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# URBAN MICROCLIMATE AND COMFORT INDICES IN VEGETATED AND NON-VEGETATED AREAS IN WET AND DRY PERIODS

# MICROCLIMA URBANO E ÍNDICES DE CONFORTO EM ÁREA VEGETADA E NÃO VEGETADA NO PERÍODO ÚMIDO E SECO

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**ABSTRACT**
Cuiabá city is nationally known as "green city" because of to its large afforestation, has experienced progressive urban expansion for years, with deforestation possibly causing a rise in temperature and the development of heat islands In this context the afforestation can be an alternative for the improvement of the thermal comfort of the residents of this city. So the study objective was to analyze the microclimate differences of vegetated and non-vegetated urban areas in rainy and sunny conditions, analyzing also the heat index and the thermal discomfort index. The sampling took place at a public place and great flow of pedestrians. Data on the air temperature (Tair), sidewalk surface temperature (Ts), and relative air humidity (Rh) were recorded using two linear transects, starting at 7 am and ending at 7 pm, in two-hour intervals. Due to the seasonality of the city's climate, measurements were taken in the dry and humid period of the year. There was a statistical difference for sidewalk surface temperature between the sites (p-value < 0.001) and an increase of approximately 10°C in both periods in non-vegetated areas. There was no statistically significant difference for the heat index and thermal discomfort index among the analyzed transects, especially in the wet season, periods of discomfort occurred. Was verified that for open sites vegetation decreased air and surface temperature, increased relative humidity, but it was not enough to have thermal comfort at all times of the day, concluding that the presence of vegetation was not enough to cause a difference in the index of each transect.

**Keywords:** Air temperature; surface temperature; relative humidity; heat index; thermal discomfort index.

**RESUMO**
O município de Cuiabá é conhecido nacionalmente como "cidade verde" devido à sua grande arborização e tem experimentado uma expansão urbana progressiva por anos, ocorrendo um desflorestamento que possivelmente esteja causando um aumento de temperatura e o desenvolvimento de ilhas de calor. Nesse contexto, a arborização pode ser uma alternativa para a melhoria do conforto térmico dos moradores da cidade. Assim, o objetivo do estudo foi analisar as diferenças do microclima de áreas urbanas com e sem vegetação em condições chuvosas e ensolaradas, analisando também o índice de calor e o índice de desconforto térmico. A amostragem ocorreu em local público com grande fluxo de pedestres. Dados sobre a temperatura do ar (Tair), temperatura da superfície da calçada (Ts) e umidade relativa do ar (Rh) foram registrados por meio de dois transectos lineares, iniciando às 7 horas e terminando às 19 horas, em intervalos de duas horas, sendo realizadas no período seco e úmido do ano. Houve diferença estatística para temperatura de superfície da calçada entre os locais (p-valor <0,001) e um aumento de aproximadamente 10°C em ambos os períodos em áreas não vegetadas. Não houve diferença estatisticamente significante para o índice de calor e índice de desconforto térmico entre os transectos analisados, especialmente na estação chuvosa, período de desconforto ocorrido. Verificou-se que para locais abertos a vegetação diminuiu a temperatura do ar e do solo, aumentou a umidade relativa, mas não foi suficiente para ter conforto térmico em todos os momentos do dia, concluindo que a presença de vegetação não foi suficiente para causar diferença nos índices de cada transecto.

**Palavras chave:** Temperatura do ar; temperatura do solo; umidade relativa do ar; índice de calor; índice de desconforto térmico.

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## 1. INTRODUCTION

Population displacement from rural areas and small municipalities to larger cities in the last decades in Brazil has resulted in disordered urban growth and chronic infrastructure deficiency in Brazilian cities and metropolitan areas, as they have grown in inverse proportion to their administrative capacity to plan (MENDONÇA; MONTEIRO, 2003).

Population growth, as well as the recovery of cultivated areas, besides acting as a transforming agent of the natural landscape and its replacement by an environment, becomes the unique climate of these areas, understood as an urban climate (MENDONÇA, 1994). Labaki et al. (2013) and Armani et al. (2015) state that the population growth of cities continuously transforms the natural and built environment, contributing to significant changes in the microclimate, which are related to the high heat storage potential of built-up areas.. The more artificial areas exist, such as the central region of cities, the greater are the changes in the local climate (GOMES; AMORIM, 2003).

Factors such as the typology of buildings, land use and the lack of adequate vegetation lead to increased temperatures in urbanized areas and the development of heat islands (PENG et al., 2011).

