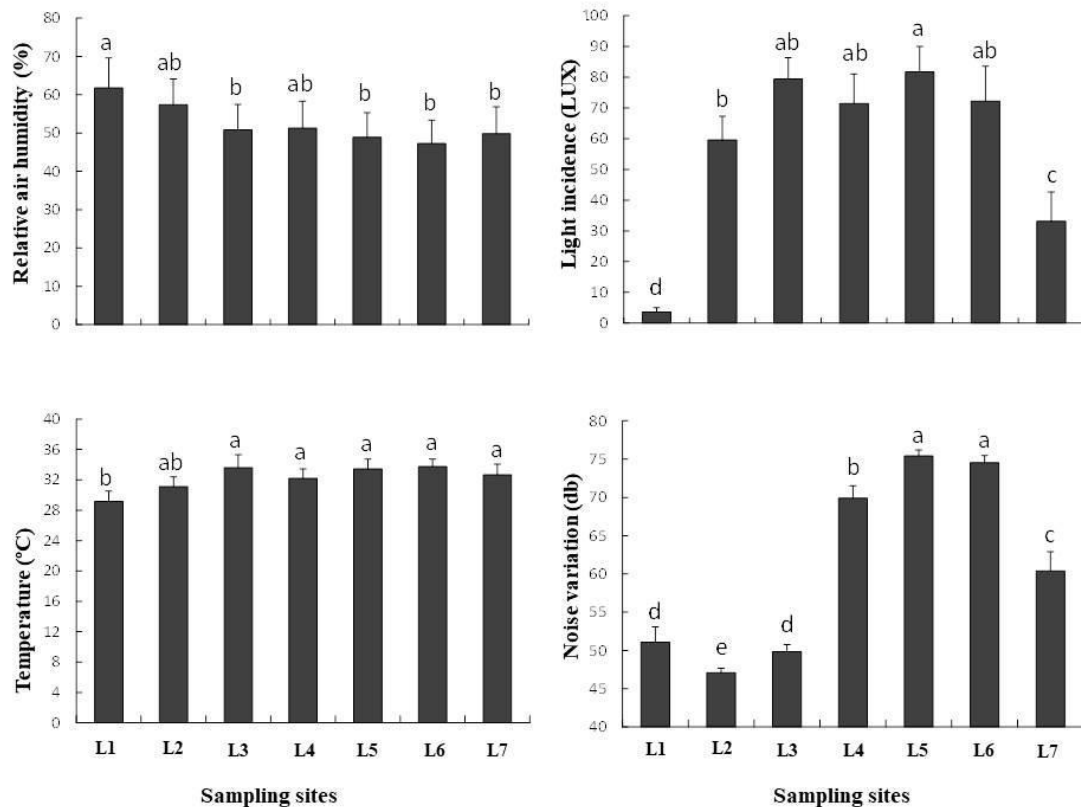
The data were treated through descriptive and statistical analysis. In the descriptive analysis, the climate and environmental data were organized in tables and graphs to demonstrate possible trends in the means, standard deviation, and standard error of each sample block. An analysis of variance was applied to corroborate the descriptive analysis, followed by the post hoc test (Tukey's test) to point out significant statistical differences between the respective sampling points in the collected climate and environmental data.

## 3. Results and Discussion

All environmental variables measured for the Arnulpho Fioravante Environmental Park and contiguous areas showed a statistically significant difference for the means of the six months sampled by the analysis of variance: relative air humidity ( $F_{6,203} = 3.92$ ;  $p < 0.05$ ); relative light incidence ( $F_{6,203} = 31.06$ ;  $p < 0.05$ ); ambient temperature ( $F_{6,203} = 9.74$ ;  $p < 0.05$ ); and environmental noise ( $F_{6,203} = 195.79$ ;  $p < 0.05$ ). Figure 3 shows the slicing of these statistical differences for each variable.

The values of relative air humidity, light incidence, and ambient temperature presented significant statistical differences for sampling line 1 (Figure 3). This site has as its main characteristic the highest vegetation cover. This vegetation cover was responsible for the lowest values of light incidence and temperature and the highest values of relative air humidity. Ambient noise values showed divergent values between line 1 and lines 5 and 6 (Figure 3). Lines 5 and 6 are characterized as the sites with the highest flow of people and traffic, a factor that indicated the high noise values.