For Leal (2012) urban planning, street afforestation and the creation of parks are efficient measures to promote improvements in the urban microclimate. In addition, in a tropical country like Brazil, urban afforestation is able to reduce excessive heat due to its low thermal conductivity and due to the interception of direct radiation (STRINGHETA, 2005; LEAL, 2012). Moreover, urban forestry areas create a more pleasant microclimate due to the shading and increase of the relative humidity of the air based on evapotranspiration, providing thermal comfort and quality of life in cities and therefore the health of the population (MÜLLER, 1998).

In general, the sensation of thermal comfort associated with the presence of afforestation is mainly related to the density of the canopy of each tree. Leaves absorb from 15% to 35% of the light energy received, pass between 30% to 50%, and reflect the rest of the light energy, that is, ≅ 30% to 40%, during the daytime period (RODRÍGUEZ-AVIAL LLARDENT, 1982). However, Holbrook (2010) reported that, in addition to the decreasing temperature, the plants contribute to the maintenance of the relative humidity because their leaves evaporate large volumes of water (≅ 97% of the amount of water absorbed by the roots) by perspiration.

Thus, the thermal comfort in cities is in fact related to climatic elements and urban arrangements. The exposure to climatic factors generates health concerns of the population with respect to the performance of their daily activities. It therefore is essential to consider these factors in the public domain (sidewalks) in the urban environment to provide improved thermal conditions for pedestrian circulation and promote the quality of life of the population.

The municipality of Cuiabá, formerly known as the "green city" because of to its large afforestation, has been in the process of urban expansion for years. The withdrawal of parts of the vegetation gave way to the city. According to research carried out by Santos (2012), urban density and the suppression of vegetation were decisive factors for altering the city's thermo-hygrometric behavior. Ribeiro et al., (2015) states that because of the few urban forestry areas in the city, the direct incidence of solar radiation on the ground increases the temperature and the city is becoming one of the hottest capitals of the country, providing possible thermal discomfort to its inhabitants

In this context, this study aimed to verify variations of urban microclimate in vegetated and non-vegetated areas, in wet and dry conditions for the Cuiabá city, Brazil.

## 2. MATERIALS AND METHODS

Cuiabá is the capital of the Mato Grosso state, which is in the central–south portion of the State in the Central–West region of Brazil. According to the Köppen's classification, the climate is of type Aw and the daily maximum temperatures oscillate between 30°C and 36°C, (BRASIL, 2010). A population density of 163.88 in habitants per km² has been reported (BRASIL, 2010). The municipal area is 3,224.68 km² in size; it is divided in 2,970.11 km² (92.1%) of rural area and 254.57 km² (7.89%) of urban area (JOAQUIM et al., 2018). The study area is located in the northern region of the municipality at 15°34'12.80"S and 56°04'27.14"W.Gr. It comprises the Administrative Political Center (CPA), constituted by a complex of public buildings of the State Government of Mato Grosso.

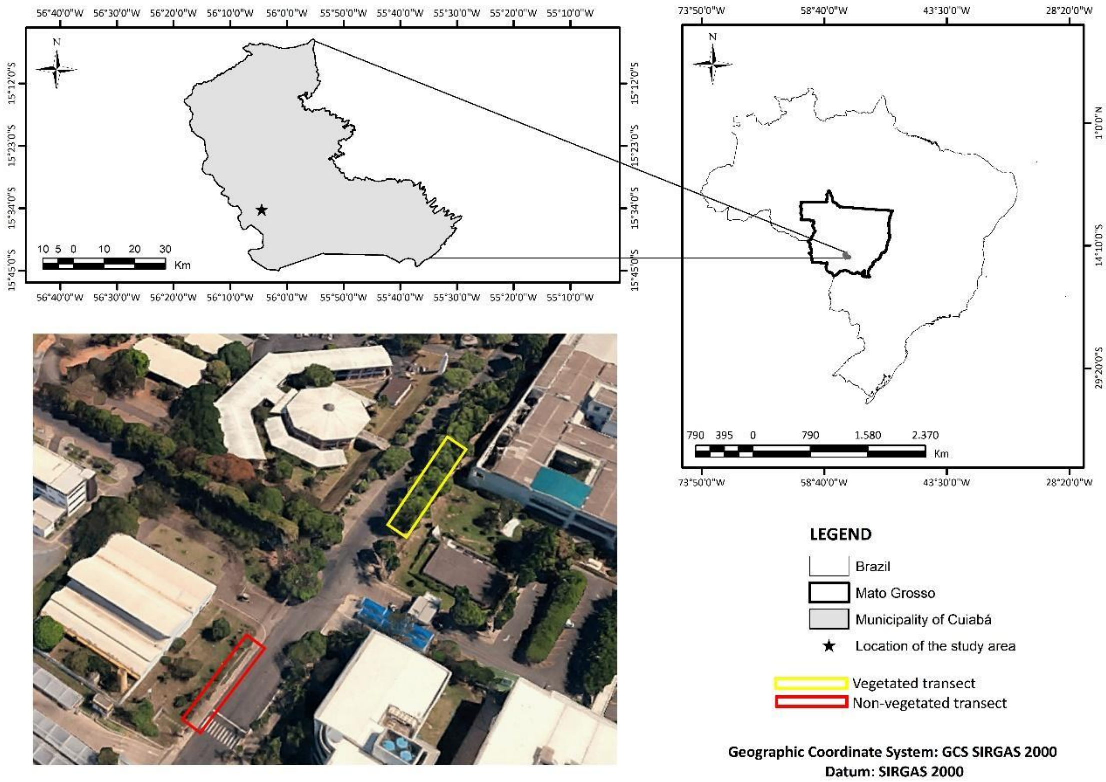


**Figure 1** - Location of the study area in the municipality of Cuiabá, Mato Grosso, Brazil. Source: Google Earth, 2017 (adapted by the authors).

Preestablished criteria were considered in the choice of the study area. The area should be public and have easy access, a great flow of pedestrians, and include urban forestry and non-urban forestry areas.

Measurements of climatological data were carried out during the day in two seasons, that is, the wet season (January 2016) and dry season (June 2016). On each day, the air temperature (Tair), sidewalk surface temperature (Ts), and relative humidity (Rh) were recorded in two-hour intervals, starting at 7 am and ending at 7 pm, totaling 21 collections per variable and per period. Two meteorological conditions were considered in the collections, clean sky in the dry period and cloudy and wet weather in the wet period to verify the microclimatic conditions of two extremes, dry and wet conditions. The data were collected on two linear transects (three points each) with approximately three meters between them. The first transect includes trees and the second one is not influenced by arborization. Note that a street with particular characteristics, such as the arrangement of the trees, crown, and shade, was chosen for the tree-lined transect to allow the measurements. Regarding the non-urban forestry transect, care was taken with respect to the attenuation of incident solar radiation, mainly ensuring that the sampling points were in places without shading of buildings.

Tair and Rh data were measured with a Kestrel 4500 Pocket Weather Tracker, made by the company NK in the Boothwyn region (Pennsylvania, Delaware County, USA), with an accuracy of ± 1 °C, and a range of measurements between 29 °C and 70 °C for air temperature, and from 5% to 95% for relative humidity, with an accuracy of ± 3%. The equipment was positioned 130 cm high in relation to the surface. For the TS data, a portable digital surface thermometer with a digital laser sight was used, produced by the company Instrutherm in São Paulo, SP, model TI-870, accuracy of ± 2 °C and range of measurement between - 50 °C to 550 °C. This measurement was made at 50 cm from the sidewalk surface.

For the thermal comfort analysis, the heat index (HI) and the thermal discomfort index were calculated. The heat index was proposed by Steadman (1979a), according to equation 1 below.

Equation 1

HI = - 42,379 + 2,049015230* Tair +10,14333127 * Rh - 0,22475541 * Tair *Rh - 6,83783 * 10-3 * (Tair)2 -5,481717 * 10-2 * (Rh)2 + 1,22874 * 10-3 * (Tair)2 * Rh +8,5282 * 10-4 * Tai * (Rh)2 -1,99 * 10-6 * (Tair)2 * (Rh)2

HI is the heat index (° F); Tair is the actual air temperature (dry bulb temperature) (° F); Rh is relative humidity (%).

The results were analyzed according com os níveis de alerta para faixas do IC e possíveis problemas na saúde decorrente da exposição humana, expressos na table 1.

| Alert level | Heat index (HI) | | Symptoms |
|---|---|---|---|
| | °F | °C | |
| **No warning** | < 80 | **< 27** | No problem. |
| **Caution** | 80 - 90 | **27 - 32** | Possible fatigue in cases of prolonged exposure and physical activity. |
| **Extreme caution** | 90 - 105 | **32 - 41** | Possible cramps, sunstroke, and exhaustion due to prolonged exposure and physical activity. |
| **Danger** | 105 - 130 | **41 - 54** | Cramps, sunstroke, and likely exhaustion. Possible brain damage due to prolonged exposure to physical activity. |
| **Extreme danger** | > 130 | **> 54** | Stroke or action and risk of imminent cerebral vascular accident. |

**Table 1**- Alert level and description of possible physiological consequences to the human body according to the heat index (HI). Fonte: Adaptado do National Weather Service Eather Forecast Office, NOAA.