**Figure 3.** Environmental parameters measured (annual mean  $\pm$  standard deviation) in seven sample lines designed in the Arnulpho Fioravante Park and adjacent areas; equal letters above the columns do not differ statistically by Tukey’s test at a 5% probability ( $p > 0.05$ ).



Source: The authors

Labaki et al. (2011) analyzed the influence of vegetation on temperature, relative air humidity, light incidence, and shading quality in wooded areas. According to the authors, tree groupings exert more influence on a larger shading scale, which may increase the ability to reduce air temperature and attenuate incident radiation, as well as intensify the sensations of thermal comfort compared to isolated tree individuals.

These microclimate characteristics were also observed in the park, as points 2 and 3 of the park presented high values of temperature and light incidence and low values of relative air humidity. In addition to a low plant density at these points, the individuals are isolated. However, tree arrangement is as important in the planning of green areas as species and density.

The effect of shading by tree vegetation produces a reduction in air temperature during the day. In this sense, shading is one of the fundamental elements for a favorable thermal comfort index (Ayres, 2004).

Noises were also important variables used to assess the representativeness of the park for the urban perimeter. According to the Brazilian standard on “Criteria for evaluating external environments” (ABNT, 2000a), mandatory conditions are set for the evaluation of the acceptability of noise in communities, guaranteeing human health. The study area fits into two of the existing categories in the standard: a mixed area, with commercial and administrative aptness (<60 dB in the daytime and <55 dB in the nighttime) and a mixed area, with recreational aptness (<65 dB in the daytime and <55 dB at night).

The category “mixed area, with recreational aptness,” in which points P1, P2, and P3 fit, shows that all the points sampled in the domain areas of the park were within the established limits. However, all points in the category “mixed area, with commercial and administrative aptness,” located in areas of avenues (P4, P5, P6, and P7) were above the limits recommended

by the technical standard.

The noise values found in P1 were higher than the other points located inside the park. Noise analysis does not distinguish types of sounds and, for this reason, the vocalization of birds and other animals and the wind on tree leaves could have favored higher values in the area of direct influence (P1) than the values found in the contiguous area (P2 to P7). According to the World Health Organization (OMS), physically there is no distinction between sound and noise; the sound is a sensory perception evoked by physiological processes in the auditory brain; thus, it is not possible to define noise exclusively based on the physical parameters of sound (OMS, 1999).

Sound disturbance, in addition to being a problem of acoustic discomfort, causes difficulties in concentration, irritation, tiredness, nervousness, sleep disorders, hearing problems, headaches, and other factors that degrade the quality of life. What should always be considered are the rights of citizens, such as living with dignity, having the quality of life and physical and mental health (Meneghetti, 2006). And how to mitigate the impacts of noise pollution in the face of the everyday chaos of large centers?

Sound propagation loses its properties when it is absorbed by the atmospheric air or acoustic barriers (Strieder, 2014). These barriers can present different types and shapes, such as vegetation, shrubs, wood, transparent synthetic materials, metallic materials, among others (Neto, 2002).

Several authors, such as Nucci and Cavalheiro (1999), Andrade (2005), and Maia (2010) have considered urban vegetation one of the most efficient barriers in reducing noise pollution. Vegetation provides dampening of continuous and discontinuous background noises of a strident nature, which occur in large cities (Loboda & Angelis, 2005).

Opinion interviews with the population showed that the existence of urban parks and their use lead to numerous benefits to human health, such as the attenuation of urban noise (Martins & Araújo, 2014). The Arnulpho Fioravante park promotes the function of an acoustic barrier even not receiving proper maintenance from the responsible agencies.

Another analysis of great relevance in the urban microclimate is the thermal discomfort index (TDI), which considers the variables temperature and relative air humidity. TDI showed statistically significant differences for the interaction between sampling points and months (ANOVA  $F_{30,168} = 8.6$ ;  $p < 0.05$ ). Table 1 shows the slicing of the interaction between sampling points and months.

Only one sample among the TDI values presented the comfort level “Feeling comfortable,” which occurred in October at point P1. All other points showed the comfort level “Feeling partially comfortable” in October. The other months presented mainly the level “Feeling very uncomfortable.” The level “Feeling very uncomfortable” was the most recurrent, both in the months and between the points. Only the area with forest (point 1) did not register levels of thermal discomfort.