The heat index was elaborated from subjective measures of how much heat it feels for given values of temperature and relative humidity of the air, in situations where the temperatures are high, being the person in the shade in light wind conditions (Steadman, 1979b). The heat index has been applied in several regions of Brazil, such as Nóbrega and Verçosa (2011) who applied it in Recife, state of Pernambuco, Silva and Streck (2014), Santa Maria in the state of Rio Grande do Sul, and França (2014) in Sorriso, Mato Grosso State.

The thermal discomfort index (TDI) was characterized by the bioclimatic index of thermal discomfort proposed by Thom (1959), adapted for tropical regions by Santos (2011), which is used for urban climate studies (equation 2).

Equation 2

$$TDI = Tair - (0.55-0.0055 * Rh) * (T-14.5)$$

TDI is the index of discomfort (°C); Tair is the air temperature (°C); Rh is the relative humidity (%). The results obtained were compared to the classification of Santos (2011) described in Table 2.

| Thermal discomfort level | TDI (°C) |
|---|---|
| Comfortable | < 24 |
| Partially comfortable | 24 - 26 |
| Uncomfortable | 26 - 28 |
| Very uncomfortable | ≥ 28 |

**Table 2** - Thermal discomfort index (TDI) classification for tropical regions.

The records of the climatic data in the urban forestry and non-urban vegetated areas were tabulated in electronic spreadsheets and directly synthesized to obtain the hourly and daily averages for each sampling point. The graphics were created using Sigma Plot Software (SPSS, version 11.0). The decision on the applicability of parametric or nonparametric statistical techniques was based on the results of the normality analysis by the Shapiro–Wilk test, resulting in non-parametricity of the data. Nonparametric statistical analysis was then performed using the Mann–Whitney U test to verify the statistical difference between the measurements at a significance level of 5%.

## 3. RESULTS AND DISCUSSION

The measurements on the transects made it possible to compare the behavior of urban forestry areas with that of non-urban forestry areas depending on the times of day and seasons in which this study was carried out.

The the air temperature (Tair), surface temperature (Ts), and relative air humidity (Rh) data were statistically analyzed. The Mann–Whitney test was carried out for the air temperature and relative humidity; in both cases, no statistical difference between the samples was determined, with p-values of 0.629 and 0.067, respectively. The presence of vegetation potentially disrupts the energy exchange by advection, causing the maintenance of the air temperature and relative humidity without significant differences, even in shaded and unshaded areas and in the wet period.

However, the surface temperature data show a statistical difference between the sites, with a p-value $< 0.001$. Because of the attenuation of the global radiation generated by arborization, less radiation reaches the surface, generating the above-mentioned statistical difference and observed amplitudes.

Table 3 shows the results of the analysis of the dataset, emphasizing the minimum, maximum, mean, and standard deviation of the air temperature, soil temperature, and relative humidity of the urban forestry and non-urban forestry transects in the dry and wet periods.

| Climate Variables | Period of the Year | | | | | |
|---|---|---|---|---|---|---|
| | Wet | | | Dry | | |
| Vegetated | Minimum | Maximum | Average | Minimum | Maximum | Average |
| $T_{air}$ (°C) | 23.2 | 29.2 | 26.6 | 19.1 | 26.2 | 23.3 |
| $T_s$ (°C) | 23.9 | 30.1 | 27.4 | 21.2 | 28.1 | 24.4 |
| $R_h$ (%) | 73.5 | 92.7 | 82.8 | 61.9 | 89.7 | 73.1 |
| Non-vegetated | | | | | | |
| $T_{air}$ (°C) | 22.5 | 28.9 | 26.5 | 19.3 | 29.1 | 23.9 |
| $T_s$ (°C) | 26.5 | 43.1 | 34.1 | 24.6 | 41.3 | 32.3 |
| $R_h$ (%) | 74.2 | 95.9 | 84.5 | 56.6 | 90.1 | 73.0 |

**Table 3** - Analysis of the meteorological variables obtained for the wet and dry periods. Daily mean values of the air temperature (Tair), sidewalk surface temperature (Ts), and relative air humidity (Rh) in vegetated and non-vegetated transects during the wet and dry periods.

The highest daily means of the Tair were observed during the wet season (≅ 26.6°C). However, in the dry period, the highest variation between minimum and maximum temperatures were recorded in the non-urban forestry transect (2.7°C higher than those in the urban forestry areas), although the daily averages did not show significant differences. The thermal amplitude during the dry period (9.8°C) is higher than that in the wet season (6.4°C) in the transect without trees.

The highest daily average TS (≅ 34°C) was obtained in the wet season in the non-urban forestry transect; and the lowest daily average TS (≅ 24°C) was observed in the dry period in this transect. The difference between the minimum and maximum values of this variable in the wet season was higher (16.6°C) in the non-urban forestry transect than that in the urban forestry area (6.2°C). The minimum and maximum are similar in the dry period and the amplitude in the transect without trees (16.7°C) is superior to that of the transect with trees (6.9°C). The daily average RH values in the wet season recorded in the shade vary from 73.5% to 92.7%. Corresponding data recorded in the sun vary from 74.2% and 95.9%. In the dry period, the daily RH averages in the shade range from 61.9% to 89.7% and those recorded in the sun vary between 56.6% and 90.1%. Figure 2 shows the average Ts, Tair, and Rh values for the urban forestry and non-urban forestry transects and the analysis of the hourly variation of these variables.

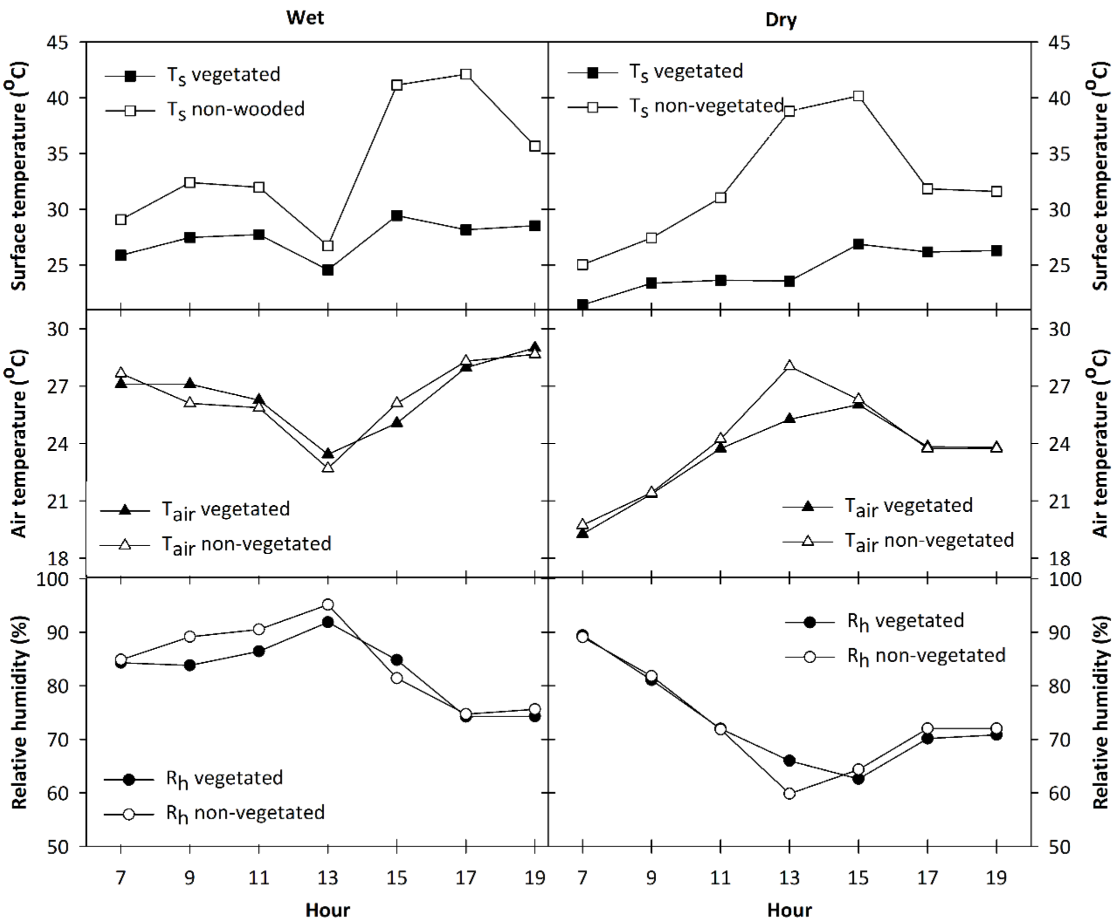


**Figure 2** - Hourly air temperature (Tair), sidewalk surface temperature (Ts) and relative air humidity (Rh) averages in vegetated and non-vegetated transects, during the wet and dry periods, between 7 am and 7 pm.

The variation between the values recorded in the wet and dry seasons (Figure 2) is attributed to the cloudiness conditions depending on the climatic characteristics of each season of the year.

The analysis of the results of the microclimatic variables was carried out in a different way, considering the dynamics of the weather relevant to the wet and dry seasons.