**Table 1.** Slicing of the interaction between the means (standard deviation) of the thermal discomfort index (TDI) for the sampling points and months of the Arnulpho Fioravante Environmental Park and contiguous areas.

Month/year	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
<b>Aug./17</b>	26.7Ab 0.40 <sup>+</sup>	27.7BCa 0.86 <sup>+</sup>	28.4Ba 0.43 <sup>++</sup>	28.1Aa 0.35 <sup>++</sup>	28.7Aa 0.55 <sup>++</sup>	28.4Ba 0.23 <sup>++</sup>	28.1Ba 0.46 <sup>++</sup>
<b>Sept./17</b>	26.9Aab1. 84 <sup>+</sup>	26.5Cb 0.29 <sup>+</sup>	28.2Ba 0.47 <sup>++</sup>	26.6Bb 0.45 <sup>+</sup>	26.8Bab 0.23 <sup>+</sup>	26.6Cb 0.08 <sup>+</sup>	26.8Cab 0.38 <sup>+</sup>
<b>Oct./17</b>	23.5Bb 0.24 <sup>*</sup>	24.5Db 0.95 <sup>**</sup>	24.7Cab 0.58 <sup>**</sup>	24.7Cab0. 93 <sup>**</sup>	25.0Ca 0.28 <sup>**</sup>	25.8Da 0.63 <sup>**</sup>	24.6Db 0.35 <sup>**</sup>
<b>Nov./17</b>	25.9Ad 0.19 <sup>**</sup>	29.2ABb 1.43 <sup>++</sup>	30.9Aa 0.29 <sup>++</sup>	28.3Abc 0.36 <sup>++</sup>	29.1Ab 0.54 <sup>++</sup>	28.9Bbc0. 41 <sup>++</sup>	27.7Bc 0.20 <sup>+</sup>
<b>Dec./17</b>	26.0Ad 0.18 <sup>**</sup>	26.2CDd 0.10 <sup>+</sup>	27.2Bc 0.27 <sup>+</sup>	28.1Ab 0.18 <sup>++</sup>	29.2Aa 0.12 <sup>++</sup>	29.5Aa 0.31 <sup>++</sup>	29.9Aa 0.12 <sup>++</sup>
<b>Jan./18</b>	25.9Ac 2.07 <sup>**</sup>	28.3ABab1. 15 <sup>++</sup>	30.1Aa 0.49 <sup>++</sup>	28.1Aab0 .78 <sup>++</sup>	29.3Aab0. 60 <sup>++</sup>	29.4Aab0. 30 <sup>++</sup>	28.0Bb 0.32 <sup>+</sup>

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ statistically from each other by Tukey's test at a 5% probability. Thom (1959) discomfort index classification (TDI), adapted by Santos (2011), presented after standard deviations, where: \*Feeling comfortable (TDI < 24.0); \*\*Feeling partially comfortable (24.1 < TDI < 26.0); +Feeling partially uncomfortable (26.1 < TDI < 28.0); ++Feeling very uncomfortable (TDI > 28.0).

Source: The authors

Loboda and Angelis (2005) consider the so-called "soil-climate-vegetation balance" as one of the functions of green areas, in which vegetation is responsible for filtering solar radiation, softening extreme temperatures and contributing to conserving soil moisture, also attenuating the temperature. Labaki et al. (2011) also observed that the arrangement of tree elements increases the ability to reduce air temperature and intensifies the sensations of thermal comfort.

The TDI values found at the points inside and outside the park showed that the park did not influence the contiguous areas since several indices of "feeling very uncomfortable" were found inside the park at points p2 and p3.

#### 4. Conclusion

The climatic and noise variables analyzed in the park indicated desirable values for human thermal and sound comfort: low temperature values, relative incidence of light and noise, and high relative humidity. In the avenues adjacent to the park, values that indicated thermal and noise discomfort were recorded.

The results of this study indicated that the values of thermal discomfort index (TDI) and noise inside the park had little influence on adjacent areas.

Both in the park and in the contiguous areas of the city, it was observed that the presence of afforestation created a microclimate favorable to human comfort.

The points that indicated thermal and noise discomfort need a plan for afforestation and reforestation to promote better attenuation of these variables and provide adequate thermal and sound comfort for society.

However, further studies are needed to evaluate the effect of these microclimates provided by the vegetation of the urban perimeter and their effect on the thermal and sound comfort of the population.

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