Note that, the weather was affected by a mass of hot and humid air during the wet season, resulting in unstable weather conditions that caused slight local precipitation of 11 mm (INMET, 2018). Oliveira et al. (2013) reported that rain gusts followed by the decrease in the cloudiness and rapid increase in the temperature of the air are normal for the wet period. Novais (2012) also stated that higher rainfall causes more cloudy days and therefore more abrupt variations in the incident global radiation, which directly interferes with the surface temperature.

The definition regarding the characterization of the climatic pattern of the wet season made by the authors corroborates with the results that are graphically represented in Figure 2. The same variation is observed for the atmospheric conditions during the day, with increased cloudiness and a significant increase in the relative air humidity indexes and a decrease in the hourly air temperature averages from approximately 9 am to 1 pm, followed by slight precipitation and a subsequent increase in both the air and surface temperatures.

The results of the joint analysis of Tair and Rh indicate the inversely proportional behavior of these variables. This means that an increase or decrease in the air temperature will result in the increase or decrease in the relative air humidity. Varejão-Silva (2006) explained that such a behavior is caused by the inverse proportionality of the relative air humidity and the vapor saturation point. Therefore, the relative air humidity will also be inversely proportional to the air temperature. An analogous behavior was also identified for the Ts variable in this study (Figure 2).

The analysis of the sidewalk surface temperature shows that the hourly means in the non-urban forestry transect are higher than those obtained in shaded areas. The lowest hourly averages were observed at ≅ 1 pm in both transects, that is, ≅ 26.7°C in the non-urban forestry transect and ≅ 24.5°C in the urban forestry area. The highest hourly averages (≅ 29.4°C) were recorded at 3 pm in the urban forestry transect, while the highest values in the non-urban forestry transect were obtained at 5 pm (≅ 42.1°C). The latter shows the highest average hourly temperature difference (≅ 14°C).

The comparative analysis of the results for the different seasons highlights the surface temperature; the difference between the maxima in the transects with and without afforestation is 13°C in the wet season, whereas it is 13.2°C in the dry period. Abreu and Labaki (2008) emphasized that the presence of trees causes the reduction in the temperature due to shading and evapotranspiration.

The differences in the TAR between the transects are less significant in the wet season (Figure 2); they are similar throughout most of the sampling period. The Tair in the early morning is slightly superior. This is due to the high specific heat of the vegetation because the trees contain large quantities of water; more time is required to absorb and lose energy (ALVES; BIUDES, 2011). The authors further note that the high air temperature records in vegetated areas in the morning period results from the loss of energy absorbed on the previous day. The energy is slowly released and consequently heats the air.

The lowest hourly means were recorded in the non-urban forestry transect (≅ 22.7°C) at 1 pm compared with the urban forestry transect (≅ 23.4°C) at the same time. At dusk at ≅ 5 pm, the maxima were obtained in the tree-lined transect (≅ 28.6°C) instead of the non-urban forestry area (≅ 29°C).

The atypical behavior displayed in Figure 2, where the air temperature in the non-urban forestry transect is lower than that in the urban forestry area, is due to precipitation occurrences (previously cited) as well as its partial interception by the tree canopy. The partial interception by the tree canopy prevents the transport of the precipitation to the surface and the temperature under the canopy of trees is not attenuated. The temperature differs from that obtained at sampling points without trees, where the evaporation of the water after precipitation decreases the air and ground temperatures. Uncommon high air temperatures have been observed in areas with dense tree canopies due to the entrapment of the air below and the reduction of heat loss by convection, which increases the air temperature near the soil surface (JIM; TSANG, 2011).

The RH of the transects is similar. The highest records were observed at ≅ 1 pm in the non-urban forestry transect (≅ 95.13%) compared with that of the urban forestry transect (≅ 91.86%). Note that the relative air humidity declines (≅ 21.7%) from 2 pm until the end of the day, reaching the lowest values at 5 pm (≅ 74%) in both transects.

The dry season in the municipality of Cuiabá is characterized by low relative air humidity indexes, with average values close to 55%. These values may reach 15% in extreme cases between July, August, and September when the average temperature is approximately 24°C and no cold fronts occur in the region. However, because the city is located in one of the hottest regions of the country, the temperature frequently reaches 40°C (INPE, 2018).

During the collection in the dry season, the hourly means of the TS are mainly significant between 11 am and 3 pm. They assume values above 40°C in the non-urban forestry transect and ≅ 26°C in the urban forestry transect in the shade, indicating a difference of 14°C. The difference of the TS and the highest values obtained at sampling points exposed to the sun are caused by two factors, that is, the absence of interception barriers of the incident radiation and the difference of the specific heat between air and water. Novais (2012) explained that the upper soil layer will heat up faster in the dry period because air has a lower specific heat than water (approximately 0,241 cal · g -1·° C -1 for air and 1 cal·g -1·°C-1 for water), causing a higher temperature gradient. Therefore, the highest heat flux in the soil coincides with the time of highest incidence of radiation at 12 pm.

The Tair data collection started in the morning with mild temperatures. The Tair values obtained for the different transects show a similar behavior (in contrast to observations in the wet season, with high Tair values in the early morning). This pattern is maintained until it reaches a peak between 12 and 1 pm (hours of intense sunshine), representing higher values than obtained at sample points in the sun. Subsequently, the Tair values decrease and maintain a balance (based on the data collection at 5 and 7 pm) at approximately 24°C in both transects.

With respect to the Rh indexes, the highest hourly averages were obtained in the beginning of the morning period at 7 am (89%) in both transects. Subsequently, the values decline and are maintained until the end of the morning. In the transition period between the morning and afternoon, at ≅ 1 pm, higher values (65.9%) are measured in the shade than in the sun (59.8%), with a gradual increase in both transects until 5 pm (constant values, ≅ 70%).

Even in the dry season, the lowest air temperature and relative humidity were recorded. According to Oliveira et al. (2013), this behavior is typical for the climate in this region, where the lower air temperature and RH values that are observed in the dry period are due to the increase of the thermal amplitude, with the lowest values occurring at night.

In general, the highest values of surface temperature occurred in the non-urban forestry transect. Falcão et al. (2010) and Novais et al.(2018) reported that the soil temperature without vegetation is higher because the soil retains the solar radiation, which differs from areas with an arboreal canopy in which much of the radiation will be reflected or absorbed by the tree crowns.

In short, the lower amplitudes observed under afforestation are due to the shading of the tree crowns that intercept parts of the incident solar radiation, reducing and consequently naturally controlling the energy flow arriving at the ground surface. Wolfram and Monteiro (2011) performed research on the influence of afforestation on the thermal comfort for pedestrians in urban areas and emphasized that the morphological characteristics of the trees, especially leaves, block and/or reduce the energy that reaches the soil. This also contributes to the reduction of long wave radiation, positively affecting the improvement of the microclimate. The greater the leaf surface is, the greater are the thermoregulatory effects on the microclimate, which in turn are closely related to the environmental comfort (MILANO, 1994; CAVALHEIRO, 1994).

Silva et al. (2018) also reached the same conclusion when analyzing comfort in a health care center, revealing the need for afforestation above 90% for the morning period and 96% for the evening. For the authors, this measure creates a favorable environment, and contributes to the recovery of the patient, both physical and mental, providing a real sense of comfort, reducing stress relations.

The analyzes of the comfort index (HI) and the index of thermal discomfort follow in figure 3.

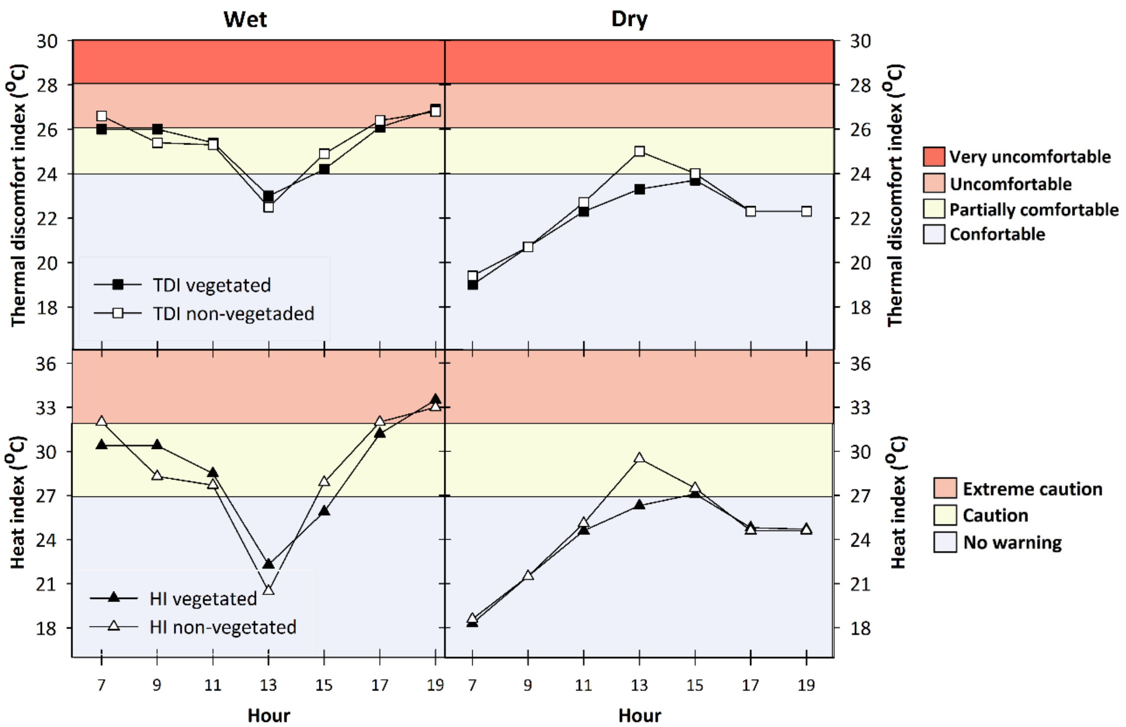


**Figure 3** - Heat index (HI) and Thermal Discomfort Index (TDI) in vegetated and non-vegetated transects, during the wet and dry periods, between 7 am and 7 pm.

It was tested the hypotheses of significant difference between the groups, and the difference in the mean values of the all groups is not great enough to reject the possibility that the difference is due to random sampling variability, then, there is not a statistically significant difference between the groups, being at all times with the same comfort ratings.

For the heat index (HI) analysis in the wet season, 64% of the results fall into the "Caution" alert level and 14% "extreme caution", with the rest of the results being in the "no warning" level. These results contrast with that of the dry period, winter for the southern hemisphere of the planet, being 79% of the data in the level "no warning".

In the TDI analysis, in the wet season, 36% of the results were "uncomfortable", and in the dry period, all the results were "comfortable" or "partially comfortable".

Because the indices analyzed depend only on air temperatures and relative humidity, the same pattern was observed for both.

Although there are no statistically significant differences between vegetated and non-vegetated transects, the importance of afforestation as a form of direct solar radiation protection is emphasized, as well as the shading that decreases soil temperature and long-wave emission. Because the transects were made in open spaces, it is hypothesized that the dynamics of the air movement in the place prevented that underneath the trees there was a statistically significant decrease in the index results.

For Fernandes et al. (2019), the natural ventilation of an environment exerts a fundamental function for the human thermal equilibrium, causing the individual to remain in an equilibrium stage for the development of their functional activities. However, a prior analysis of certain conditions such as: the climate, the size and orientation of the openings, the form of the building, used construction materials and afforestation are necessary.

The benefits of afforestation in urban areas are irrefutable, a well-urban forestry city can be sensed and remembered as a pleasant and beautiful place that humanizes, given the environmental services provided by afforestation (MATOS; QUEIROZ, 2009). In addition, the increase of green areas in cities has been considered as an attribute of real estate appreciation based on the improvement in the quality of life provided by green spaces.

## 4. CONCLUSIONS

The best thermal conditions were observed in the transect influenced by tree vegetation. The results of the sample analyses indicate the difference of the sidewalk surface temperature between the transects with and without arborization in the two seasons. The difference between the minimum and maximum temperature of the sidewalk surface in the wet season was 16.6°C. In the dry period, the difference was 16.7°C, the difference was ≅10°C higher in both seasons without trees, with statistical differences between the transects (p-value < 0.001). This is due to multiple factors that affect the study area, such as the absence of an interception of incident radiation, excess waterproofing, and agglomeration of buildings, which contribute to the worsening of the heat island effect in urban centers and to an increase in the sensation of thermal discomfort. The air temperature in the transect without a tree was 0.1 ° C lower in the wet season (due to the occurrence of precipitation) and 2.9 ° C higher in the dry season. However, there were no statistically significant differences for the variables air temperature and relative humidity.

For the heat index (HI) analysis in the wet season, 64% of the results fall into the "Caution" alert level and 14% "extreme caution”. In the TDI analysis, in the wet season, 36% of the results were "uncomfortable", and in the dry period, all the results were "comfortable" or "partially comfortable". However, there was no statistically significant difference for the heat index and thermal discomfort index among the analyzed transects, concluding that the presence of vegetation was not enough to cause a difference in the index of each transect.

The city of Cuiabá is characterized by high temperatures throughout the year. It is of great importance for the planning and implementation of management of urban afforestation according to the master plan of the municipality to preserve and create new green areas and seek a balance between the city growth and quality of life of the population. It is noteworthy that especially in the rainy season, summer in the southern hemisphere of the globe, there were periods of discomfort, indicating an attention of the people who frequent this place.

It is suggested that further studies be carried out, with sampling periods that consider the four seasons.

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